

Asthma Free School Zone Project

Assessment of Air Quality in Various Locations within Community Board 3 Manhattan and Identification of “Hot Spots” That May Adversely Affect Health of CB3 Residents

From:

Real World Foundation

To:

Con Edison Task Force of Community Board #3

and

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I. EXECUTIVE SUMMARY

A one year study of air quality was conducted at 10 sites in Community Board 3 Manhattan (see Figure III-1. Map of air sampling sites, page 7). In each of four seasons air quality was measured over four weeks or more at each site. Sites were arrayed widely across CB3. Measurements were made of particulate matter at the 2.5 micron level ($PM_{2.5}$) and of elemental carbon (EC) and related black carbon (BC) and ozone in one season. Comparisons were made between readings available from three nearby Department of Environmental Conservation (DEC) sites.

The first aim of the project was to demonstrate whether there was meaningful variation in exposure between sites on a weekly basis. This was established. For individual sites, the average particulate $PM_{2.5}$ exposure over the whole period varied from 18.3 ug/M^3 (at PS 34) to 13.0 ug/M^3 (at the AFSZ office), a ratio of 1.40. Four sites exceeded the 15 ug/M^3 annual average NAAQS and 6 sites were below. On a weekly basis, the variation was substantially greater. For weekly results, the average ratio of the highest site to the lowest was 2.5 but the range went up to a 7.5-fold difference.

For the various carbon measures, similar ratios were observed. For elemental carbon, the overall ratio of the highest to lowest site was 3.78, but it increased to 8 fold in one week. For organic carbon, the overall ratio of highest to lowest was 3.1 but ranged as high as 6 fold in one week. Variation was influenced by season. Exposures to $PM_{2.5}$ were substantially higher in summer than in the fall, winter and spring campaigns. EC data were too sparse to draw a conclusion on seasonality.

The second aim of the project was to examine whether there were consistent differences in exposure at various sites. There was no consistent gradient in exposure with distance from the northeast corner of the Community Board 3 area. Two of the four sites exceeding 15 ug/M^3 were located a short distance from the northeast corner, but two other sites exceeding the value were more distant.

There was a suggestion that higher elevation in certain locations was associated with increased exposure, but data were too sparse; there were not enough sites to compare height and distance. The lack of a clear increase at ground level across the 10 sites was not expected. Conversely, our mostly street level observations were higher compared to the DEC sites, which are elevated.

The third goal was to compare local gravimetric results to ambient DEC air monitoring. The gravimetric filter results observed in this study were somewhat higher than the averages calculated from ambient air monitoring. The differences were modest in the fall-winter-spring campaigns and meaningful in the summer campaign. This increase was statistically significant but is based on limited observations, despite the magnitude of the study. An additional concern is that exposure measurements were conducted near the limit of quantitation of the gravimetric filter analytical method.

The fourth goal was to determine whether time variation using real time aerosol monitoring would reveal peak exposures not identified through week long averages. The time resolved $PM_{2.5}$ data at 3 sites and BC data at two sites revealed multiple substantial and contrasting excursions (temporary peaks) which were obscured by the long term averaging of gravimetric sampling. These suggested very local sources which might be identified and abated.

The fifth goal of assessing ozone concentrations yielded no useful information beyond what is available from the DEC sites.

Conclusions: The project has demonstrated intra-site variation in $PM_{2.5}$ and carbon exposure between the 10 sampling sites in CB3. The project also demonstrated very large short time excursions in exposure level not reflected in longer term samples. These peak exposures vary between sites. A spatial trend from northeast could not be confirmed, perhaps because very high exposures were observed at sites remote from that corner of the neighborhood.

What is the health significance of these observations? There is ample evidence that increases of $PM_{2.5}$ within prevailing exposure levels are associated with increased respiratory and cardiovascular illnesses. There is ample evidence that increases in diesel particulate matter - a component of the particle exposures - are associated with increased asthma and other respiratory effects. The particulate matter studies are based on community-wide exposure monitoring of the type conducted by the DEC – rooftop sampling – and daily and yearly average exposures. These exposures may vary 10-fold from day to day, which was observed in the DEC data used in this study. The established EPA standards for particulate matter are based on this data. The EPA is reevaluating the PM standards, and many believe that exposures in compliance with current standards cause adverse health effects.

