Pace University

Fundamentals of Environmental Science II

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GOTHAM PARK ENVIRONMENTAL ANALYSIS

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INTRODUCTION

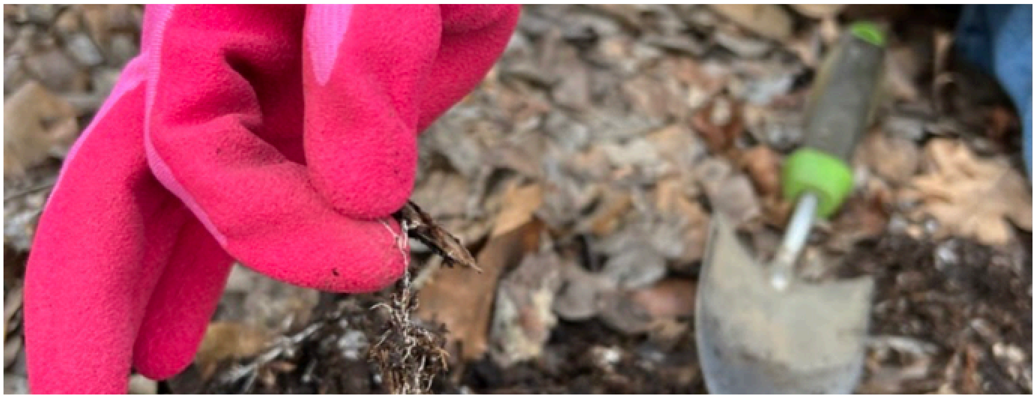
Gotham Park is a new park that looks to “unlock the potential of the forgotten spaces under the iconic Brooklyn Bridge.” They are “creating a new type of urban community park that nurtures connection, curiosity, wonder, and resilience” (Gothampark.org)

They collaborate with many schools and organizations and were excited by the idea of having their water, air, and soil quality analyzed in order to make sure it remains a safe space for community members.

In this collaboration, we practiced and honed our sampling and analytical skills while providing Gotham Park with data that they can use to inform their activities and offerings to the public.

Project Summary: Gotham Park is a new park that looks to "unlock the potential of the forgotten spaces under the iconic Brooklyn Bridge." They are "creating a new type of urban community park that nurtures connection, curiosity, wonder, and resilience" (Gothampark.org). Gotham Park collaborates with many schools and organizations and was excited by the idea of having their water, air, and soil quality analyzed by our class. In this collaboration, the students at Pace University's Fundamentals of Environmental Science II (ENS 202) practiced and honed their sampling and analytical skills while providing Gotham Park with data to inform their activities and offerings to the public. In the pages to follow, we provide data and analysis of water, air, and soil quality.

Project Abstract: As a class, we investigated water, air, and soil quality in lower Manhattan with a primary focus on Gotham Park, but included other areas within the Financial District as well. Different methodologies were carried out pertaining to each study with the creation of visual representations that display the findings and overall results to analyze the quality & evaluate the health of the area's water, air, and soil. The water results showed that Gotham Park's scupper had higher nitrate and phosphate levels than those from the Combined Sewer Overflow areas along the East River, however, all levels are well below drinking water standards (10 ppm). These data point to the importance of future monitoring and more green infrastructure in the Park. The air results showed that the measurements for nitrogen dioxide, particulate matter, and ozone were all below the EPA's standards for each (100 ppb for nitrogen dioxide, 150 μg/m3 for PM10 & 9 μg/m3 for PM2.5, and 0.07 ppm for ozone). Lastly, the soil results showed that the measurements for the metal(loid) concentrations were all below the New York State Department of Environmental Conservation's standards. Overall, this study finds that the water, air, and soil in and around Gotham Park are safe for regular interaction. We emphasize the importance of continued monitoring of water, air, and soil quality in densely populated cities (including others other than New York City) to protect the environment as a whole from constant anthropogenic activity while managing to keep urban areas and all inhabitants safe.



WATER

Abstract:
This research investigates nutrient pollution in aquatic systems, focusing on water samples from Gotham Park, Pace Farm, and Combined Sewer Overflow (CSO) sites along the East River. The objective of this study is to assess and compare nutrient levels in these samples, specifically nitrate and phosphate concentrations (ppm), as well as salinity (ppt). We hypothesized that water quality from Gotham Park scuppers would be lower in nutrient (nitrate and phosphate) and salinity levels than water from CSOs along the East River. We found that Gotham Park's scupper has a salinity of 0 ppt, which is within the standard freshwater range, comparable to the collected rainwater at the Pace Urban Farm. However, median nitrate and phosphate levels were higher in Gotham Park's scupper than in water samples collected from CSO sites. These findings suggest potential nutrient pollution coming from the Brooklyn Bridge and from stormwater entering the East River. We emphasize the significance of monitoring and the importance of increasing Green Infrastructure to minimize nutrient sources in urban aquatic ecosystems

Introductio: Nutrient pollution, characterized by an excess of nutrients like nitrogen and phosphorus, present a significant threat to aquatic ecosystems, leading to detrimental effects such as algal blooms, hypoxia, and the degradation of water quality. Algal blooms and hypoxia are the result of excess nutrient concentrations in aquatic ecosystems (NOAA, 2024a). These nutrients stimulate reproduction of aquatic photosynthesizers like algae, which consume oxygen from the water through respiration and decomposition. The marine animals that rely on this oxygen supply for survival face great stress and or death because of this process, which ultimately leads to eutrophication.

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The impacts of this travel all the way up the food chain, harming aquatic ecosystems as a whole, lessening the ecosystem's ability to be resilient to environmental perturbations. The effects of marine nutrient pollution extend beyond those aquatic organisms directly affected; humans too rely heavily on waterways for survival and quality of life. Many industries, such as fishing, tourism, and water sports rely heavily on healthy aquatic ecosystems. Other human activities, such as fishing, boating, and swimming, are integral to the cultural fabric of many communities and can be severely impacted by the effects of nutrient pollution. The issue extends to social welfare issues as well; reduced fish populations and spoiled water bodies threaten food security, especially for communities that rely heavily on fish for protein. On top of it all, algal blooms produce toxins detrimental to the health of animals and humans and can contaminate drinking water and seafood. The significance of nutrient pollution analysis and mitigation is underscored in this study, where we will evaluate and compare different water samples from waterways around the Gotham Park, New York City area.

In urban settings like New York City, the concentration of these nutrients can be particularly high due to runoff from dense populations, combined sewer overflows (CSOs), industrial activities, and agricultural activities coming down the Hudson River to the city. This lab will provide insight on the nutrient pollution concentrations of phosphate (PO43-) and nitrate (NO3-) in this unique urban aquatic system, aiming to ensure the safety and quality of water in downtown NYC. We hypothesized that in comparison to water from CSOs along the East River, the water quality from Gotham Park scuppers would have lower levels of salinity and nutrients (phosphate and nitrate). By combining field investigations, laboratory experiments, and data analysis, this lab aims to enhance our understanding of urban water quality issues and contribute to healthier ecosystems and communities.

WATER

Methods

In this lab, the class collected water samples from the New York Estuary at different sites in Lower Manhattan, rainwater from Pace University, and scupper water in Gotham Park. We collected samples on April 2, 2024. The date of collection saw 0.87 inches of rainfall (NOAA, 2024). Each of the three lab groups collected two samples per site. In order to have an accurate sample, we rinsed a 50mL Falcon tube with the sample's water twice by filling it and swirling the water around then dumping it. This ensured that the sample was an accurate representation of the water tested. For each site, we threw a 5-gallon bucket attached to a rope into the water and completed the rinsing process twice before filling it a third time to sample the water. The class then froze each of their samples until testing on April 12, 2024. The samples were taken out of the freezer that morning to thaw out for testing. The biology department also took samples to test for microbes and did not freeze their samples. In the testing portion of this lab, we tested for concentration of phosphate (PO43-) and nitrate (NO3-) in parts per million (ppm) and salinity in parts per thousand (ppt).

Nitrate was tested by filling an empty 50mL falcon tube with 20mL of sample water and adding one level spoonful of Nitratest Powder and one uncrushed Nitratest tablet. We then mixed the samples by inverting them and shaking the closed tubes for one minute. The sample then sat still for one minute, then was inverted gently three times, and sat still for an additional minimum of three minutes. We then removed the cap and wiped the top clean with a tissue. We decanted the clear mixture into a clean 50 ml falcon tube and the solid gray solution settled on the bottom was discarded into the waste bin. With the new solution, we added one Nitricol tablet, which we crushed and mixed for one minute. Then, we let these samples sit for ten minutes. With this sample, we filled a cuvette tube with 10mL of the sample and tested it in the Photometer. We selected Phot 63 on for result as mg/L (equivalent to ppm) NO3-. Each time we tested a sample, we blanked the machine by using a deionized water sample in a cuvette tube. We also wiped the outside clean with a clean kimwipe each time. Each group completed this once per sample site.

