DETERMINING THE EFFECTS OF FILTRATION ON AIRBORNE PARTICULATE MATTER IN A NEW YORK CITY PUBLIC SCHOOL

Environmental Sciences

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Abstract

Elevated levels of Particulate Matter (PM) are affecting Harlem's residents. With a disproportionate level of asthma incidence, and lower IQ levels, young children are being subjugated to sub-standard living conditions. This project sought to find if PM levels in a NYC public school classroom with an air filter are lower than a NYC public school classroom without an air filter. The experiment was conducted by setting up an Aero 212 PM sensor in both classrooms which were controlled for closed doors and windows during the sampling time. The classroom without the air filtered showed an average of 1.33 $\mu g/m^3$ and the classroom with an air filter showed an average of 0.51 $\mu g/m^3$. These averages are well below the EPA yearly limit standard of 15 $\mu g/m^3$ and far below the EPA daily exposure limit of 35 $\mu g/m^3$, however the air filter was able to reduce PM levels in a classroom by 61.30%. A T-test was performed and it was concluded that on a 99% confidence interval that the air filter had a significant effect on the reduction particulate matter levels. The Frederick Douglass Academy, the school involved in this study, is in a particularly high cancer rate area due to PM as determined by the EPA. And therefore, this project should be taken into consideration by policy makers and local leaders to add filters to classrooms throughout the building.

Table of Context **Page**

Introduction

New York City is one of the most populated cities in the United States. With that being said, one should expect this city to have high environmental awareness and sustainability. Unfortunately this isn't the case; Harlem has been targeted the worst when it comes to environmental safety. Asthma rates in Harlem and the South Bronx are far worse than for any other section of the city, about 25% (Perez-Pena, 2003) and children are being born with lower I.Q.s (Hoepner, et. al., 2009). This is due to the high levels of particulate matter (PM) in our air that come from the same vehicles that bring us our goods (WeAct, 2009). However, over the past few years people have become more concerned about their health and the world. Today local programs like The Harlem River Park Task Force and WeAct are trying to raise awareness about Harlem air quality, especially in Harlem. Areas in Harlem suffers from high levels of PM, while better social economic areas such as the Lower East Side, or Upper West Side may have better PM data(EPA, 2007).

PM levels in Harlem schools is a sensitive issues that requires more attention. With one of the highest incidents of asthma the areas in which children attend on a daily basis have not been studied sufficiently. Children spend about 8 hours of the day, 5 times a week in school. If people are informed about their environment and their communities and what can harm them together we can come up with solutions to make our community better. The purpose of this project is to determine the effects of filtration on particulate matter in a NYC public school. It is expected that the classroom with air filtration will have a significantly lower level of PM particularly for Pm smaller than 3.0 microns than in the non filtered classroom because air filters are designed remove PM and are more effective towards smaller particles. With the information that is obtained we can come up with solutions to better this school all year round.

Project Design

SCIENTIFIC PROBLEM
What are the differences in PM readings between a high school classroom with air filtration and a high school classroom with no air filtration?
HYPOTHESIS
The classroom with air filtration will have a significantly lower level of PM particularly for PM smaller than 3.0 microns than in the non filtered room because air filters are designed remove PM and are more effective towards smaller particles.
OBJECTIVES
Determine the PM levels in an high school classroom with air filtration and one with no filtration.
Determine if the levels found are up to EPA standards.
Propose improvements if needed.
INDEPENDENT VARIABLES
Classroom with presence of air filtration, Classroom with absence of air filtration
DEPENDENT VARIABLES
PM concentration levels
CONTROLS
Both classrooms contained closed windows and closed doors
CONSTANTS
Sampling time in each classroom
ASSUMPTIONS
Temperature will remain the same, sampling time is enough, PM sensors will run correctly throughout the experiment, PM sensors measure the counts of PM in every 500 L of air

Background Information

Particulate Matter are solid and liquid particles suspended in the air. Most are hazardous. They can contain for instance dust, pollen, soot, smoke, liquid droplets, and carcinogenic chemicals (EPA, 2009). Particles that are smaller than 10 microns will impact human health – in particular their respiratory system (Warbelow, n.d). PM smaller than 3 microns cause cancer because they penetrate the body, its cells, and nuclei damaging the DNA (Warbelow, n.d). PM smaller than 3 microns is a byproduct of diesel engines found on the very trucks that deliver our goods (WeAct, 2009). Most places in Harlem have a high incidence of PM proven to be the cause of at least 1 cancer patient out of every 10,000 inhabitants. (See figure 3)

Harlem has a very high incidence of asthma and cancer directly related to PM as compared to the rest of the city. The reasons for this are the bus depots and waste treatment plants that dot the area and highways that encircle the area (See figure 4). The area in which this public school is surrounded has an elevated level of PM that exceed the yearly limit of 15 $\mu g/m^3$ and the daily exposure limt of 35 $\mu g/m^3$, both set by the EPA (EPA, 2009). The risk of cancer in the surrounding area of the school within a 5 block radius in any direction is higher than one in every 10,000 people (EPA, 2009). More over this is almost 3 times greater than the national average of 36 in a million (EPA, 2009).

Air toxics, also known as toxic air pollutants or hazardous air pollutants, are those pollutants that cause or may cause cancer or other serious health effects, such as reproductive effects or birth defects, or adverse environmental and ecological effects (NATA, 2009). Examples of toxic air pollutants include benzene which is found in gasoline; tetrachloroethylene which is emitted from some dry cleaning facilities; and methylene chloride which is used as a solvent and paint stripper by a number of industries. Asthma and lung cancer rates are increasing in parts of Massachusetts due to high instances of disease PM being produced by trucks on neighboring highways (McEntee, 2009).