The rooftop community average exposure to $PM_{2.5}$ is the product of diverse local emissions sources, some major and affecting wide areas, and some smaller and narrower. The presence of “hot spots” at ground level and rapid variation in exposure level suggests local sources. Abatement of these local sources would reduce exposure at the site, and also subtract from the overall community load. In this study, substantial excursions were observed with real time PM and BC monitoring equipment. Further observation could identify the specific activities associated with those excursions, and perhaps reveal abatement opportunities.

Further studies could be improved by three changes in methods. First, now that we have demonstrated the feasibility of gravimetric sampling for $PM_{2.5}$ on quartz filters which permit simultaneous analysis for elemental and organic carbon, that method would be preferred to gravimetric on PVC filters as the major mode of study. The gravimetric and carbon combination yields information on variation of content of the $PM_{2.5}$, which could be helpful in identifying sources.

Second, higher volume portable pumps and impactors have recently become available. These would reduce necessary sampling time to 1/3, and would permit more reliable gravimetric sampling and shorter sampling periods.

Third, the design assumed that ground level samples would be substantially higher than those at elevation. Sites could be selected with more elevations in mind, to clarify the relationship between $PM_{2.5}$ and elemental carbon levels, and elevation.

Fourth, the drastic effect of humidity on Sidepak results, and the difficulties in standardization, suggest that future work must exploit these instruments for evaluating short term variations rather than extended sampling periods.

II. BACKGROUND AND SIGNIFICANCE

The Community Board 3 Manhattan (CB3) district includes the 14th Street Con Edison power plant, the Manhattan sides of the Williamsburg, Manhattan, and Brooklyn Bridges, and FDR Drive. Despite these significant sources, air quality in this neighborhood has not been characterized in any systematic manner. This project was designed to evaluate spatial and temporal trends in air quality throughout CB3. The long range goal was to determine whether there are significant local exposure conditions not identified by the existing NYS DEC monitoring system. The project would try to identify “hot spots” that could adversely impact the health of CB3 residents. The intention in funding this project was to add to the available information so that in the future there could be a stronger basis for further study and for possible site-specific strategies for pollution reduction. The project was led by Real World Foundation in close collaboration with the Hunter College Urban Public Health Program. Ms. Lori Bukiewicz, MPH (RWF) and Professor Franklin E. Mirer, PhD (Hunter) led the implementation for each institution. Project planning began in August 2008. Field data collection commenced on November 12, 2008 and was completed August 27, 2009.

Research Questions

The project was directed at five main research questions:

- Does exposure to PM_{2.5} vary meaningfully across the sites in CB3?
- Is exposure to PM_{2.5} consistently higher at some sites in CB3 than others?
- Does exposure to PM_{2.5} at the sites in CB3 vary from community ambient air monitoring results?
- Does elemental carbon vary meaningfully across sites?
- Do elemental carbon and PM_{2.5} vary together?

URBAN AIR POLLUTION

PM_{2.5} health effects

Increases in the particulate air pollution within the range of levels found in typical American cities are associated with increased mortality from respiratory and cardiovascular conditions (Krewski et al 2005, Krewski et al 2005, Eftim et al 2008, Gehring et al 2006). Reductions in fine particle exposure are associated with reduced mortality (Laden et al 2006). Increased community particle exposure is associated with increased emergency room visits for asthma and other respiratory conditions (Peel et al 2005). Diesel particulate related to traffic is also associated with asthmatic reactions in adults (McCreanor et al 2007).