Phosphate was analyzed by filling an empty 15 mL Falcon tube with 10 mL of sample water. We then added one Phosphate No 1 LR tablet, crushed and mixed it, followed by adding Phosphate No 2 LR tablet and crushed and mixed this. These stood still for ten minutes. We then filled the cuvette tubes with these samples and used the Photometer. We selected Phot 28 on the Photometer for the result as mg/L PO43-. Again, we ran a blank on the instrument for each sample by using a deionized water sample, and wiped the outside clean with a tissue each time. Each group completed this once per sample site.

When testing for salinity, we used a refractometer. We used the deionized water cuvette as a blank each time before testing, and used the samples in the cuvette tubes for the salinity testing. Each group completed this once per sample site.

WATER

Figure 1: Map of sampling sites for water testing in lower Manhattan, NYC.

Results and Discussion: The National Oceanic and Atmospheric Administration, defines normal saltwater salinity levels as an average of 35 ppt, while normal freshwater salinity levels are less than 0.5 ppt (NOAA, 2024a). Our study of saltwater bodies found that CSO 3 had mean salinity values of 9.67 ppt, CSO 4 had 9 ppt, and CSO 5 had 13.67 ppt, all of which were lower than the normal saltwater salinity threshold. Rainwater (Pace Farm) and Scupper (Gotham Park) had salinity levels of 0 ppt, which is within the usual range for freshwater. This comparison indicates that the East River areas have lower salinity levels than standard saltwater concentrations, and Pace Farm and Gotham Park have salinity levels within the healthy freshwater ranges.

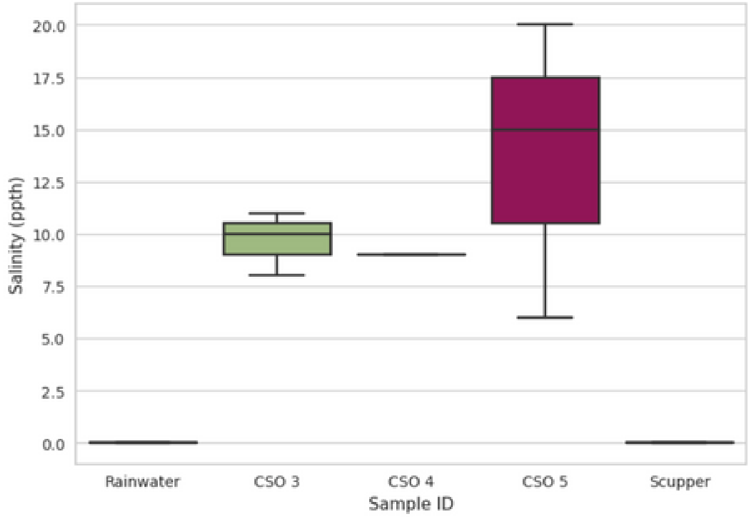


Figure 2. *Salinity of water samples derived from CSO sources, rainwater collected at Pace University's Urban Farm, and scupper from Gotham Park. Salinity is measured in parts per thousand (ppt).*

WATER

According to the EPA's Water Monitoring & Assessment standards, normal saltwater nitrate levels should be less than 1 ppm, but in wastewater treatment plants, they can reach 30 ppm. Furthermore, NOAA states that nitrate concentrations above 1 ppm can contribute to eutrophication (NOAA, 2024b). Our average nitrate level measurements in the East River including CSO 3, CSO 4, and CSO 5 were consistently above the usual range, with mean values of 6.54 ppm, 2.06 ppm, and 2.3 ppm, respectively. Similarly, nitrate levels in freshwater sources, such as rainfall collected at Pace Farm and from the scupper at Gotham Park, were above 1 ppm, at 1.94 ppm and 3.21 ppm respectively. While these data indicate elevated nitrate, they are well below the EPA standard for drinking water (10 ppm) (EPA, 2024).

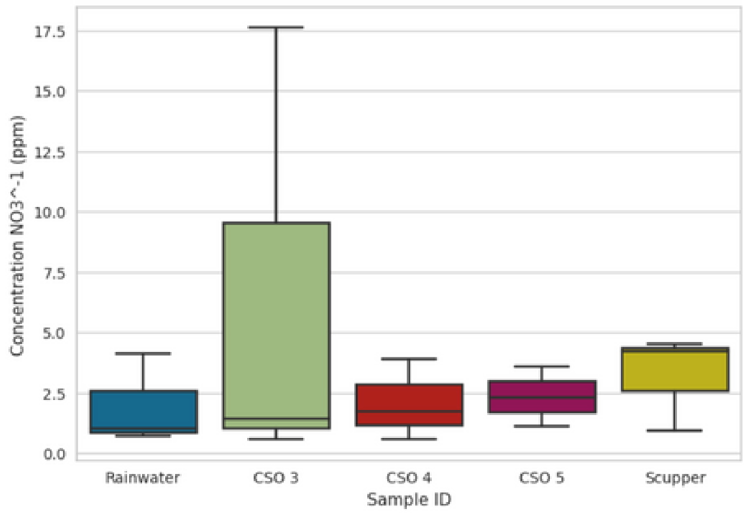


Figure 3. *Concentration of NO3- in water samples derived from CSO sources, rainwater collected at Pace University's Urban Farm, and scupper from Gotham Park. NO3- is measured in parts per million (ppm).*

According to Algaebarn, acceptable saltwater phosphate ion levels vary from 0 to 0.2 ppm (Chernoff, 2023), however the University of Wisconsin Madison reports healthy freshwater levels between 0.005 and 0.05 ppm ("Information on phosphorus amounts & water quality," 2003). In our study, the average phosphate ion concentrations in saltwater samples from CSO 3, CSO 4, and CSO 5 in the East River were 0.69 ppm, 1.35 ppm, and 0.78 ppm, which exceeded the standard range. Similarly, rainwater collected at Pace Farm had a phosphate ion level of 0.53 ppm and the scupper at Gotham Park had an average phosphate ion concentration of 1.47 ppm, which are both above the normal range for freshwater, indicating potential nutrient pollution in these freshwater sources.

WATER

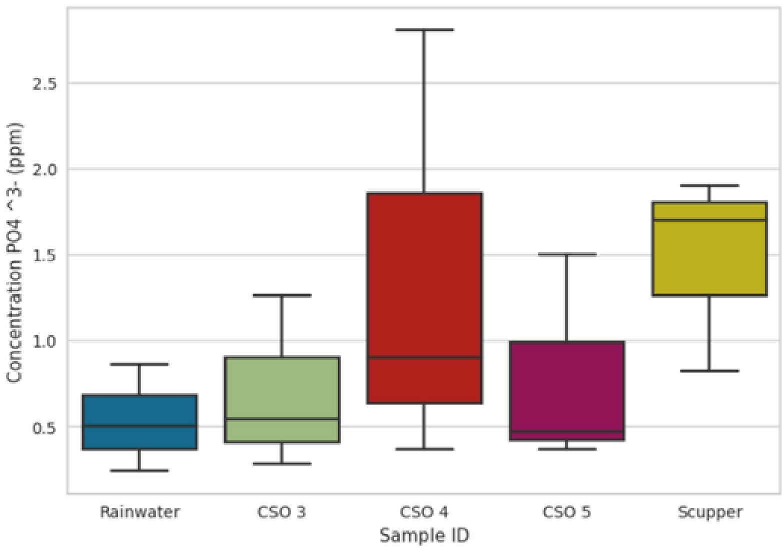
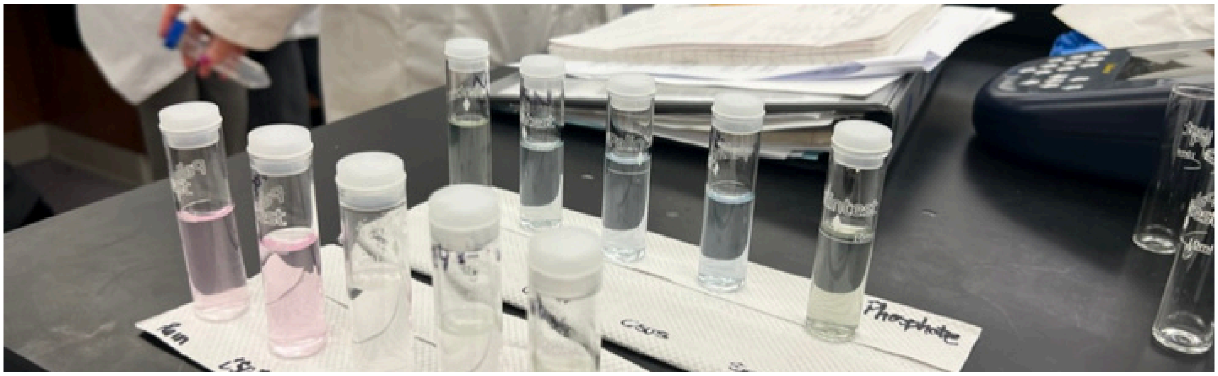


***Figure 4**. Concentration of PO43- in water samples derived from CSO sources, rainwater collected at Pace University's Urban Farm, and scupper from Gotham Park. PO43- is measured in parts per million (ppm).*

Conclusion: To summarize, we found that water samples from Gotham Park's scupper had lower salinity and higher nitrate and phosphate levels than those from the Combined Sewer Overflow areas along the East River. While it was raining at the time of sampling, there may not have been enough rain to trigger a CSO event. The potential sources of nutrients coming from the Brooklyn Bridge could be investigated further. This points to the importance of building and monitoring Green Infrastructure in Gotham Park.