In 2003 Harlem Hospital conducted a study in which it was found that one in four children in Harlem had asthma (Perez-Pena, 2003). This was twice the amount of what researches expected and one of the highest rates ever documented at the time (Perez-Pena, 2003). The Centers for Disease Control and Prevention estimated asthma rates to be about 6 percent nationally at the time; there was speculation that New York City's rate was much higher, and the rate of the South Bronx and Harlem reached the high teens and nearly 20% (Perez-Pena, 2003). Also 25 % of the children diagnosed had no prior knowledge that they had asthma. This can be credited to parents not taking the proper course of action to get their children checked out, and doctors being hesitant to diagnose children with asthma (Perez-Pena, 2003).

In a recent study done lead by Dr. Lori Hoepner of the Mailman School of Public Health at Columbia University, it was concluded that children born to mothers that had high exposure to air pollution during pregnancy were more likely to have lower IQ's than those not exposed to air pollution (Hoepner, et. al., 2009). The IQ's of children around the age of five were measured and compared. The children that were exposed to polycyclic aromatic hydrocarbons or PAH's, had an IQ less than 4.67 points on average (Hoepner, et. al., 2009).

When children are exposed to high levels of PM it may have a long lasting impact. Researchers studied children in Menorca, Spain to see how exposure to certain household gasses affected them (Morales et al., 2009). The children were tested to see if they had attention-hyperactivity behaviors and basic functioning. "Early-life exposure to air pollution from indoor gas appliances may be negatively associated with neuropsychological development through the first 4 years of life, particularly among genetically susceptible children" (Morales et al., 2009).

Locality

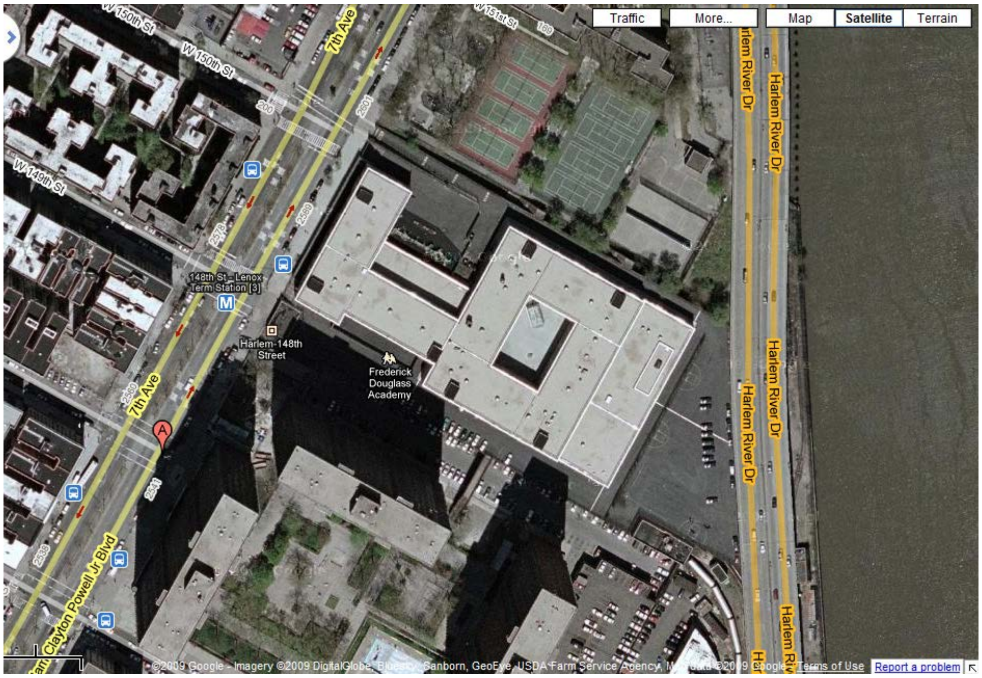

Figure 1- The Frederick Douglass Academy. This Experiment was conducted at the Frederick Douglass Academy. 2581 Adam Clayton Powell Jr. Blvd New York NY 10039.

Materials

Materials	Quantity	Description
MET one Aero 212(PM sensor)	2	Used to collect Particulate Matter
Cart	2	Used to move the materials around
Universal Battery (Car Battery 12 Volt)	2	Used to power the PM sensor
Dell Latitude India	2	Used to hold the data that is collect by the Sensor
Spip4h(program)	1	The program used to display the data from the PM sensor
Microsoft Excel	1	To make graphs
Air Cable (Bluetooth device)	2	To collect data from the PM sensor
Volt meter	1	Used to find out the power level of the car battery
Air Cable (Bluetooth receiver)	2	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 Spip4h
PM Sensor Wire Alligator clips	2	Used to power the P.M. sensor while using a Car Battery
BlueAir 503 model	1	Used to filter the air

Procedures

(Steps for gathering Obtaining PM data)

1. Connect PM sensors to a computer via Bluetooth serial ports to turn it on
2. Place sensors on the carts and connect to batteries
3. Make sure the sensor is running with HyperTerminal first then connected to Spip4h
4. Take each set up sensor and place one in each room
5. Take readings for about a week at one minute intervals and record what time the readings started
6. When finish, record time of exit. Recording time is important in order to know at what time sampling started and at what time sampling ended.

