DETERMINING PARTICULATE MATTER CONCENTRATIONS IN NEW YORK CITY TRAIN STATIONS

Observational Project

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Introduction:

Air pollution is affecting the lives of millions, causing many health problems such as asthma and premature deaths (EPA, 2008). Particulate matter (PM) is a broad class of chemically and physically diverse substances that exists as either liquid droplets or solid particles ranging from many sizes. Much research has been done on PM showing that hazardous levels can have negative consequences and has even been found at these levels by the EPA in elementary and secondary schools (Ligman et al., n.d.) and even inside of school buses (harming students on their way to school) (Hill, 2005).

In New York City, millions of people use the Metropolitan Transportation Authority (MTA) every day for transportation across the city. This ranges from students trying to get to school, adults trying to get to work, pregnant women, babies, the elderly and just about any kind of person that you could find in the diverse city of New York. However, not much research has gone into determining the PM levels in the MTA train stations. With the construction that has been taking place in train stations, it is very likely that PM levels are high and so dangerous levels of PM in train stations is an issue that needs to be addressed.

Project Design Chart

Scientific Problem
What are the PM levels in NYC train platforms, are they safe, and why are they the way they are?
Hypothesis
As previous research conducted by the EPA has shown indoor sites to have higher PM levels than outdoors (Ligman et al., n.d.), the train station platforms are likely to have exceeded the EPA standards by exposing passengers to more than 150 $\mu g/m^3$ of PM_{10} or 35 $\mu g/m^3$ of $PM_{2.5}$ in a day. Train tracks are constantly going under construction, which would tend to increase the PM

concentrations. Since these train tracks are underground, it would be as if the PM is stuck within the train stations. The 96th street station in particular should have the highest levels of PM since it has been going under constant construction for the past two years. Since the 148th street station is within five blocks of a construction site, which also happens to be bus depot, it will most likely have a high concentration of PM. The trains should could have high levels of PM since vehicles are known to have the same PM as their surrounding ().
Objectives
Determine the PM levels in the train stations along the 3 train.
Compare these levels to the ranges determined by the EPA.
Determine possible causes and effects of these PM levels.
Independent Variable
The train platforms
Dependent Variable
PM concentrations
Constants
Procedure for taking measurements
Assumptions
Sample time is sufficient to get a good sense of the PM concentrations
P.M. sensor maintains the same calibration throughout the experiment
The PM levels are independent of time of day.
Limitations
Materials and the precision of the meters
Amount of time that measurements are taken for

Locality:

Along the MTA 3 train track line, the following ten stops:

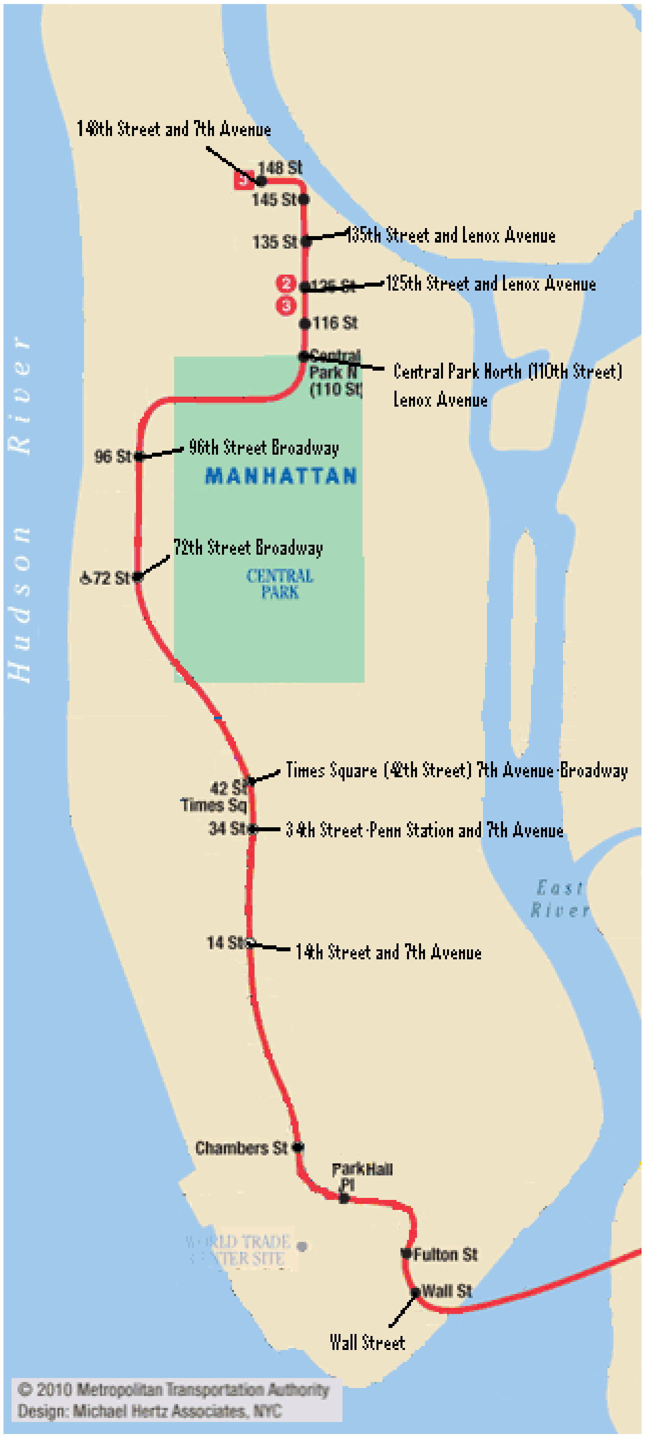

Figure 1: Map of designated stops

Background Information:

In 1990, the US Congress passed the Clean Air Act, aiming to reduce air pollution. As a result, the Environmental Protection Agency (EPA) focused on particulate matter (PM). As defined by the EPA, particulate matter is a highly complex mixture comprising particles emitted directly from sources or formed through atmospheric chemical reactions that ranges from many sizes and shapes and consists of many chemicals such as carbon, sulfate and nitrate compounds, and metallic materials (Stephenson, 2006). PM can also consist of aerosols, smoke, fumes, dust, ash and pollen and is hazardous because it is small enough to evade the body's mechanisms of blockading foreign objects (i.e. nose hairs and mucus) (Thurston, n.d.). More specifically, the EPA identified two types of PM sizes, coarse particles and fine particles. Coarse particles, also known as PM_{10}, are between 2.5 and 10 micrometers in diameter and fine particles, also known as $PM_{2.5}$, are smaller than 2.5 micrometers in diameter.

According to Dr. Thurston, a professor at NYU School of Medicine and once the Deputy Director of the NYU Particulate Health Research Center, sources of PM include industrial sources, residential wood combustion, motor vehicle exhausts, road dust generated by traffic, and for $PM_{2.5}$ primarily, chemical reactions in the atmosphere through emissions of fossil fuel combustion (2009). This means construction sites, highways, bus depots, or any site that involves a high activity of vehicles would most likely have high concentrations of PM.

In correspondence to the Clean Air Act, the EPA set the National Ambient Air Quality Standards (NAAQS). In this, it was determined that on average, a person shouldn't be exposed to 150 $\mu g/m^3$ of PM_{10} in a 24-hour time period more than once per year on over three years). Furthermore, a person shouldn't be exposed to 35 $\mu g/m^3$ of $PM_{2.5}$ in a 24-hour period. However, in Canada, standards for a 24-hour time period are 50 $\mu g/m^3$ for PM_{10} and 30 $\mu g/m^3$ for $PM_{2.5}$ (Thurston, 2009).

Research has shown PM exposure to have negative effects. The EPA claims that PM exposure could lead to increased respiratory symptoms (i.e. irritation of the airways, coughing, or difficulty breathing), decreased lung function, aggravated asthma, the development of chronic bronchitis, irregular heartbeat, nonfatal heart attacks and premature death in people with heart or lung disease (EPA, 2008; Thurston, n.d.). It has been found that cardiopulmonary mortality increased by 0.21% for each 10 $\mu g/m^3$ increase of PM_{10} within 1-2 days after the exposure and chronic obstructive pulmonary disease hospitalization rates increased by 2.5%, pneumonia rates by 1.95%, and cardiovascular disease rates increased by 1.27% (Thurston, n.d.). In addition, a decrease of PM exposure by $10 \mu g/m^3$ has shown to increase life expectancy by an average of 7 months (Pope, Ezzati & Dockery, 2009).

In New York City, the Metropolitan Transportation Authority (MTA) is used by millions to travel. By the end of a week, one could have spent hours on the trains. According to the MTA, on an average weekday, 5,225,675 people use the trains, 2,979,391 on an average Saturday and 2,310,944 on an average Sunday.