AIR

Abstract: This study explores the complicated dynamics of ground-level ozone, particulate matter
(PM), and nitrogen dioxide (NO2) in urban environments, focusing on three particular locations in New York City: Gotham Park, on the Brooklyn Bridge, and within Pace University. Ground-level ozone, a consequence of urban air pollution, is a significant health threat, especially in places with considerable vehicular traffic and industrial emissions. Particulate matter, including PM10 and PM2.5, poses additional complications due to its capacity to penetrate deeply into the respiratory system, resulting in a variety of health issues. Nitrogen dioxide, which is predominantly emitted by combustion activities, contributes to the development of secondary pollutants, further degrading air quality in urban areas. Aeroqual sensors were used to monitor air quality parameters at each location, including PM10, PM2.5, O3, and NO2 concentrations.
The results indicate that ozone levels were highest on the Brooklyn Bridge and lowest at Pace University, with Gotham Park having intermediate levels. PM10 and PM2.5 concentrations were
generally low, with somewhat higher levels near the Brooklyn Bridge. The highest NO2 levels were found in Pace University, most likely due to heating sources and lack of ventilation. In summary, we found that concentrations of all pollutants (O3, NO2 and PM) were below National Ambient Air Quality Standards throughout Gotham Park (and at each location), despite their proximity to vehicle emissions from busy streets. Overall, our findings provide quantitative data on the low concentrations of air pollutants in Gotham Park and emphasize the health-promoting impacts of this new urban green space.

AIR

Introduction: Nitrogen oxides (NOx), ozone (O3), and particulate matter (PM) are prominent pollutants that significantly impact air quality and human health. NO and NO2 (NOx) are primarily formed through the combustion of fossil fuels in vehicles and industrial processes, leading to them reacting with other compounds in the atmosphere (Munsif et al. 2021). Ozone, a crucial component of the Earth's stratosphere, is formed at ground level through complex photochemical reactions involving precursor pollutants like nitrogen oxides and volatile organic compounds (VOCs) in the presence of sunlight (Mohammad et al. 2024). Particulate matter encompasses a variety of solid and liquid particles suspended in the air, arising from various sources such as vehicle emissions, industrial processes, construction activities, and natural sources like dust storms and wildfires (Payra et al. 2022).

Maintaining air quality is essential for human health, environmental sustainability, and overall well-being. Standardized measurements of air quality play a pivotal role in understanding the extent of pollution levels, identifying sources of contamination, and implementing effective mitigation strategies. The Environmental Protection Agency (EPA) outlines the maximum safe concentrations for six "principal" pollutants: carbon monoxide (CO), lead (Pb), nitrogen dioxide (NO2), ozone (O3), particulate matter (PM2.5/PM10), and sulfur dioxide (SO2) in the National Ambient Air Quality Standards (NAAQS) (Figure X). In a park setting within the city, where people gather for recreation and leisure, monitoring air quality becomes particularly crucial to safeguarding human health and the environment. Air quality measurements in parks also contribute to the selection and maintenance of suitable vegetation. Different plant species have varying tolerances to air pollutants, making it crucial to consider air quality when choosing plants for landscaping and green spaces (Molnár et al. 2020). By assessing air quality parameters such as pollutant concentrations and particulate matter levels, park managers can make informed decisions about which plant species are best suited to thrive in the local environment. Additionally, monitoring air quality over time allows for the evaluation of plant health and the identification of potential stressors, guiding efforts to maintain a diverse and resilient ecosystem within the park.

Pollutant [links to historical tables of NAAQS reviews]		Primary/ Secondary	Averaging Time	Level	Form
Carbon Monoxide (CO)		primary	8 hours	9 ppm	Not to be exceeded more than once per year
			1 hour	35 ppm	
Lead (Pb)		primary and secondary	Rolling 3 month average	0.15 $\mu g/m^3$ [1]	Not to be exceeded
Nitrogen Dioxide (NO_2)		primary	1 hour	100 ppb	98th percentile of 1-hour daily maximum concentrations, averaged over 3 years
		primary and secondary	1 year	53 ppb [2]	Annual Mean
Ozone (O_3)		primary and secondary	8 hours	0.070 ppm [3]	Annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years
Particle Pollution (PM)	$PM_{2.5}$	primary	1 year	9.0 $\mu g/m^3$	annual mean, averaged over 3 years
		secondary	1 year	15.0 $\mu g/m^3$	annual mean, averaged over 3 years
		primary and secondary	24 hours	35 $\mu g/m^3$	98th percentile, averaged over 3 years
	PM_{10}	primary and secondary	24 hours	150 $\mu g/m^3$	Not to be exceeded more than once per year on average over 3 years
Sulfur Dioxide (SO_2)		primary	1 hour	75 ppb [4]	99th percentile of 1-hour daily maximum concentrations, averaged over 3 years
		secondary	3 hours	0.5 ppm	Not to be exceeded more than once per year

Figure 5. *The Environmental Protection Agency's National Ambient Air Quality Standards for CO, Pb, NO2, O3, PM2.5/10, and*

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For this section, we will be focusing on the concentrations of O3, NO2, PM2.5 and PM10 within Gotham Park, Brooklyn Bridge, and Pace University. In Gotham Park, we hypothesized that concentrations will be above National Ambient Air Quality Standards, especially by streets and underneath the highway due to vehicular emissions. Furthermore, we hypothesized that all pollutants will be below the National Ambient Air Quality Standards throughout Brooklyn Bridge and Pace due to the presence of mitigating factors, such as the dispersion of pollutants through prevailing wind patterns and the natural filtration processes facilitated by the proximity to the East River and proper indoor ventilation. By assessing air quality parameters such as pollutant concentrations and particulate matter levels, park managers can make informed decisions about plant selection for landscaping and green spaces, ensuring a diverse and resilient ecosystem that enhances the overall quality of life for park visitors and the surrounding community.

AIR

Methods and Materials:

Aeroqual Sensor Measurements

We began our air quality analysis of Gotham Park, New York City and the surrounding areas on March 1st, 2024. For air quality assessment, essential materials including Aeroqual sensors, timers, and lab notebooks were gathered before the class headed to Gotham Park to begin sampling. Aeroqual Sensors included an ozone sensor head, a particulate matter sensor head, and a nitrogen dioxide sensor head to be attached before each measurement. With only two Aeroqual sensors available, the class divided into two groups to begin measurements in Gotham Park. One group prepared to record concentrations of particulate matter (PM) while the other was to record nitrogen dioxide (NO_2), and the first group to finish was expected to document ozone (O_3) concentrations in the park. It is important to note that both ozone and nitrogen dioxide concentrations were measured in parts per million (ppm), while particulate matter was measured in milligrams per cubic meter (mg/m^3) because particulate matter varies in size and cannot be appropriately measured using units in parts per million.

Initializing the sensor heads used for each measurement of the pollutants involved attaching sensor heads, powering on the device, and waiting for calibration according to the Aeroqual sensor directions. Once the Aeroqual sensor warmed up for about 3 minutes, a stabilization period of approximately 7 minutes was given to ensure that the sensors were detecting the most accurate concentrations of the pollutants. Once the Aeroqual device was ready, measurements commenced, with data logged at one-minute intervals over a 15 minute period.