(Steps for setting up Bluetooth.)

1. Hook up sensor to Bluetooth device via a serial cable.
2. Using a voltmeter make sure the car battery has enough voltage then plug in the PM sensor.
3. Open up control panel, then net work connections, then bluetooth device, and click on the bluetooth serial number
4. Look to see what COM port it was assigned and assign correct COM port to the Spip4h configuration by checking the appropriate box.
5. Open up Spip4h.
6. Make sure the bout rate is at 9600.
7. Make the Display of date on DISP-1st box.

8. On the bottom right hand corner click 1 hr Intervals.
9. Click close and save.
10. Now hit acquire. You are now receiving data.
11. Open up the folder in which the data is saved in.
12. Copy and paste all data so that all the data is in one big file and save.
13. Open up Microsoft Excel.
14. Click Data on the tool bar and click import external data.
15. Click import data and click the file you saved.
16. Select Delimited, click next, select comma, click next, and click finish.
17. Save data file.

(Converting counts to concentrations)

The Aero 212 (the PM sensor that was used) will give readings in counts for that one Bin for a certain period. For example, if readings were taken every 5 seconds, then the sensor will take in air, and at the end of 5 seconds, it will tell how many particles were counted that time. Does not matter how often readings are taken, to acquire a liter of air, the machine must be on for a minute. If readings are being taken every 60 seconds, then that means within those 60 seconds, only half a liter of air was sampled. To carry out the conversion of counts to concentrations, the formula of D= M/V will be used. The D will be 2,000Kg/m^3, where this is an assumption because this seems to be a reasonable estimate between the density of water and the density of solid rock. To change the Density from 2,000Kg/ m^3 to units that are in centimeters, the decimal place must move over 3 times. (2,000,000 µg/ cm^3)

To carry out this conversion, we must assume that the particles are spheres. Seeing how the sizes of the particulates are 2 microns in diameter, 1 micron will be the radius. Let us say for example on average, 289 Bin 2 particles on average were found for 30 seconds for the readings. 289 * 2= 578. In one min, there were 578 particles in a liter of air. Seeing how the radius of the particle is 1, well use the formula of a sphere. $4/3(\pi) r^3$. When r= 1, the volume will be 4.2. 578 * 4.2 = 2427.6 μm^3. Then multiply this by 1.0* 10^12 cm^3, and 2.43*10^ -9 cm3. 2.43*10^ -9 cm^3 is the mass. To find the volume, multiply 2.43*10^-9 cm^3 * 2,000,000 µg/ cm^3 to get it. The mass of the Bin 2 particulate is .00486µg. To find the concentration:

(e.g. 1) $$[\ \ ] = \frac{.00486ug}{Liter} \frac{(.5L)}{(1m^3)} = 9.72\ \mu g/m^3$$

In this example, the Particulate Matter concentration is 9.72 µg/ m^3. These steps were taken for all of other data. This meter samples a liter of air per minute, but after testing the meter, the flow rate was only 500 mL, instead of 1 Liter.

(Calculating concentration averages)

To calculate the averages of the concentrations, an average function was used on excel. Then to calculate the percentage difference between both averages the average of the filtered classroom was divided by the average of the non filtered classroom and then that value was subtracted from 100%.

Results

The room without an air filter, (Rooom 308), had an average of 1.33 µg/m³. The room with air filtration, (Room 310), had an average of 0.51 µg/m³. The graph below shows that throughout the majority of the sampling, the room with air filtration had lower levels of PM. The data was plotted in 1 minute intervals.