Materials

Materials	Quality	Description
MET one Aero 212(P.M. sensor), Texas	1	Used to collect Particulate Matter
Backpack	2	Used to move the materials around (primarily the P.M. sensor and laptop)
Cabela's Rechargeable 12-Volt Battery (IA-018049)	1	Used to power the P.M. sensor
Laptop	1	Used to collect the data from the sensor
HyperTerminal(program)	1	The program used to start up the meter
Microsoft Excel	1	To make graphs and organize data
Air Cable Serial 3 (Bluetooth device) San Jose, California	1	To collect data from the PM sensor

Locality Chart	1	To record the time displayed by HyperTerminal to match it with the locality that you are taking the data from
Volt meter	1	Used to find out the power level of the car battery
Air Cable Serial 3 (Bluetooth receiver) San Jose, California	1	To connect to the computer, so the data can be sent from the P.M. sensor to the computer so that data can be displayed on HyperTerminal
PM Sensor Wire Alligator clips	1	Used to power the P.M. sensor while using a Car Battery
Spip4h	1	The program used to display the data from the P.M. sensor

Procedures

Steps for Obtaining PM data from train platforms

Measuring of data will begin at the first stop (148th street). When at this station, the materials will be set up. The PM sensor will be connected to the battery and then connected to the computer via Bluetooth (using Hyper Terminal to start up the meter). Once the computer is gathering data from the sensor successfully through spip4h, we can begin to record data. The PM sensor needs to be secured in a backpack and the laptop needs to be readily accessible. Starting off at one end of the platform, the person with the PM sensor will begin to walk at a constant speed to the other end. This way, an average of the whole entire station can be taken. The time displayed by spip4h, at the beginning and at the end of this process will need to be recorded in the locality chart in the proper slot. It would be beneficial to note down in the comments section whether there was construction being done on the station. Repeat this process for every designated stop. There is no set sample time since each platform has a different length and the objective is to get the average of the entire platform.

Steps for converting measurements from the meter into a concentration

Assumptions:

The particles are spherical

The density of each particle is 2000 kg/m^3

Equations:

Mass (of each individual particle) = density x volume

Volume (of each particle) = $4/3\pi r^3$

Numbers to know:

Flow rate: 1.127 L/min or 0.8873 min/L (60 s / 1 min)(1 L / 10^{-3} m^3) = 53238.68678 s/ m^3

Frequency of measurement: $(5\ s)^{-1}$

In order to find the particulate matter concentration of a train platform, first the average of each bin measurement must be taken. Then, the mass of each individual particle must be calculated. This number is multiplied by the average of particles recorded, by the frequency of measurement, and by the flow rate.

For example, for bin 10, on 96th street, the average of particles was 11.75676, so:

Concentration = (Average of particle number recorded) x (mass of individual particle) x (flow rate) x (frequency of measurement)

= (11.75676) x (Density x volume) x (flow rate) x (frequency of measurement)

$= (11.75676) \times (2000\ kg/m^3 \times 4/3\pi r^3) \times (53238.68678\ s/m^3) \times ((5\ s)^{-1})$

$= (11.75676) \times (2000\ kg/m^3 \times 4/3\pi (5 \times 10^{-6}\ m)^3 \times (53238.68678\ s/m^3) \times ((5\ s)^{-1})$

$= 1.31 \times 10^{-7}\ kg/m^3\ (10^9 \mu g / 1 kg) = 131\ \mu g/m^3$

Therefore, the PM concentration for bin 10 at 96th street was 131 $\mu g/m^3$.

Steps for setting up Bluetooth.

1. Hook up sensor to Bluetooth device.
2. Plug in the air filter and make sure the voltmeter works.
3. Open up control panel, then net work connections, then blue tooth device, and click on AIRserial3x06723.
4. Look to see what COM part it was assigned.
5. Open Hyper Terminal program.
6. Name the connection.
7. Select the COM port it was assigned.

8. Press ESC until arrows appear.
9. Once the arrows appear press H.
10. Press T and setup the time interval.
11. Press S and the device would start collecting data according to the time interval.
12. Press Q to stop and copy the data.
13. Open notepad.
14. Paste the data you copied on notepad and save it under a file.
15. Open up Microsoft Excel.
16. Click Data on the tool bar and click import external data.
17. Click import data and click the file you saved.
18. Select Delimited, click next, select comma, click next, and click finish.
19. Save data file.

Observations and Results

In the first trial, 96th street had the highest PM concentration in all bins (as seen in figures 2-9), with some levels reaching 334.79 $\mu g/m^3$, exceeding the EPA standards of 150 $\mu g/m^3$ for PM_{10} and 35 $\mu g/m^3$ for $PM_{2.5}$. The 125th street station and 72nd street station had the second highest concentrations, followed by 42nd street. The 148th street station had the best air quality, with averages only going as high as 7.18368 $\mu g/m^3$.