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In Gotham Park, a group recorded NO2 concentrations in a table for every minute for 15 minutes while walking slowly, noting visual observations and location as we went. Another group recorded PM concentrations, pausing every minute to write them down in the table. Ozone measurements followed the same conduct. Sensor heads were switched accordingly, repeating the setup process for each pollutant. The same set up protocol for sensor head attachment was repeated for all other recordings, as well as a similar procedure. On the Brooklyn Bridge, one group recorded O3 concentrations at a stationary spot, while another group walked, recording PM concentrations. Groups met to record Brooklyn Bridge NO2 concentrations, as well as to record indoor measurements conducted inside Pace University, logging O3and NO2 concentrations every minute for 15 minutes each. Areas chosen for air quality analysis are shown in **Figure 6.**

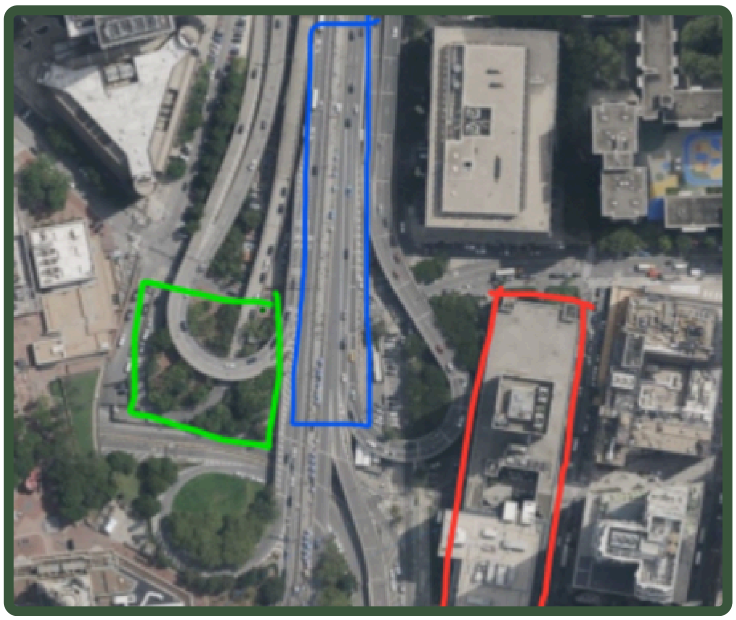

Figure 6. *Map of Gotham Park (green), Brooklyn Bridge (blue), Pace University (red)*

Results: Air quality measurements within Gotham Park were generally consistent across all pollutant types. The ranges of maximum and minimum concentrations for each gas are as follows: PM10: [0.003-0.008 mg/m3]; PM2.5: [0.001-0.004 mg/m3]; NO2: [0.007-0.022 ppm]; O3: [0.027-0.047 ppm] (Table 1, Appendix).

Ozone concentrations (Figure 5) within and around Gotham Park ranged from 0.027-0.047 ppm (Table 1 Appendix). Levels were highest at the Brooklyn Bridge [0.040-0.051 ppm] (Table 2, Appendix) and lowest in Pace University [0.000-0.018 ppm] (Table 3, Appendix).

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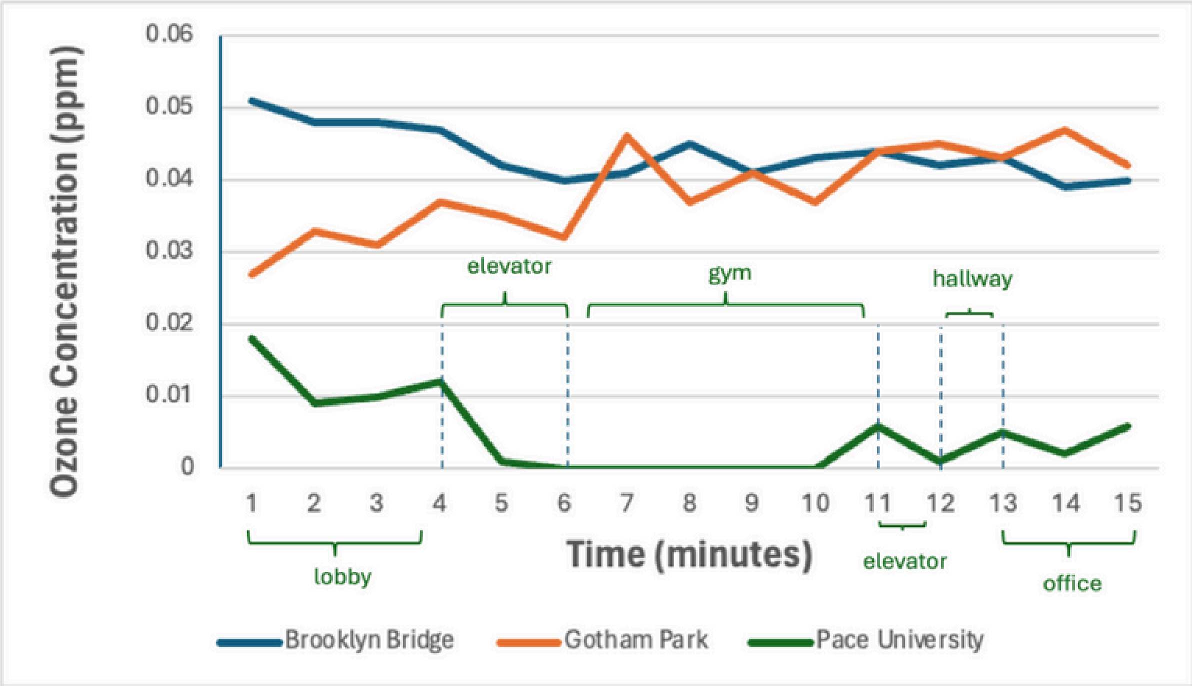

Figure 7. O3 Concentrations in 3 Locations

NO2 concentrations (Figure 6) were highest and most varied in Pace University [0.000-0.072 ppm] (Table 3, Appendix). Values for NO2 at the Brooklyn Bridge ranged from 0.021-0.036 ppm (Table 2, Appendix). Comparatively, median NO2 concentrations at Gotham Park were lower than both the Brooklyn Bridge and inside Pace, with a range of values from 0.007-0.022 ppm (Table 1, Appendix).

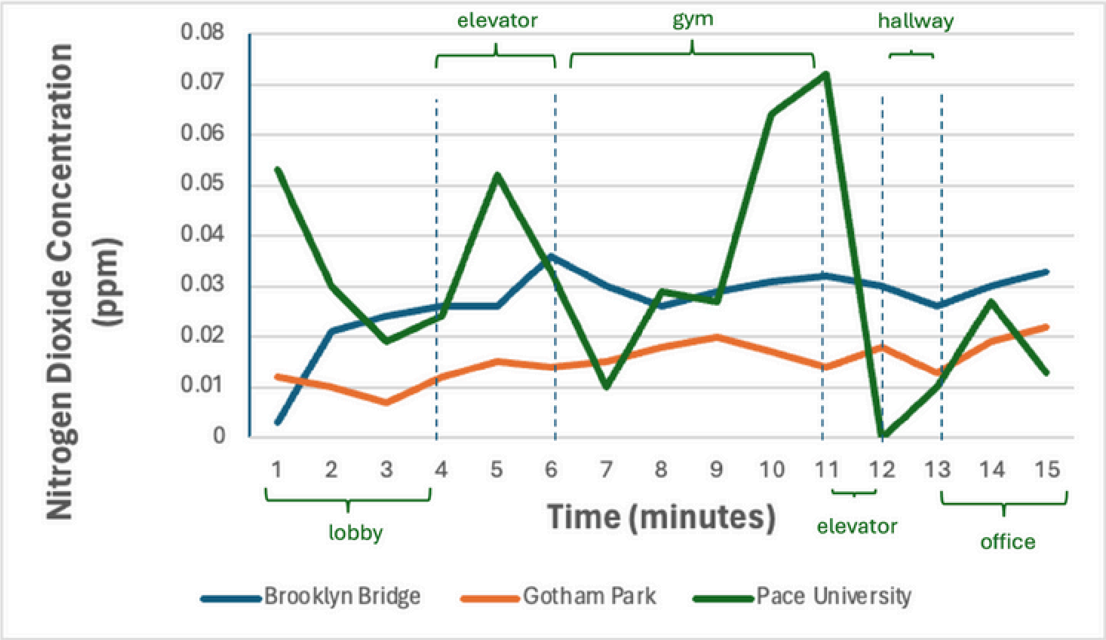

Figure 8. NO2 Concentrations in 3 Locations

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Particulate matter concentrations vary based on location and particle size. On the Brooklyn Bridge, PM10 concentrations (Figure 7) ranged from 0.003-0.006 mg/m3 and PM2.5 (Figure 8) from 0.001-0.003 mg/m3 (Table 2, Appendix). In Gotham Park, PM10 concentration values ranged from 0.003-0.008 mg/m3 and PM2.5 from 0.001-0.004 mg/m3 (Table 1, Appendix). Neither PM10 nor PM2.5 were measured in Pace University due to time constraints.