Rates of childhood asthma are geographically diverse in New York City, where extensive surveillance data are collected (New York City Department of Health and Mental Hygiene). Asthma hospitalizations among children averaged 5.4 per thousand citywide, but specific neighborhood rates ranged from 1.1 to 11.9 (in East Harlem). Clearly there is a negative correlation of the income level of a neighborhood with asthma hospitalization rates. Contrasting air pollution levels may be among the causes. However, community ambient air monitoring data in New York City don't

appear to show such steep gradients. (New York State Department of Environmental Conservation 2009) However, such ambient air monitoring data are not intended to measure street level exposure and variation of exposure in urban canyons. Particulate exposure data at street level demonstrate increased exposure compared to ambient measures, (Kinney et al 2000) but additional data and time-resolved measurements would guide future health studies. Exposure studies conducted only in areas thought to be heavily polluted or known to be at high risk can not demonstrate a difference with lower risk areas.

National Ambient Air Quality Standards

Increases in exposure to particulate matter in the range of current National Ambient Air Quality Standards (NAAQS) are associated with the health effects noted above. The key exposure limits are 15 ug/M³ for particulate matter 2.5 microns and below (PM_{2.5}) averaged over a year, and 35 ug/M³ averaged over a 24-hour period. The 24-hour limit was revised downward from 65 ug/M³ in 2006.

Ambient Air Quality Monitoring Network

The New York State Department of Environmental Conservation (DEC) maintains a large network of monitoring sites across New York State as part of EPA's national network. Substantial numbers of these sites are located in the New York metropolitan level, including lower Manhattan. As described in the methods section below, nearest to CB3 are sites at Pace College, Division Street, and PS 19.

III. METHODS

Site selection

Ten locations were selected within the CB3 district to serve as air sampling sites. Our project team confirmed available sites taking into account the proximity to probable sources of pollution, security, accessibility, etc. The sites were agreed upon by CB3, Hunter College and AFSZ. NYC Housing Authority (NYCHA) housing complexes and NYC Department of Education (DOE) schools provided most of the sites so that the project could assess exposures for these sensitive populations where it is known there is a high asthma prevalence and where such choices would simplify access and permission to work in these spaces through NYCHA and the DOE. Site locations were dispersed throughout the district to include all its neighborhoods: the East Village, Lower East Side and Chinatown. At the request of CB3 members, a higher concentration of sampling sites was selected to be in the northeast corner of the district to better characterize air quality near the 14th Street Con Edison power plant.

It should be noted that during our four air sampling periods Con Edison's East River Generating Station operated five energy producing units. These units are fueled by natural gas, oil or a mixture of both. Con Edison reports that during our sampling periods two of the five units burned only natural gas. A third unit burned natural gas 82%, mixed fuel 18% and oil 0% of the time. A fourth unit burned natural gas 77%, mixed fuel 23% and oil 0.07% of the time. And a fifth unit burned natural gas 94%, mixed fuel 2% and oil 4% of the time. This was relevant because particulate matter emissions from oil combustion are approximately 12 times greater than from natural gas

combustion.¹ No relationship was found between our findings and the data provided by Con Edison.

Site descriptions

Table III-1 shows all sampling sites that were utilized during the project. The initial sites selected were six public elementary schools, one NYCHA apartment, one church office, one privately owned apartment, and the AFSZ office. Construction activities began at PS 188 after week 1, preventing us from continuing with that site past the first week. A nearby school, PS 15, replaced that site. The NYCHA apartment resident was unable to continue with the project past the first sampling period; a nearby NYCHA community center became its replacement. Construction activities at PS 110 prevented us from sampling at that site during the last period and with the single sampling period remaining, that school site was not replaced. Figure III-1 shows the geographic location of all project sites.