Out of all of the train stations tested, six out of seven were at one point violating the EPA standards. The 72nd street station, the 96th street and the 125th street station all violated the PM standard of 150 $\mu g/m^3$ of $PM_{10}$by having levels of bin 3 at 155.031 $\mu g/m^3$, 334.792 $\mu g/m^3$, and 184.627 $\mu g/m^3$ respectively. The 42nd street, 72nd street, 96th street, 110th street, 125th street and 135th street stations all violated the EPA standards of 35 $\mu g/m^3$ of $PM_{2.5}$ by having levels of PM bin 2 at 42.0074 $\mu g/m^3$, 62.4489 $\mu g/m^3$, 129.786 $\mu g/m^3$, 38.7941 $\mu g/m^3$, 74.8859 $\mu g/m^3$, and 39.6813 $\mu g/m^3$ respectively. The 96th street station had another account of a PM levels that exceeded the EPA's standards, with a concentration of bin 1 at 49.4641$\mu g/m^3$.

In the second trail, the results were similar, with the 96th street station having the highest levels and 148th street having the lowest levels.

Analysis of Results

In answering the scientific problem of PM levels in NYC train platforms and their level of hazard, PM levels in NYC train stations are high enough to exceed EPA standards of 150 $\mu g/m^3$ for PM_{10} and 35 $\mu g/m^3$ for $PM_{2.5}$, being of harm to the citizens of NYC. The hypothesis was correct in believing that the 96th street station would have the highest concentration of PM. In fact, while taking measurements, construction was being done on the tracks. However, the hypothesis was wrong in believing that the 148th street station would also have high levels. Instead, it was the complete opposite, and the 148th street station was the only station which did not violate the EPA standards.

The 96th street station has been under construction for at least one year. This alone could explain why the levels were so high, since construction tends to lead to high levels of PM (Thurston, 2009). Furthermore, the data obtained might not be the best representation of the average PM concentration in the 96th street station due to the fact that construction was going on at the exact same time that the data was obtained. Nevertheless, the MTA s exposing the public to hazardous levels of PM.

While the 148th street station is located within a 5 block radius of a construction site and previous bus depot, it had the lowest PM concentration. This could be explained by the structure of the station. Unlike 96th street and most other stations along the red line, the 148th street station is clearly exposed to the outside. Ligman's research showed that the outdoors tended to have lower concentrations of PM (n.d.). Perhaps as the other stations are enclosed, they collect the PM through time, while the 148th street station keeps recirculation its air. On this note, it is reasonable to believe that 72nd had some of the highest levels after 96th because of its proximity to the 96th street station. As 96th street continues with its construction, it is possible that the PM travels and accumulates at the 72nd street station.

The high levels of PM at the 125th street station are more difficult to explain. The 125th street station is mostly not affected by the construction in the 96th street station, especially since if it was, the 110th street station would have also had some of the highest levels. However, the 125th station is located in one of the busiest streets of Harlem, which is known to have higher PM levels than the rest of New York City. Due to the high activity of cars on top of this station, and its location in an area known for high PM concentrations, it is possible that PM has accumulated within the station. This old also explain the mil level of PM seen at the 145th street station.

The 110th street station had the second lowest pm concentrations, despite the fact that it is in between two stations with high levels. It is possible that since the 110th street station is located under Central Park, the PM levels are lower than what there would be otherwise. However, there is a lack of attained research showing any correlation between parks and PM levels to make this assumption.

Conclusion

- 96th street had the highest levels of PM concentration as high as 334.79 $\mu g/m^3$.
- Six out of the seven stations tested violated the EPA standards.
- Construction on tracks increases PM levels beyond the EPA standards.
- There might be a correlation between enclosed stations and their being in Harlem.
- There might be a correlation between stations and their being under a park.

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Suggestions for Improvement and Future Ideas

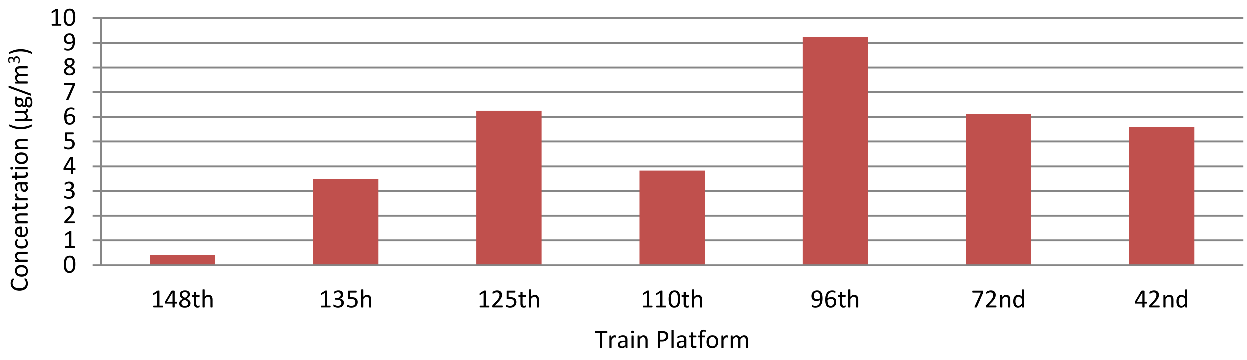
- Make sure that all materials are running perfectly. Initially, this project was suppose to measure air quality in at least ten stations, but only got to seven. That was because on the day of data collection, the battery that was suppose to power the meter wasn't fully charged and the meter dyed out as we arrived at the 34th street station.
- It would be best to obtain data on more than one day or more than once in a day. Try to figure out when construction on a site is being done and when it isn't. Possibly try going during the morning, afternoon and then even the evening, all in one day.
- Try to figure out the demographics of the surrounding. For example, on the both 125th street and 110th street had measurements that were mostly due to their outside location, and not anything with MTA performance.