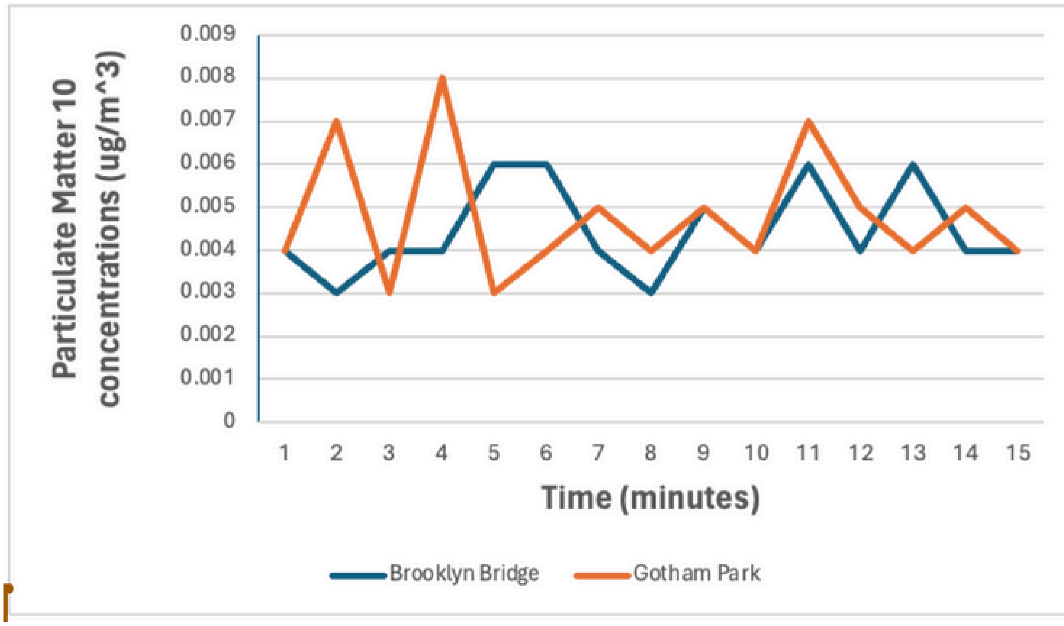

Figure 9 PM10 Concentrations recorded on the Brooklyn Bridge and in Gotham Park. The EPA's standard for PM10 is 150 μg/m3 (EPA Authors, 2024).

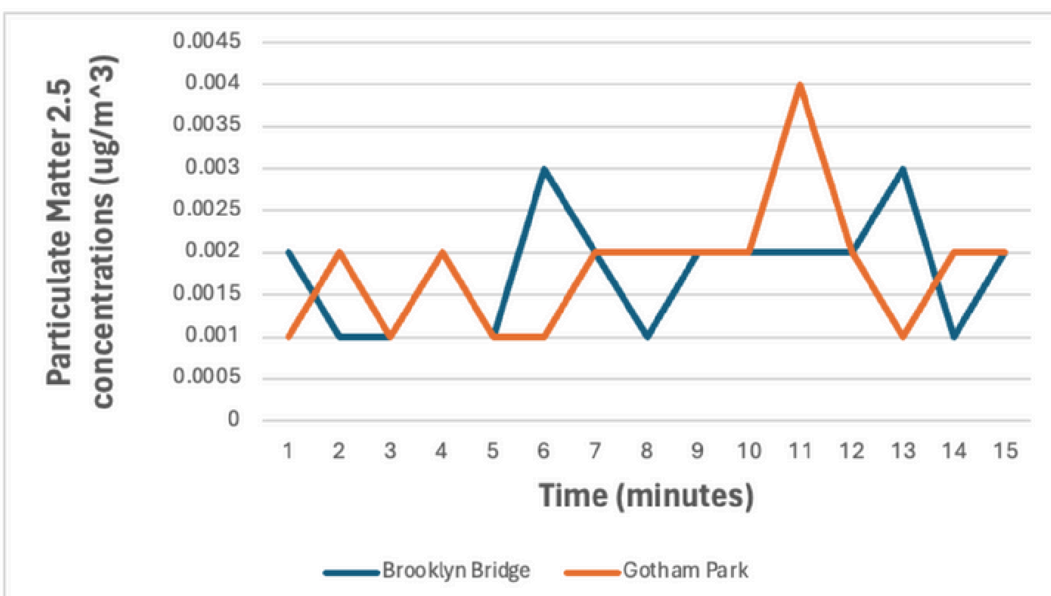

Figure 10 PM2.5 Concentrations recorded on the Brooklyn Bridge and in Gotham Park. The EPA's standard for PM2.5 is μg/m3 (EPA Authors, 2024)

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Discussion: In conclusion, our data supported that the O3, NO2, PM2.5 and PM10 were all recorded below the EPA NAAQS. Our hypotheses were not supported by our data as we had hypothesized that Gotham Park would be highest in PM 2.5 and 10, NO2 , and O3 because of its proximity to the Brooklyn Bridge traffic and ground vehicle traffic underneath it. The EPA standard for nitrogen dioxide is 100 ppb and our highest was recorded at 72 ppb concluding that all three locations had recorded levels below 100 ppb (EPA Authors, 2024). The highest recorded level for NO2 in Gotham Park was 22 ppb which is well below the standard. We did record a high level of NO2 in the elevator at One Pace Plaza which our groupmate Ryan hypothesized that could be because of the elevator motor, and they found evidence that elevators emit some concentrations of NOX.

The EPA's standard for PM10 is 150 μg/m3 and for PM2.5 is μg/m3 (EPA Authors, 2024). In Gotham Park, the highest recorded concentration for PM10 was 0.008 μg/m3 and 0.004 μg/m3 for PM2.5. As such, we conclude that concentrations for PM10 and PM2.5 fall below the maximum safe concentrations for particulate matter. The ozone concentration standard made by the EPA is 0.07 ppm. In Gotham Park, the levels monitored did not exceed 0.047 ppm which makes them well below the national standard. All in all, the air pollutant levels in Gotham Park for particulate matter, ozone, and nitrogen dioxide all were recorded below the national standards set by the EPA. However, continued monitoring and observations are recommended to ensure that the levels continue to stay below standards especially as stricter standards could be proposed in the future to establish the health and safety of park goers.

SOIL

Abstract: The study aimed to investigate soil quality in Gotham Park, specifically near the corner of Rose Street and Avenue of the Finest, just beneath the overpass leading to the Brooklyn Bridge, with a focus on potential anthropogenic influences and suitability for public interaction.The study followed a systematic approach, dividing the park into sections and then quadrants for sampling. A variety of techniques were used to analyze samples, including metal analysis, bulk density testing, pH measurement, texture analysis, and soil color identification. The findings indicated low levels of metal(loid)s in all areas, with slightly elevated copper, nickel and zinc near the bridge scuppers. Soil bulk density showed slightly compacted soils in the lower horizons, alkaline pH indicative of urban runoff and concrete,, and soil texture varied, indicating potential human influences on soil health. Soil color revealed high levels of organic matter. To summarize, we found the surface soils of Gotham Park, NYC, to be suitable for interaction with the public. Soils below 8 inches depth (not analyzed in this study) may exhibit different qualities and should remain undisturbed. Overall, the surface soils in this section of Gotham Park are in a rather healthy state, which is encouraging for the area's future development as a public area, particularly for the students and residents nearby.

Introduction: Soils are the foundation of all life on the Earth's surface, sustaining nutrient cycles for microorganisms, plant life, and animal life within the biosphere. Soils take thousands of years to form, and are composed of complex interactions between minerals, organisms, and broken down organic matter. Our current systems based on the exploitation of natural resources have had negative effects on the Earth's soil including heavy metal contamination, nutrient leaching, and other forms of pollution that are increasingly common. Heavy metal pollution is a serious problem stemming from increasing industrialization, as it leads to water pollution, human health risks, phytotoxicity in plants and a decline in crop production (Nyiramigisha et al. 2021). Lead contamination alone can reduce oxygen available for plant uptake and harm growth (Salam et al. 2022). The intensity of lead contamination varies across the city (Figure X+1).

SOIL

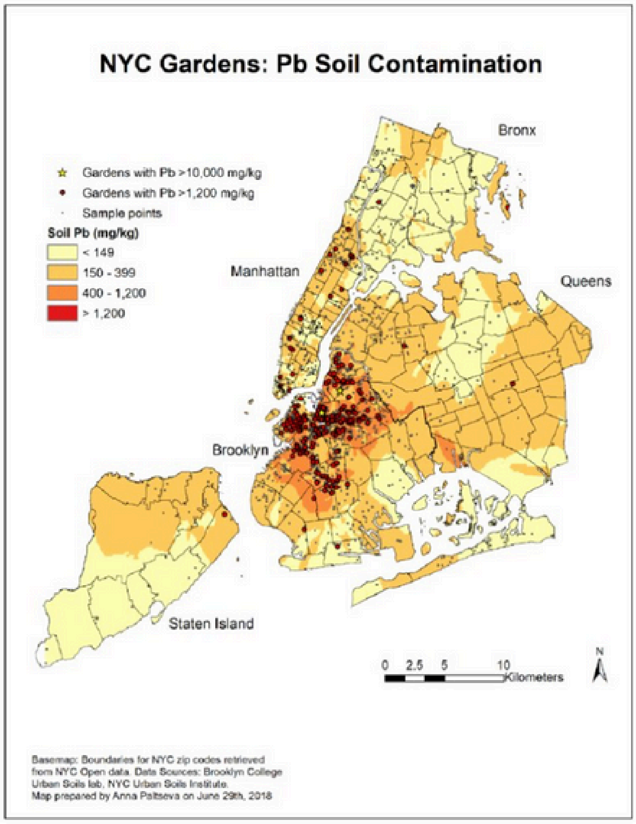

Figure 11. Map of lead contamination intensities across the five boroughs of New York City (Paltseva & Cheng, 2019)

In the most industrialized centers, urban parks represent crucial havens for residents of cities and plant and animal life with extremely limited habitat area, however, pollution is often at its highest within these centers due to increased anthropogenic pollutant point sources. Healthy soil is crucial in maintaining greater ecosystem cycles, supporting plant life which provides essential habitat to threatened species trying to thrive within cities, and human city residents with reduced access to green spaces. In these urban centers, parks like Gotham Park provide crucial environmental services, and need to be maintained and prioritized.