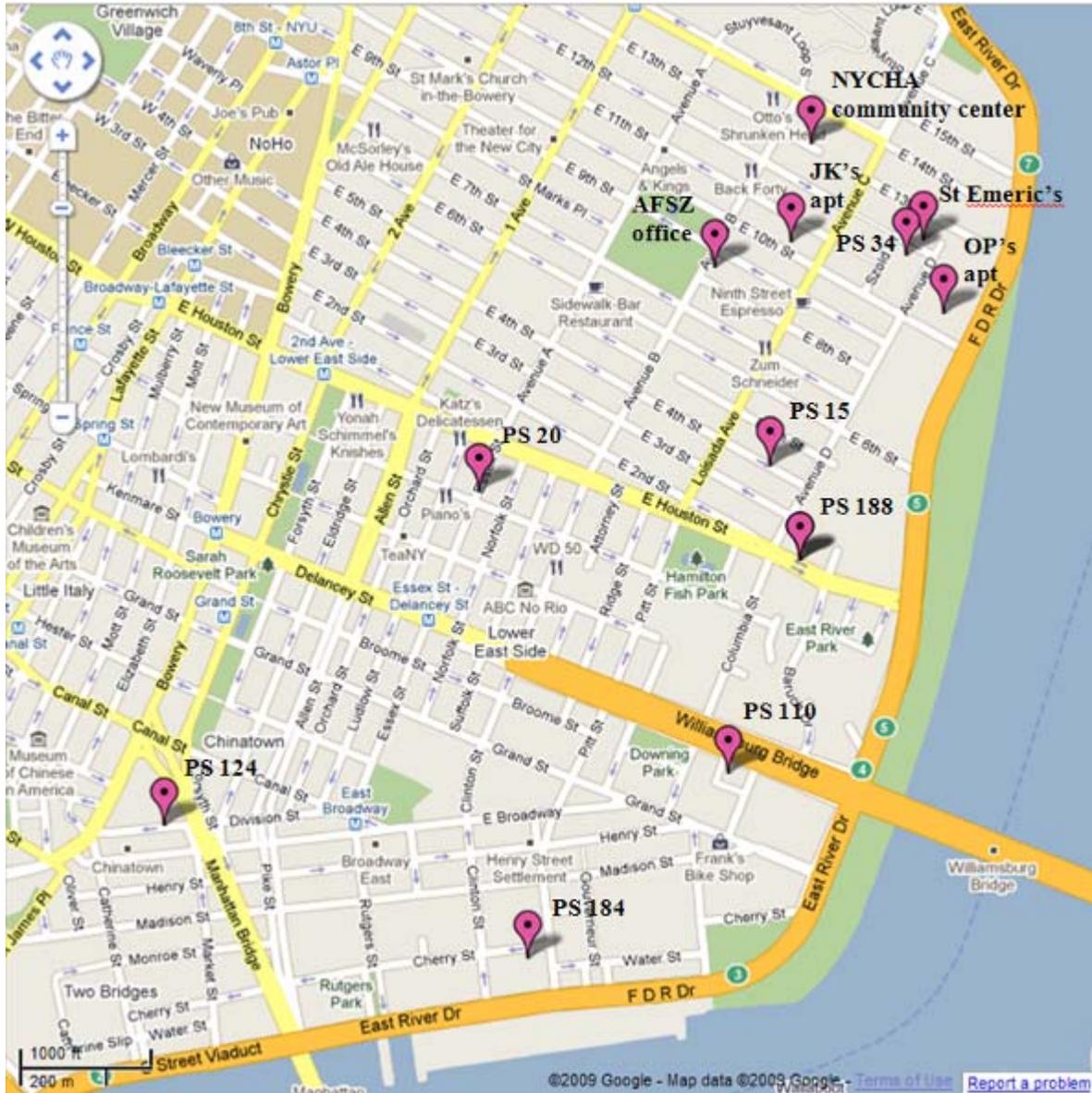
Table III-1. Project air sampling sites

Site	Address	Equipment	Equipment location	Sampling dates	Site notes
AFSZ office	131 Ave. B, 1 st fl 10009	Sampling pump & PMI, Sidepak, Aethalometer, ozone monitor	South facing window, ground level, main room	11/12/08 – 12/24/08 2/11/09 – 3/11/09 5/13/09 – 6/11/09 7/29/09 – 8/27/09	Sampler faces entrance area set back from the street. Street has continuous but low-density traffic flow. Street sometimes has idling vehicles, including mobile health vans with diesel generators.
NYCHA Community Center	611 E. 13 th Street 10009	Sampling pump & PMI, ozone monitor	West-facing activity classroom window, ground level	2/18/09 – 3/11/09 5/13/09 – 6/10/09 7/29/09 – 8/27/09	Sampler faces playground on a dead-end street. Building construction in adjacent lot facing sampler.
10 th Street apartment	381 E. 10 th St. 5 th fl. 10009	Sampling pump & PMI	North-facing bathroom window, 6 th level	11/12/08 – 12/23/08 2/11/09 – 3/11/09 5/13/09 – 6/10/09 7/29/09 – 8/27/09	Sampler faces back yards that are enclosed by apartment buildings on all 4 sides, all approx 5 stories.
NYCHA apartment	465 E. 10 th ,7A 10009	Sampling pump & PMI	North-facing bedroom window, 8 th level	11/12/08 – 12/17/08	Only sampled the 1 st season at this site. Very near ConEd and the East River. Sampler facing the ConEd stacks.