Annexes

Figure 2: Locality Chart

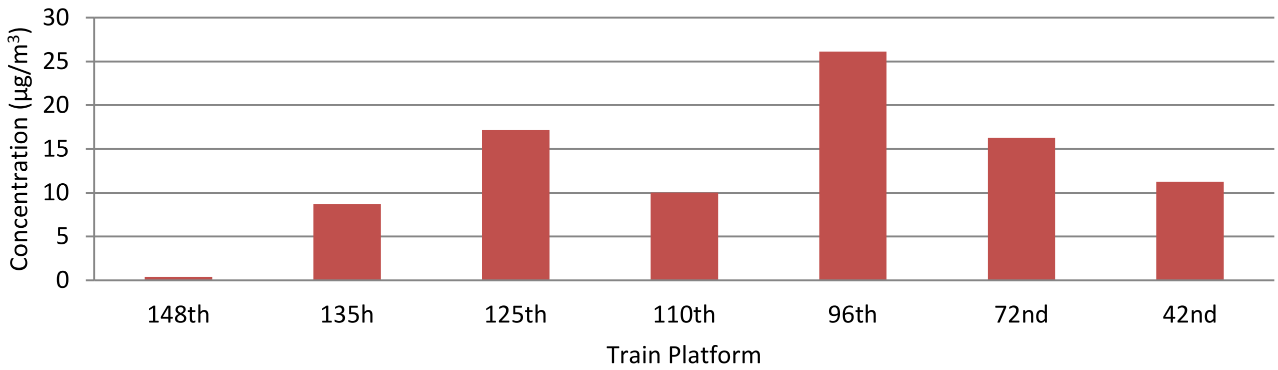
Location	Initial Time	Ending Time	Comments
148th			
135th			
125th			
110th			
96th			
72nd			
42nd			
34th			
14th			
Wall Street			

Figure 3



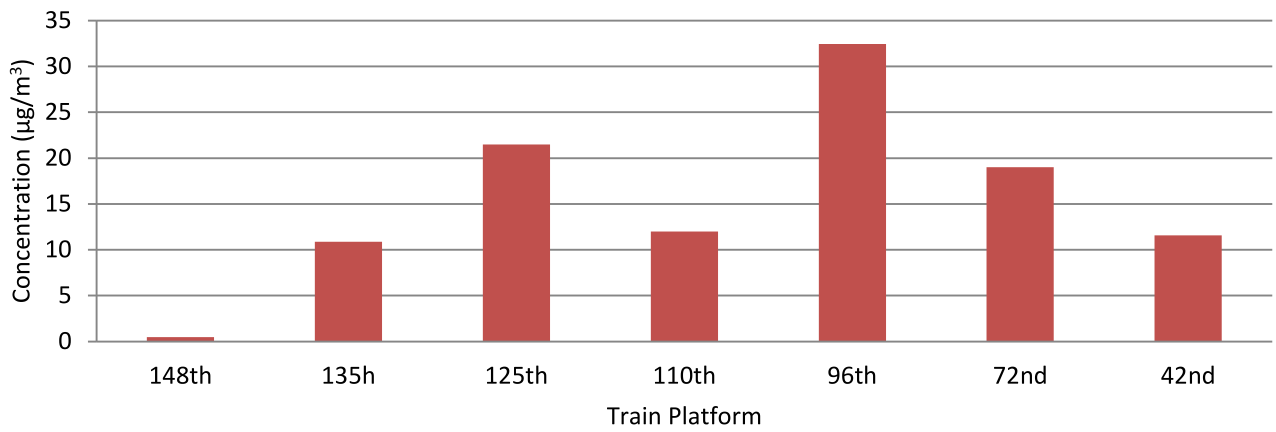
Bin 0.3 Concentrations in NYC MTA (red line) Train Platform, April 14, 2010