Our study examined soil quality at multiple site locations in Gotham Park, analyzing heavy metal concentrations, soil pH, texture by feel, Munsell color, and bulk density. Due to its proximity to the Brooklyn Bridge, the ENS 202 class hypothesized that contaminant concentrations would be high and likely not ideal for human or plant health. We hypothesized that the soil at Gotham Park will not be healthy due to low air quality, excessive precipitation events, and traffic concentrated around the Brooklyn Bridge – directly alongside and above our site location. Specifically, we predicted that there will be high concentrations of heavy metals from leaded paint, formerly leaded gasoline, vehicle emissions, air pollution, and water pollution in runoff from the Brooklyn Bridge.

SOIL

Methods: For this study, our class gathered various soil samples from 3 different areas of Gotham Park (Figure 12.).

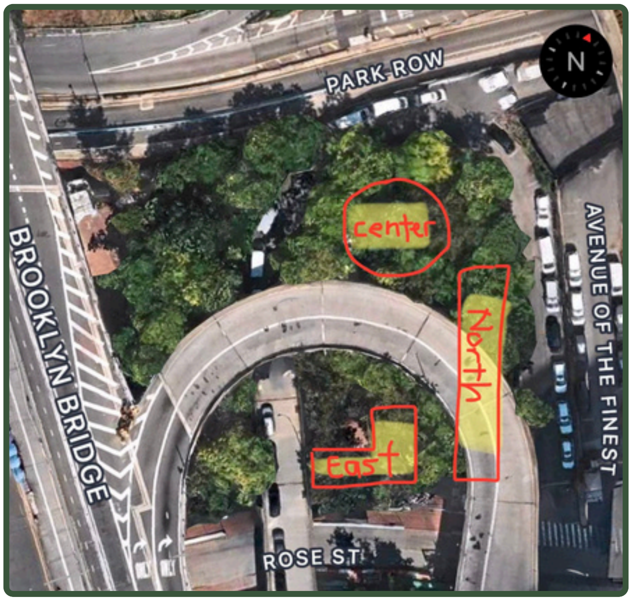

Figure 12. Map of 3 different areas (Center, North, East) in Gotham Park

We divided each of our areas into four quadrants and collected 2 bulk density samples in each–one from the upper level of compost and mulch, and one from the lower, underlying soil. To go about this, we used a standardized ring device to collect each sample, with a volume of 98.174 cm^3. This left us with 8 bulk density samples per group, and 24 bulk density samples total.

We then conducted a series of tests on each sample. To measure the concentrations of heavy metals, we utilized an XOS X-ray fluorescence (XRF) device. We laid each sample under the lid of the device and then ran a 30-second test. After each run, we notated the levels of lead (Pb), arsenic (As), cadmium (Cd), copper (Cu), nickel (Ni), and zinc (Zn) in the sample. We repeated this process 3 times for each sample and recorded the average for each.

To measure bulk density, we needed to record the oven-dry weight of each sample. Once we had recorded all of the final dry weights of each sample, we calculated the bulk density with the following equation:

$$D = M/V$$

where D = the bulk density (g/cm3), M= the final weight of each sample (g), and V= the volume of the cylinder (98.174cm3). We then tested the pH of each sample. To go about this, we measured 20 g of soil from the first sample using a scale, weighing boat, and spatula. We removed any large particles such as rocks and twigs. We then used a 50 mL Falcon tube to measure out 20 mL of deionized water and added the 20 g sample to the Falcon tube. We thoroughly mixed the tube for 60 seconds and then propped it up to sit for 15 minutes. This process was repeated with each of the 8 samples. After the samples had sat out for 15 minutes, we used a pH probe to record the pH level of each sample.

Afterward, we performed physical tests to determine the texture and color of each sample. To distinguish the texture of each, we collected a clump of soil with our bare hands, added a few drops of deionized water, and then created a ball of damp soil. We judged each sample by feel and sturdiness. We then tested the color of each sample by comparing them to a Munsell chart. We carefully recorded the texture and Munsell color of each sample in our notebooks.

Results: The bulk densities found in the Center section of Gotham Park exhibited the lowest median value slightly above 0.2 g/cm3 in the upper soil layers, but had the highest median value in the lower soil layers (Figure 13). For the upper layer samples, the East section had the widest range of bulk density values while the North section had the widest range of values for the lower layer samples. The diamond points indicate outliers, or data points that are more than 1.5 times greater than the interquartile range (75th-25th percentiles, or areas inside the boxes). However, all lower layer samples in all 3 sections exhibited higher bulk density measurements compared to the measurements found in the upper layer samples. The higher bulk densities in the older, lower layers of the soil shows that it is more compacted and denser than the younger, upper layers which helps to assess compaction and whether water can infiltrate through the soil or not.

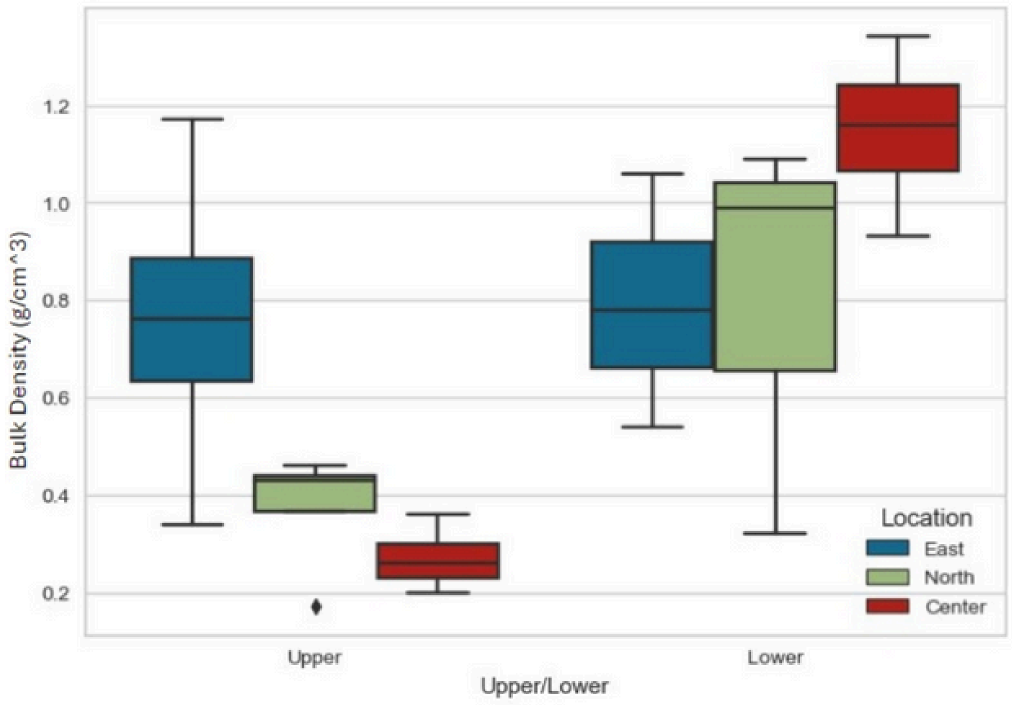

Figure 13: Bulk densities in all 3 sections for upper/lower soil samples

SOIL

TThe Center section had the lowest median value for pH in the upper soil layers while the East section had the highest median value. In the lower soil layers, the North section had the lowest median value for pH while the East section had the highest median value (Figure 14). The majority of the samples in both the upper and lower layers had alkaline pH values that were closer to 7 (neutral) than to 14 (extremely alkaline) (Figure 14).

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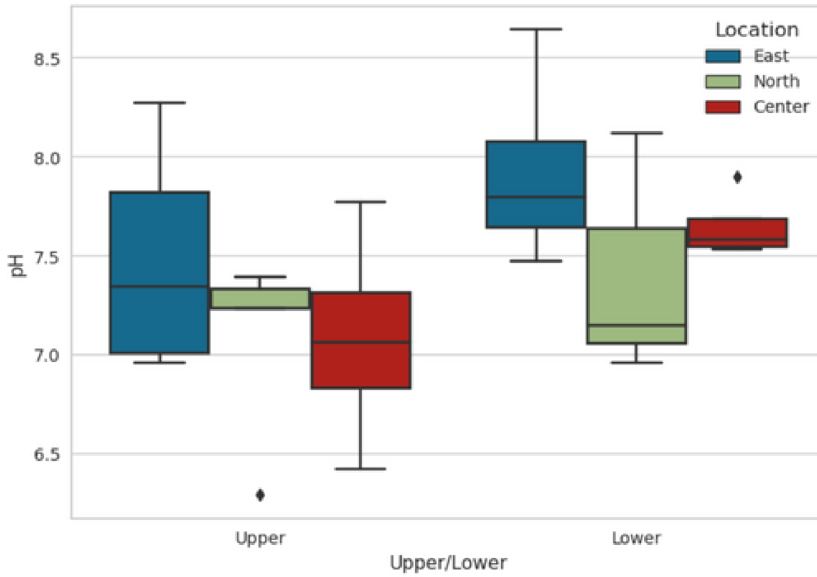

Figure 14. pH values in all 3 sections for upper/lower soil samples

The proportions of sand, silt, clay and texture distributions for the upper soil samples in the Center, East, and North sections within Gotham Park are shown in the figure below (Figure 15). Majority of the upper samples in all 3 sections consisted of organic matter (most likely compost) which is beneficial since it helps to provide nutrients, increases water & air retention, and improves biological activity.