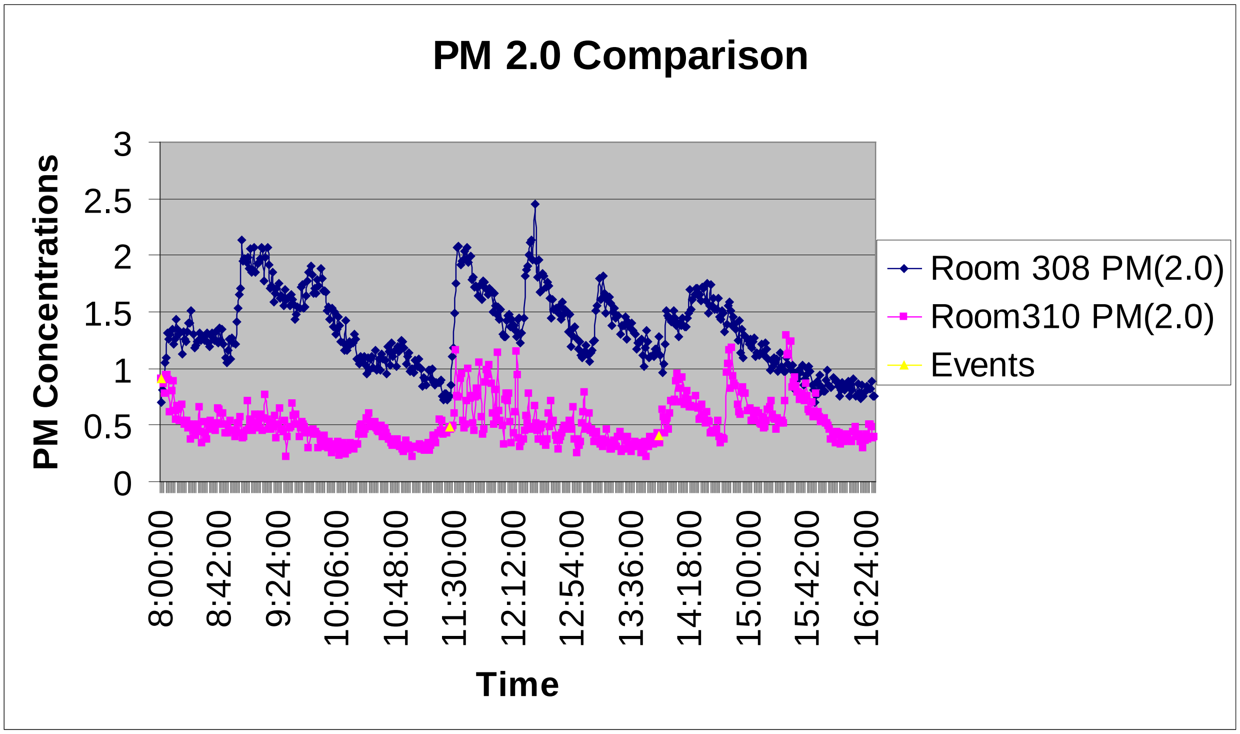

Figure 2- In the graph above PM concentration levels in Room 310 were lower than PM concentration levels in Room 308 on average by 0.82 µg/ m³. The levels in Room 308 never exceeded over 2.5 µg/ m³.

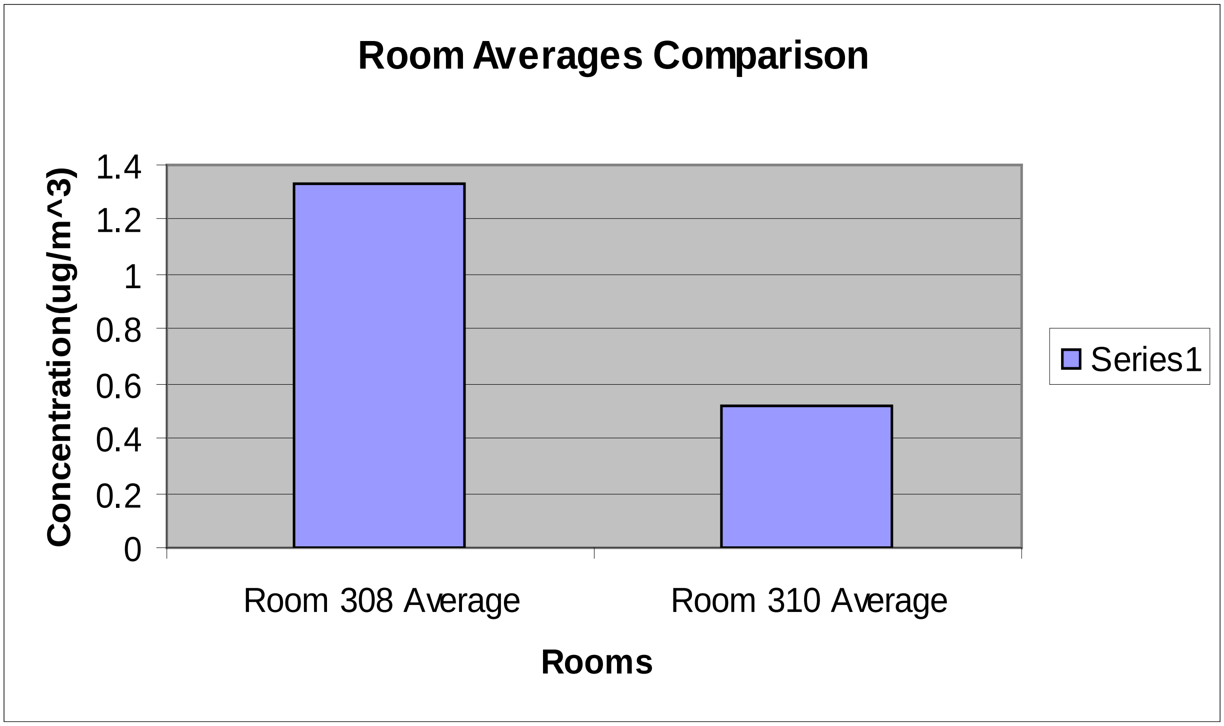

Figure 3: The graph above shows the PM averages of each room.