Figure 4



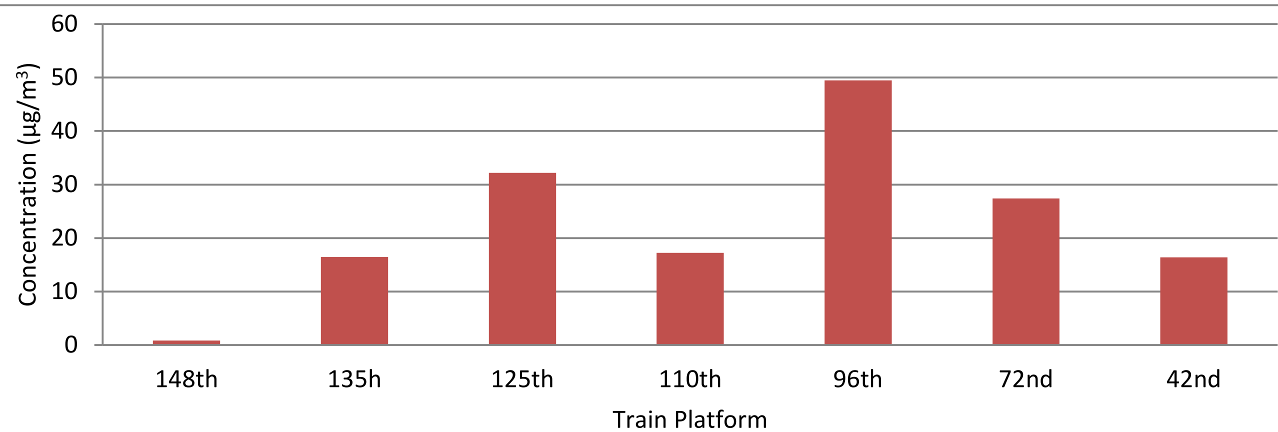
Bin 0.5 Concentrations in NYC MTA (red line) Train Platform, April 14, 2010

Figure 5



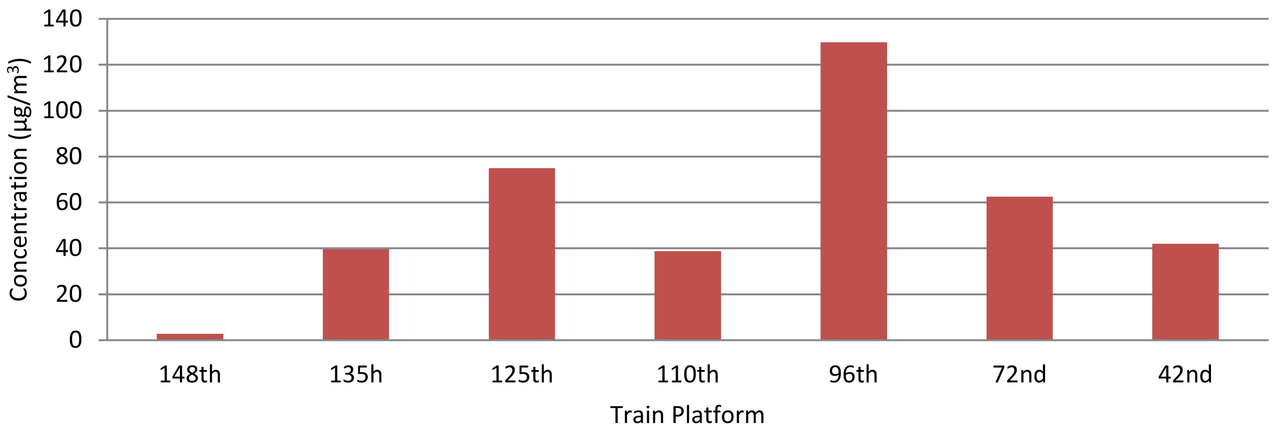
Bin 0.7 Concentrations in NYC MTA (red line) Train Platform, April 14, 2010

Figure 6



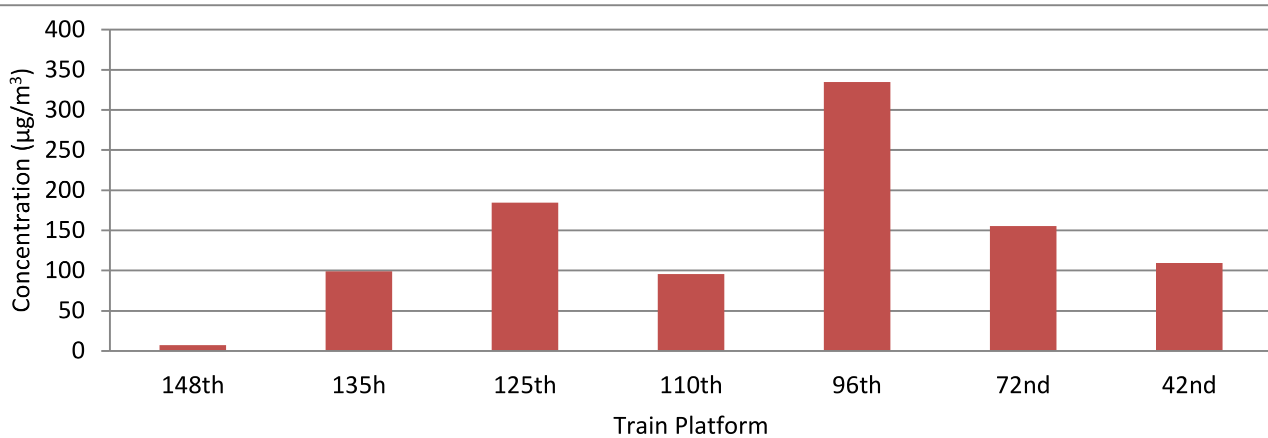
Bin 1 Concentrations in NYC MTA (red line) Train Platform, April 14, 2010