Figure 15. Soil Textural Triangle for Upper Soil Samples in all 3 sections

SOIL

Texture distributions for the lower soil samples in the Center, East, and North sections within Gotham Park (Figure 16). Only two lower samples in the North section consisted of organic matter. All four lower samples from the Center section consisted of a sandy loam texture which is very useful for soil drainage.

The average lead concentrations for all of the soil samples in the 3 sections were below the New York State Department of Environmental Conservation's (NYSDEC) Soil Cleanup Objectives (SCO), which uses the EPA's new federal Soil Screening Level (SSL) of 200 ppm (NYSDEC, 2020) (Figure 17). While all samples are an order of magnitude lower than this standard, we noticed that almost all subsoil layers (except for in the North section where the averages are the same) had slightly higher lead concentrations than the upper layers. This is most likely due to the accumulation of lead gasoline or paint emissions in the older subsoil layers. However, even the subsoil layers are below NYSDEC's "background" or Unrestricted Use SCO (UUSCO) of 63 ppm for lead. We predict that layers beneath those we sampled (below 8" depth) may contain higher lead concentrations. These underlying soils should remain undisturbed to limit any potential exposure.

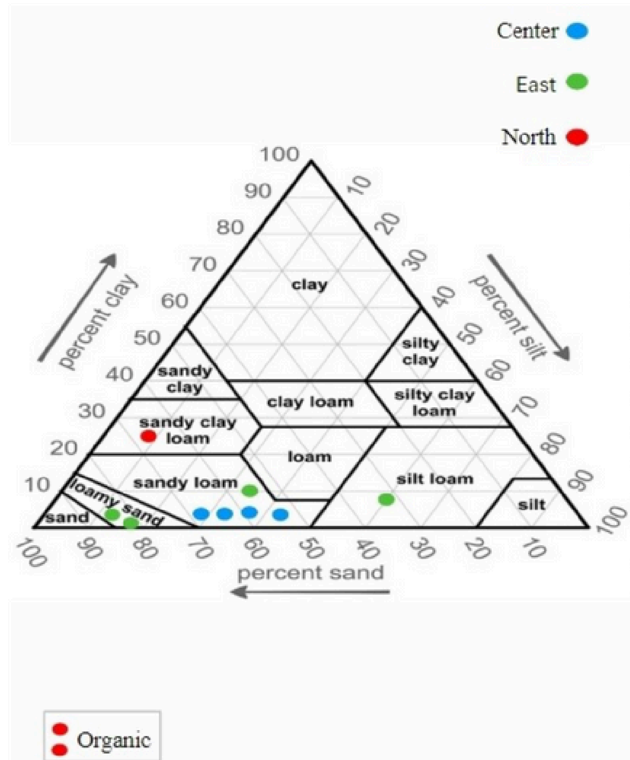

Figure 16. Soil Textural Triangle for Lower Soil Samples in all 3 Sections

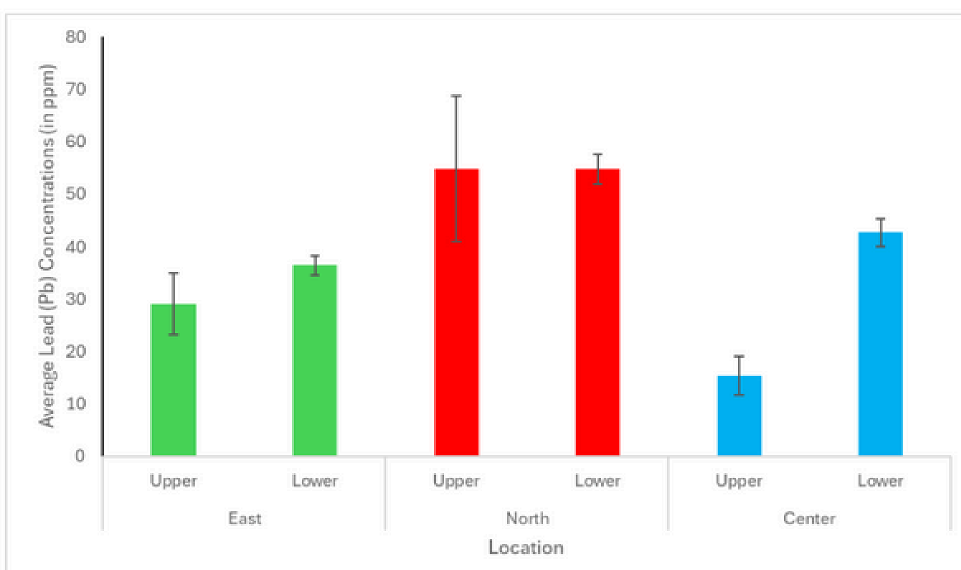

Figure 17. Average Lead Concentrations in the 3 Sections for Upper/Lower Samples

SOIL

The average arsenic concentrations for all of the soil samples in the 3 sections were well below the NYSDEC UUSCO of 16 ppm. Similar to the trend observed for lead, arsenic concentrations in all lower soil layers were higher than upper soil layers in all three locations with the center section exhibiting the highest average concentration in the lower layer of 12 ppm (Figure 18).

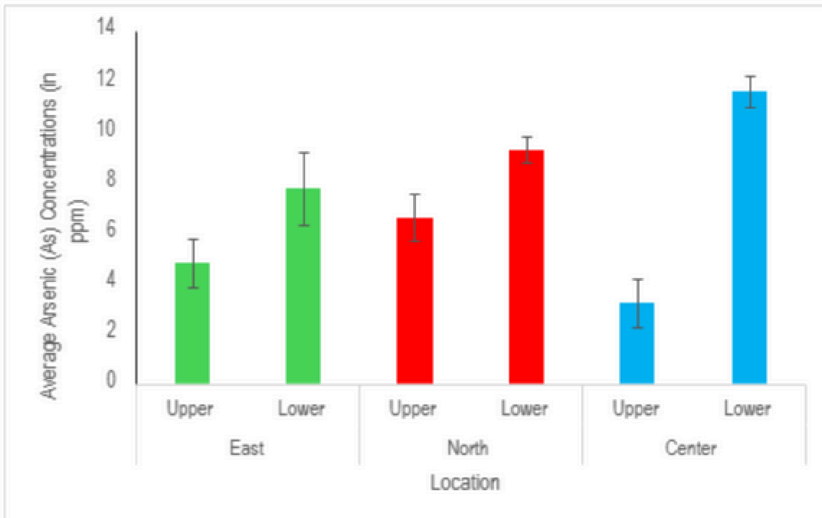

Figure 19. Average Copper Concentrations in the 3 Sections for Upper/Lower Samples

The average nickel concentrations for the soil samples in the 3 sections were relatively low with concentrations below 20 ppm except for the upper layer in the North section which exhibited the highest average copper concentration of 45 ppm. (Figure 20). All samples are at or below the UUSCO of 44 ppm, and are well below the Residential SCO of 87 ppm.

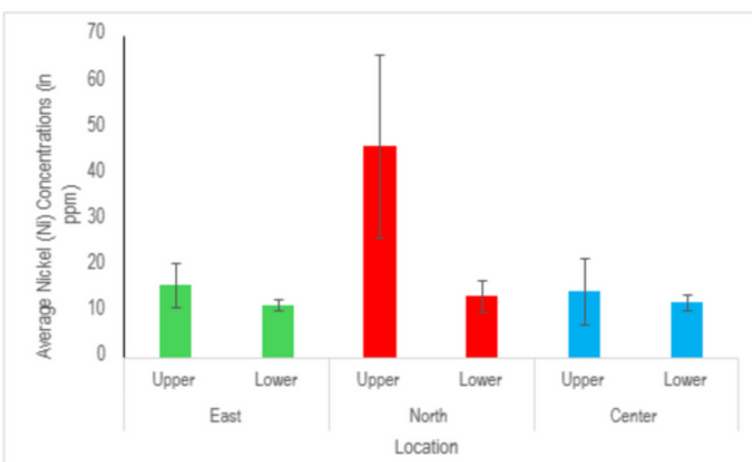

Figure 20. Average Nickel Concentrations in the 3 Sections for Upper/Lower Samples

SOIL

The average zinc concentrations in the upper soil layers were higher in the East and North sections of the park with the lowest average concentration being in the upper layer of the Center section (Figure 21). This sample comes from the region impacted by the scupper drainage. All average concentrations are well below the UUSCO criteria of 660 ppm for zinc.