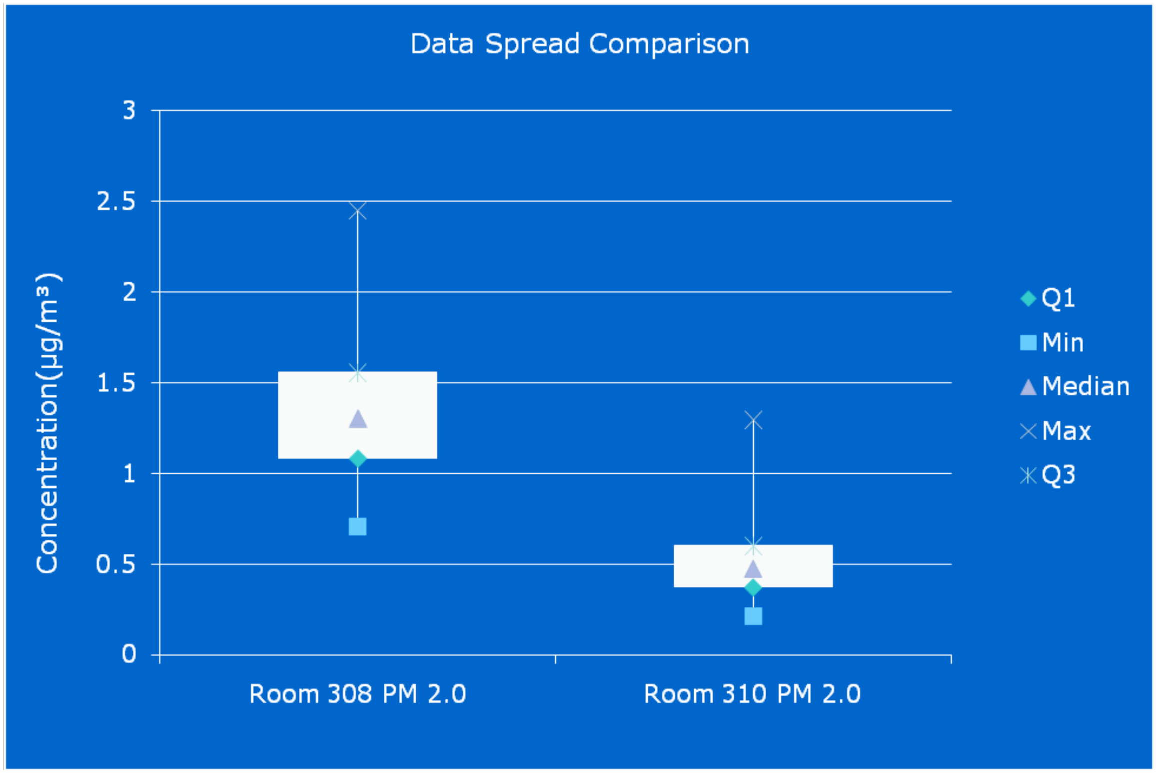

Figure 4: The box plot above shows the data spread of each room.

Analysis

In figure 2 we see the difference an air filter makes in a classroom setting. PM smaller than 3.0 microns in diameter have a strong effect on health. When students were in both classrooms P.M. levels rose. In the unfiltered room the average was approximately 1.33 µg/m³ and the average of the filtered room was approximately 0.51 µg/m³. This shows that when students are present in the classrooms the air filter was able to reduce the P.M. levels by about 61.30%. The spikes found on the graphs are mostly due to the entering and exiting of students during those times. The opening of the doors will lead to a fast increase in PM levels. The data for room 308 has a greater range than the data for room 310. The median for room 308 is greater than the maximum for room

310 by 0.1µg/m³. Since the mean of the filtered room doesn't fall within one standard deviation of the unfiltered room's mean the air filter had a significant effect on the PM levels. As predicted the classroom with the air filter present had a significantly lower PM level ($M = 0.51$ µg/m³, $SD = 0.19$) than the unfiltered classroom ($M = 1.33$ µg/m³, $SD = 0.34$), $t(1020) = 47.2608$, $p < 0.05$. The Frederick Douglass Academy, the school involved in this study, is in a particularly high cancer rate area due to PM as determined by the EPA. And therefore, this project should be taken into consideration by policy makers and local leaders to add filters to classrooms throughout the building.

FDA is located just north of the Mother Clara Hale Bus Depot which stored diesel consuming buses that have been proven to be major sources of fine PM of the kind studied here. Prevailing southerly winds constantly blow the plume of particles to the school. This major source of contamination is compounded by the presence of various other Stationary Point Source emitters and TRI sites in the area, highways that encircle Harlem, and a valley that keeps the PM enclosed in the area. However, this bus depot has recently been demolished for reconstruction in 2009. The demolition of the bus depot has most likely caused a significant drop in PM concentration levels in the surrounding area.

However according to EPA's B. Ligman, indoor PM levels tend to be 59% higher than outdoor PM as found in an experiment conducted by the EPA's Indoor Environmental Division. In order to determine if these PM levels are safe or unsafe these particles need to be characterized in order to identify its composition.

Conclusions

The hypothesis that PM concentration levels in Room 310, the filtered room, will be lower than the PM concentration levels in Room 308, the unfiltered room was correct. The average concentration level measured at any given time in room 310 was 0.51µg/m^3 and in room 308 was 1.33µg/m^3. A t-test performed concluded that on a 99% interval the air filter had a significant effect on the particulate matter levels in a classroom. Although these levels don't exceed the EPA yearly limit standard of 15µg/m^3 we still need to be concerned. These low levels can be attributed to the recent demolition of the Mother Clara Hale Bus Depot. In the past this bus depot has been known to be one of the primary sources of PM concentration levels in the surrounding area.

One way to maintain PM levels in the school down and improve the environment in and around FDA is to; install air filters in all classrooms, just like all classrooms have air conditioners and heaters, air filters should also be included. Students have the right to clean air especially in a place that is considered a safe environment for children, a school. ;using alternative energy such as aeolic and solar power on the roofs of FDA can generate enough clean electricity to completely stop the use of burning fossil fuels for the production of electricity; re-locating the Mother Clara Hale Depot, now that it has been demolished for reconstruction, to dilute their emissions from northern Manhattan and spreading them out equally along the city. Failure to take action will lead to an increase in acute health disorders and an unfair substandard of life for the students of FDA and the residents of Harlem.