¹ Energy Information Administration, Natural Gas 1998: Issues and Trends
http://www.eia.doe.gov/pub/oil_gas/natural_gas/analysis_publications/natural_gas_1998_issues_trends/pdf/chapter2.pdf

Site	Address	Equipment	Equipment location	Sampling dates	Site notes
PS 110 Florence Nightingale	285 Delancey St 10002	Sampling pump & PMI	North-facing window in phys ed office, ground level	11/13/08 – 12/23/08 2/11/09 – 3/11/09 5/13/09 – 6/10/09	Sampler faces play yard protected by 3 walls of the school, unprotected on east side. Williamsburg Bridge ramp approx 1 block to the north. No sampling Period 4.
PS 124 Yung Wing	40 Division St 10002	Sampling pump & PMI	North-facing classroom window, ground level	11/12/08 – 12/23/08 2/11/09 – 3/11/09 5/13/09 – 6/10/09 7/29/09 – 8/27/09	Sampler faces play yard protected by 3 walls of the school, unprotected on east side. Manhattan Bridge ramp approx 1 block to the east.
PS 15 Roberto Clemente	333 East 4 th St 10009	Sampling pump & PMI	Season 1&2: North- facing closet window, ground level	11/18/08 – 12/23/08 2/11/09 – 3/11/09	Reports from school staff that adjacent church's chimney bellows smoke at times, unsure when. Low- traffic street.
			Season 3&4: North- facing classroom window, 2 nd level	5/13/09 – 6/10/09 7/29/09 – 8/27/09	
PS 184 Shuang Wen	327 Cherry St 10002	Sampling pump & PMI, ozone monitor	North-facing office window, ground level	11/12/08 – 12/23/08 2/11/09 – 3/11/09 5/13/09 – 6/10/09 7/29/09 – 8/27/09	FDR is 1 block to the south, East River is 2 blocks to the south. Low- traffic street.
PS 188 Island School	442 E. Houston 10002	Sampling pump & PMI	Boiler room, facing west, ground level	11/13/08 – 11/18/08	Only sampled here for 1 week – heavy duty outdoor school construction began soon thereafter.
PS 20 Anna Silver	166 Essex St 10002	Sampling pump & PMI, Sidepak, Aethalometer	West-facing window in main office coffee room, ground level	11/13/08 – 12/23/08 2/11/09 – 3/11/09 5/13/09 – 6/10/09 7/29/09 – 8/27/09	Sampler faces busy double lane Essex St., approx 5 feet from the sidewalk.
PS 34 Franklin D Roosevelt	730 E 12th St 10009	Sampling pump & PMI	Season 1&2: East- facing window in Staircase A, rooftop, 6 th level	11/12/08 – 12/23/08 2/11/09 – 3/11/09	Very near ConEd stacks. Exposed to air through window grating. For the 1 st 2 rounds the sampler faced east. We lost our power supply and had to move sampler to location approx 10 feet away, same elevation but facing north. Surrounding streets have a lot of traffic at school pick- up and drop-off but otherwise not busy streets.
			Season 3&4: North- facing window in exhaust fan room on roof (6 th level)	5/13/09 – 6/10/09 7/29/09 – 8/27/09	
St. Emeric's Church	185 Ave. D 10009	Sampling pump & PMI, Sidepak	North-facing bathroom window, ground level	11/14/08 – 12/23/08 2/11/09 – 3/11/09 5/13/09 – 6/11/09 7/29/09 – 8/27/09	Adjacent to Con Ed plant. Samplers face the stacks.