Figure 7



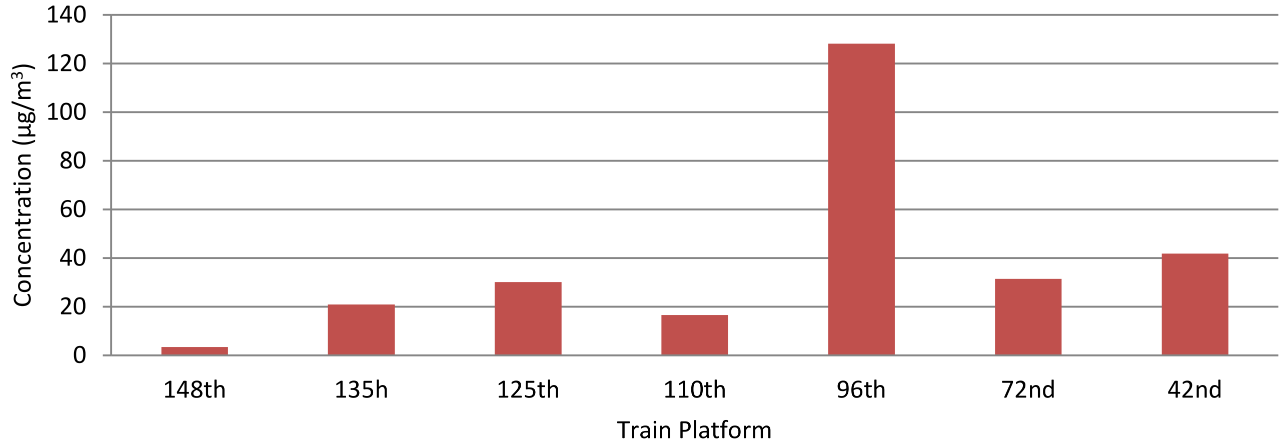
Bin 2 Concentrations in NYC MTA (red line) Train Platform, April 14, 2010

Figure 8



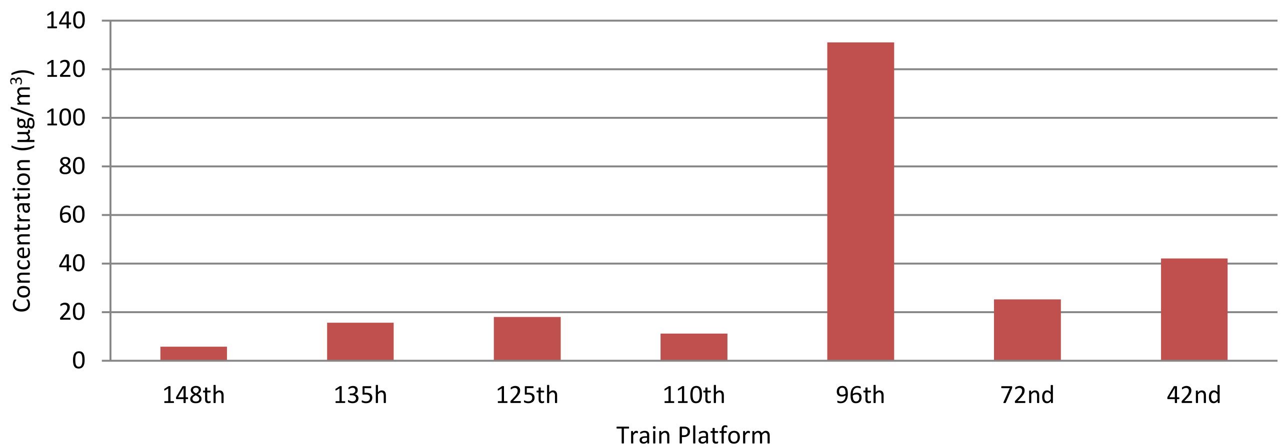
Bin 3 Concentrations in NYC MTA (red line) Train Platform, April 14, 2010