Limitations

A new air filter needs to added to the filtered room. The BlueAir 503 series that was used only covers about 566 sq ft. The rooms are about 1,130 sq ft. The effect the number of students in a classroom has on the air quality needs to be determined since both classrooms did not have equal amounts of students at any time. Sampling air in both classrooms for more days, when school is in session is also needed. Try to get the EPA support in hopes that they will in the near future partner with FDA and set up an air quality monitoring station

Future Research

For the future, PM levels in all rooms of FDA shall be measured. This will help in determining if overall the school is safe for students. If not we can pin point where the source of PM in the school is coming from. From there we can take action in improving the school.

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Annexes

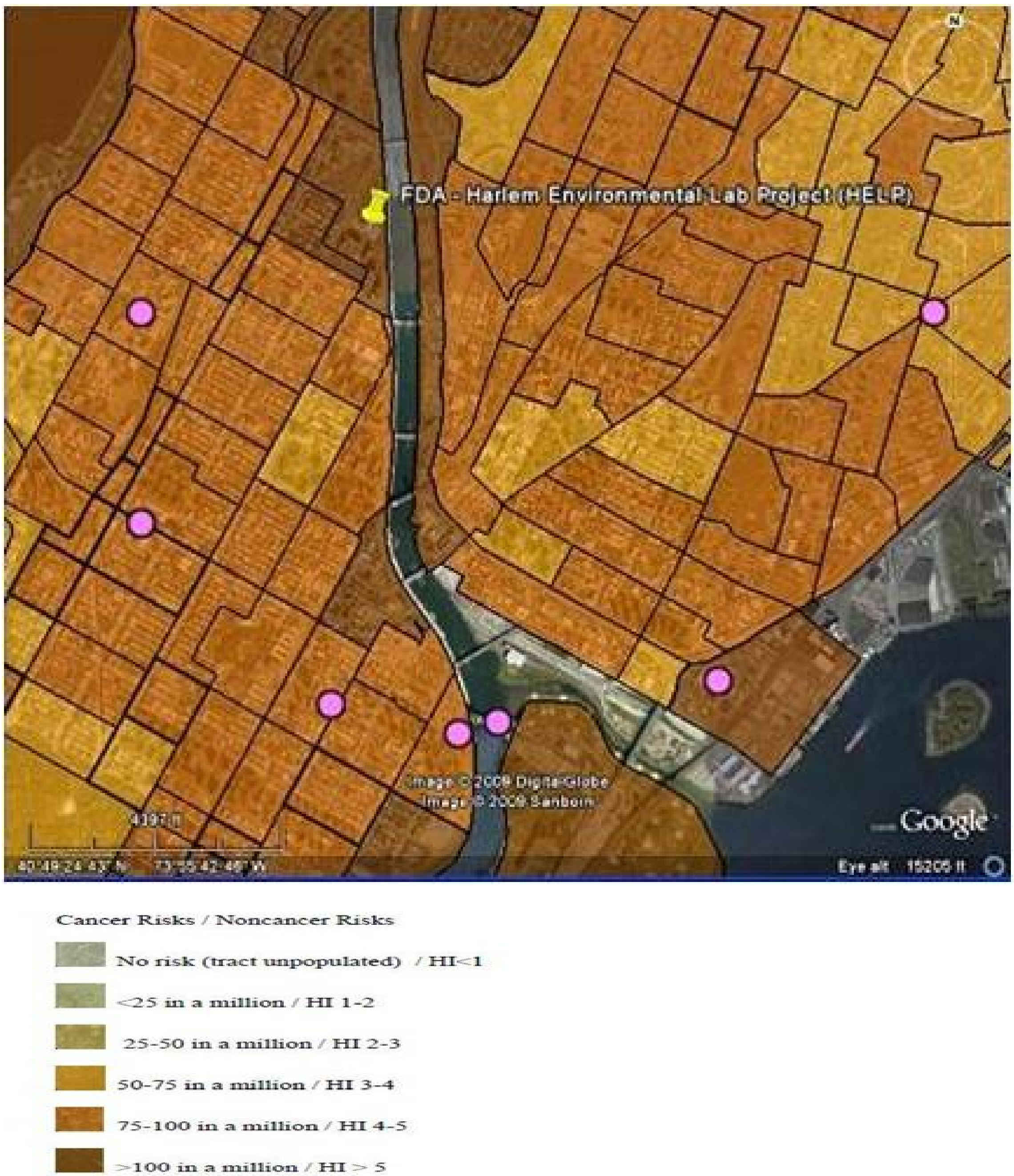

Figure 5: The risk of cancer in the surrounding area of the school within a 5 block radius in any direction is higher than one in every 10,000 people (EPA, 2009).