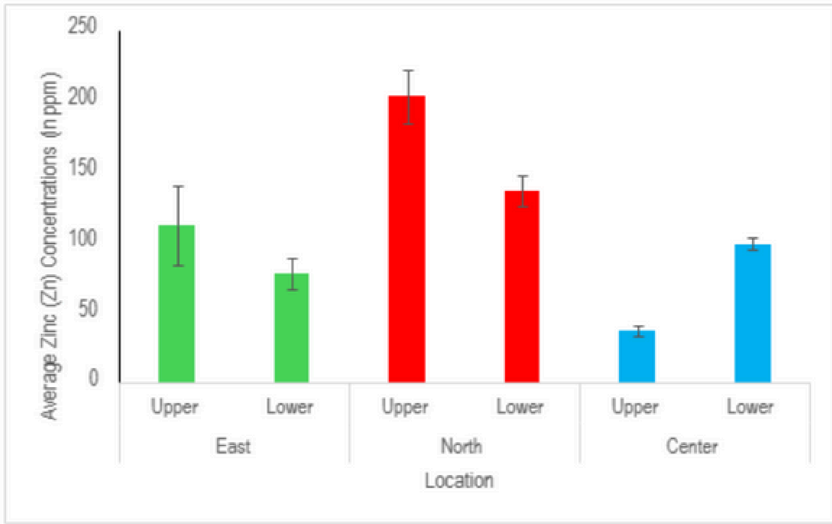

Figure 21. Average Zinc Concentrations in the 3 Sections for Upper/Lower Samples

Discussion: For the most part, the soil testing demonstrated that metal levels were far below NYS's most stringent Unrestricted Use Soil Cleanup Objectives (NYSDEC, 2023). The findings with most metal content were near scuppers, so were likely directly impacted by the runoff. This in turn made these portions of the soil slightly more alkaline, which is less favorable for most plants and crops. The pH will affect the available nutrients for plant intake (Neina, 2019). While our data show that the soils are free from contamination, we would not recommend growing edible food as there may be additional and emerging sources of contamination from the Brooklyn Bridge that could impact the safety of produce.

Because of this the best plants would be delphiniums and hostas. Small shrubs and plants take little care and are much less expensive than trees and crops. Finding plants with little water needs for the summer months is important to consider due to cost and conservation purposes. The best trees would be Willow (Sallows/ Osiers), Dogwood (Cornus florida), and White Oak (Quercus alba). Trees provide beneficial ecosystem services for the community. During hot summers (which are intensified by urban areas such as NYC), trees act as a natural cooling effect, which is proven to increase physical and mental health, as increased greenery is correlated to greater positive emotions and increased comfortability and socialization when compared to hardscaped areas (Coder 2011). This cooling system not only provides benefits for the earth, but also for community members who can safely benefit from time outdoors in the hotter months. Trees are also great carbon sequestration which in large amounts can help offset anthropogenic increases of carbon, especially in cities.

SOIL

Certain plants will grow best in Gotham Park based upon hardiness zone 7, an average pH of 7.5 for all samples, and weather conditions.

SHRUBS: delphiniums, and Hostas are easy to maintain, cost-effective

TREES: Willow, Dogwood (Cornus Florida), and White Oak, has a cooling effect.

CONCLUSION

Project Conclusion: To conclude, all of the data and subsequent analysis suggest that Gotham Park has healthy soil and favorable air quality. The quality of the water entering Gotham Park is slightly suboptimal, potentially due to the scuppers along Avenue of the Finest. Considering the dense population and high vehicle traffic of Gotham Park's Lower Manhattan location the overall data provides a positive outlook for the overall health of Gotham Park.

Soils had low concentrations of heavy metals and other contaminants and the air quality area was surprisingly healthy, providing evidence that the soil quality and air quality is optimal for the health of community members seeking to engage with the Park.

The water quality is less than ideal, with evidence of higher nutrient concentrations and metals including zinc and copper, entering the Park from scuppers connected to the Brooklyn Bridge. Given our results, we suggest the continued monitoring of water, air, and soil quality. In addition, we have provided recommendations for flora to be planted at Gotham Park that will ultimately benefit the environment of downtown Manhattan and the community the park serves. Future studies may involve collaborations with hydrologists to investigate the volume of water entering and leaving Gotham Park, as well as analysis of the interactions and responses of newly planted flora with a specific focus on the Northern study area.

Acknowledgments: First, we would like to thank the Gotham Park administration, specifically Rosa Chang and Megan Brosterman, for allowing us to conduct sampling and research in the park. We would also like to thank the Pace Environmental Department for providing the equipment necessary for all of the labs conducted. Special thanks to Dr. Egendorf, our fearless leader, for designing the studies, and Dr. Palta for initiating this collaboration and providing expert support. Thanks again to everyone for taking the time to listen to our presentation.

Appendix

Water

Sample ID	Site	Group	Salinity (ppth)	Concentration NO_3^- (ppm)	Concentration PO_4^{3-} (ppm)
Rainwater	Pace Garden	Wormies	0	4.1	0.86
		Center Stage	0	0.7	0.5
		Soilerz	0	1.02	0.24
CSO 3	East River	Wormies	10	17.6	1.26
		Center Stage	11	0.6	0.54
		Soilerz	8	1.42	0.28
CSO 4	East River	Wormies	9	3.9	2.8
		Center Stage	9	0.56	0.37
		Soilerz	9	1.74	0.9
CSO 5	East River	Wormies	6	3.6	1.5
		Center Stage	20	1.1	0.47
		Soilerz	15	2.3	0.37
Scupper	Gotham Park	Wormies	0	4.2	1.9
		Center Stage	0	0.94	0.82
		Soilerz	0	4.5	1.7

Table 1 Concentrations of salinity, nitrate, and phosphate in samples taken from the Pace Garden (rainwater), East River (CSO 3-5), and Gotham Park (scupper). Salinity is measured in parts per thousand (ppth). Nitrate and phosphate are measured in parts per million (ppm).

Air

Gotham Park - Raw Data

Minute	Gas Concentration			
	PM_{10} (mg/m^3)	$PM_{2.5}$ (mg/m^3)	NO_2 (ppm)	O_3 (ppm)
1	0.004	0.001	0.012	0.027
2	0.007	0.002	0.010	0.033
3	0.003	0.001	0.007	0.031
4	0.008	0.002	0.012	0.037
5	0.003	0.001	0.015	0.035
6	0.004	0.001	0.014	0.032
7	0.005	0.002	0.015	0.046
8	0.004	0.002	0.018	0.037
9	0.005	0.002	0.020	0.041
10	0.004	0.002	0.017	0.037
11	0.007	0.004	0.014	0.044
12	0.005	0.002	0.018	0.045
13	0.004	0.001	0.013	0.043
14	0.005	0.002	0.019	0.047
15	0.004	0.002	0.022	0.042

Table 1 Gas concentrations of O3, NO2, PM10, and PM2.5 measured in Gotham Park, New York, NY on March 1, 2024.

Brooklyn Bridge - Raw Data

Minute	Gas Concentration			
	PM_{10} (mg/m³)	$PM_{2.5}$ (mg/m³)	NO_2 (ppm)	O_3 (ppm)
1	0.004	0.002	0.023	0.051
2	0.003	0.001	0.021	0.048
3	0.004	0.001	0.024	0.048
4	0.004	0.002	0.026	0.047
5	0.006	0.001	0.026	0.042
6	0.006	0.003	0.036	0.040
7	0.004	0.002	0.030	0.041
8	0.003	0.001	0.026	0.045
9	0.005	0.002	0.029	0.041
10	0.004	0.002	0.031	0.043
11	0.005	0.002	0.032	0.044
12	0.004	0.002	0.030	0.042
13	0.006	0.003	0.026	0.043
14	0.004	0.001	0.030	0.047
15	0.004	0.002	0.033	0.042

Table 2 Gas concentrations of O3, NO2, PM10, and PM2.5 measured on the Manhattan half of the Brooklyn Bridge, New York, NY on March 1, 2024.

Pace University - Raw Data

Minute	Gas Concentration	
	NO_2 (ppm)	O_3 (ppm)
1	0.053	0.018
2	0.030	0.009
3	0.019	0.010
4	0.024	0.012
5	0.052	0.001
6	0.033	0.000
7	0.010	0.000
8	0.029	0.000
9	0.027	0.000
10	0.064	0.000
11	0.072	0.006
12	0.000	0.001
13	0.010	0.005
14	0.027	0.002
15	0.013	0.006

Table 3 Gas concentrations of O3 and NO2 measured inside Pace University, New York, NY on March 1, 2024.

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