Figure 9



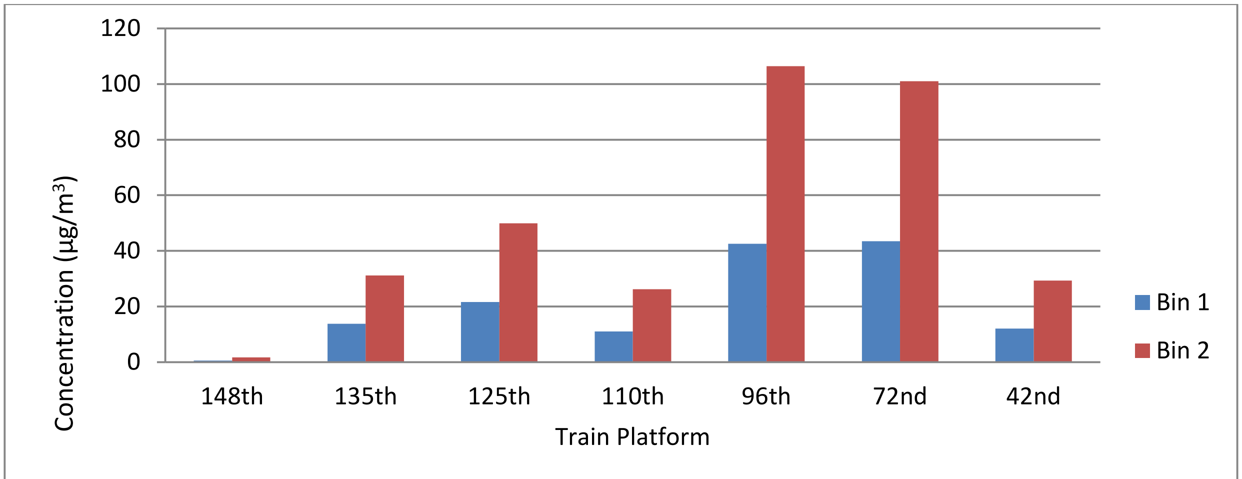
Bin 5 Concentrations in NYC MTA (red line) Train Platform, April 14, 2010

Figure 10



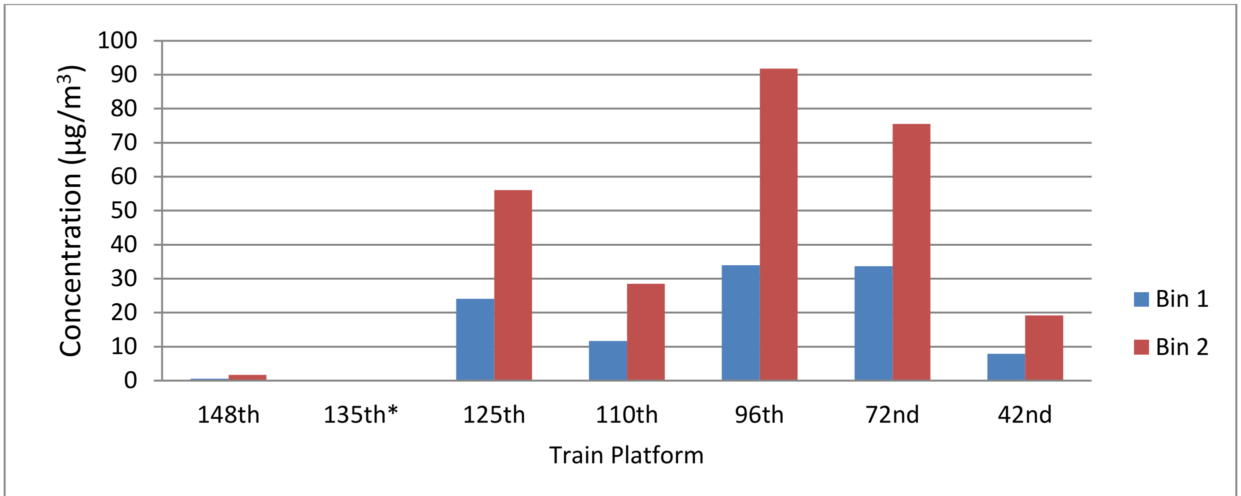
Bin 10 Concentrations in NYC MTA (red line) Train Platform, April 14, 2010

Figure 11



$PM_{2.5}$ Concentrations in NYC MTA (red line) Train Platform, May 13, 2010

Figure 12



$PM_{2.5}$ Concentrations in NYC MTA (red line) Train Platform, May 13, 2010

Figure : Project set up