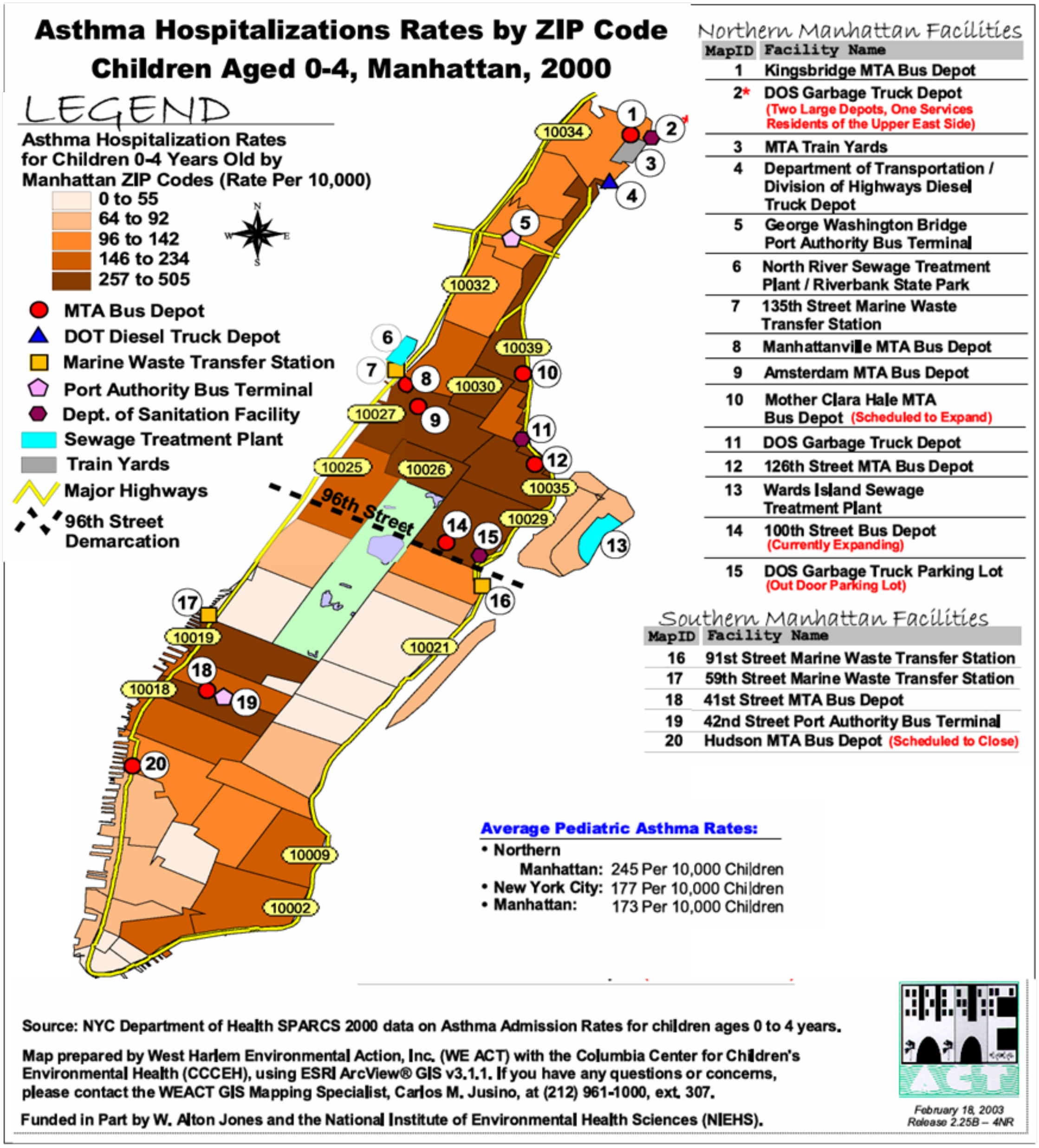

Figure 6-Asthma Hospitalization Rates in Manhattan by Zip Code of Children Aged (0-4): The darker shades for incidence of asthma in the order of 257 – 505 children between the ages of 0-4 per zip code. (We Act, 2009)

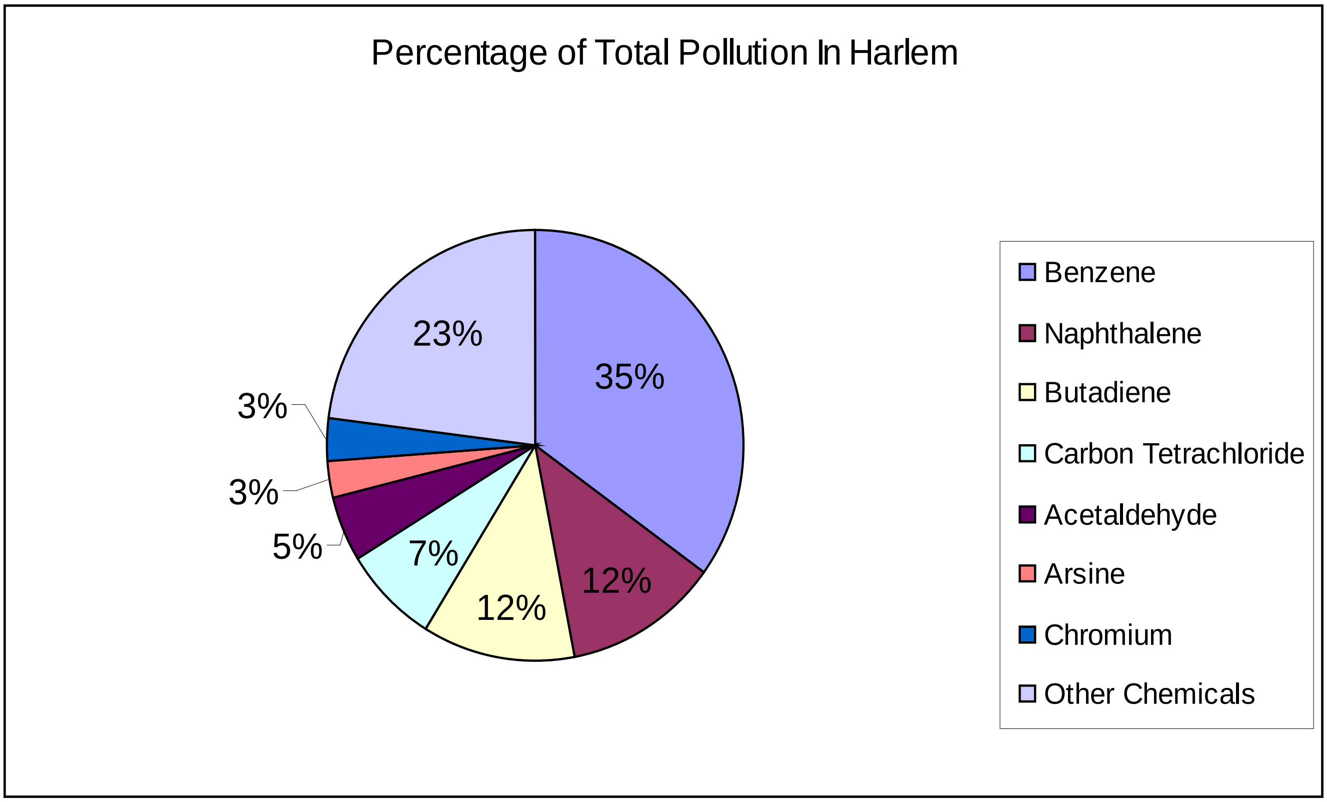

Figure 7: Many chemicals found in the air cause cancer.

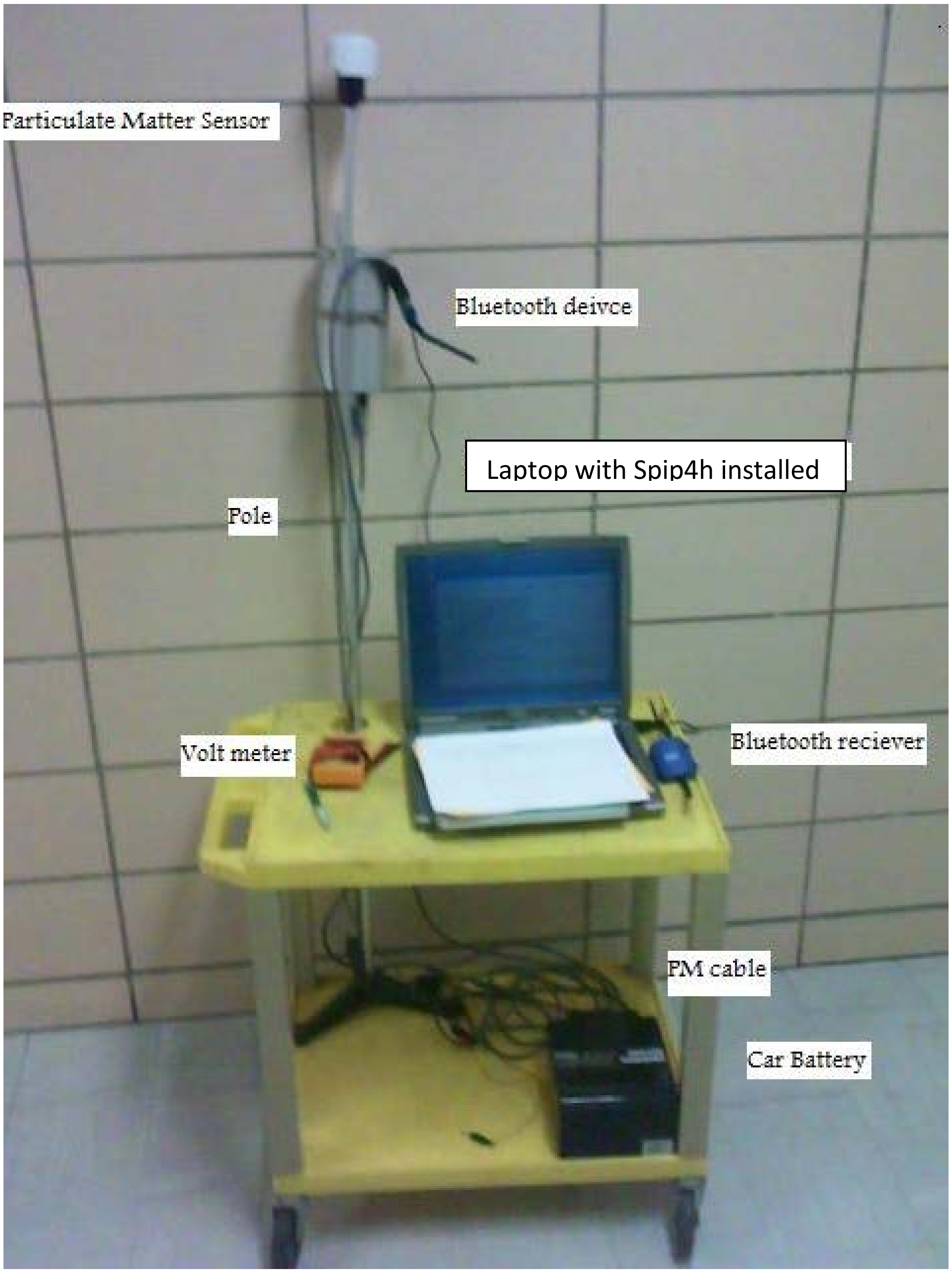

Figure 8: The above picture is the set up of the actual project. Refer to the materials list for details of the materials