Figure III-1. Map of air sampling sites



The majority of sites chosen were at street level (referred to as 1st level in this report) to capture the air most people are breathing, including those walking on the streets. One site was on the second level, two sites on the sixth level, and one was on the eighth level.

PS 124 houses a New York State Department of Environmental Conservation (DEC) monitoring station on its roof. This site is identified as “Division Street” on the DEC website.

For analysis purposes, the distance of each site from the northeast corner of the CB3 district was calculated using Google Earth.

Air sampling equipment

Our project team selected air samplers appropriate for continuous monitoring of outdoor PM_{2.5}, elemental carbon, organic carbon and ozone (Table III-2).

Table III-2. Project air sampling equipment

Equipment	Analyte	Sample collection	Analysis method
SKC AirChek XR5000 (sampling pump) paired with SKC Personal Modular Impactor (PMI) 	PM _{2.5}	PVC filter	NIOSH 0600
	Organic carbon Elemental carbon Total carbon	Quartz filter	NIOSH 0500 NIOSH 5040
TSI Sidepak AM510 Personal Aerosol Monitor 	PM _{2.5}	Real-time	Light scatter
Magee Scientific Aethalometer 	Elemental carbon	Real-time	Light scatter
Aeroqual S-500 Handheld Monitor 	Ozone	Real-time	Gas sensitive semi-conductor

SKC AirChek XR5000 air pumps, connected to SKC Personal Modular Impactors (PMI), filtered PM_{2.5} onto 37 mm PVC or quartz filters. Pre-weighed PVC filters were used for PM_{2.5} gravimetric analysis. Pre-weighed quartz filters were used to allow for gravimetric analysis of PM_{2.5}, elemental carbon and organic carbon.

To measure PM_{2.5} in real time we chose the TSI Sidepak AM510 Personal Aerosol Monitors. These devices, synchronized with National Institute of Standards and Technology time, detected and recorded the concentration of PM_{2.5} at continuous one-minute intervals.

To measure elemental carbon in real time we chose Magee Scientific Aethalometers, also synchronized with National Institute of Standards and Technology time. These detected and recorded concentrations of elemental carbon at continuous one-minute intervals.

Handheld ozone monitors, the Aeroqual S-500, were used to obtain real-time measurements of ozone at continuous two-minute intervals during the summer (4th) period.

Training

Project team leaders trained team members who became primary and alternate fieldworkers. Six fieldworkers were trained and went out into the field over the lifetime of the project. Training included background information about air quality and particulate pollution. Hands-on training included instruction on the sampling pump, PMI, Sidepak and Aethalometer operation, air filter extraction, cleaning and calibrating equipment, downloading Sidepak and Aethalometer data, and general protocol for each site, including use of the tool kit and field log (Figure III-2). The tool kit consisted of all the items necessary for fieldworkers to complete operations at each site, such as air filters, a calibrator, gloves, tweezers to extract filters, and a screwdriver to access areas of the Sidepak to be cleaned, as well as field log sheets to document activities at each site.

Figure III-2. Project field log sheet

AFSZ / CB3 Site _____

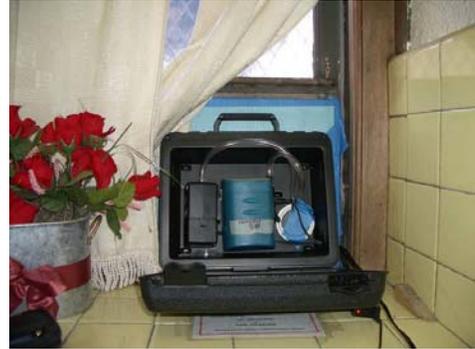
Date _____ **Time** _____ **Name** _____

Pump & Impactor (PM 2.5 filter)		Check
Check that pump is still running	<i>Record pump SN #:</i>	
	<i>Record counter #:</i>	
	<i>Record time:</i>	
Check flow rate.	<i>Record flow rate:</i>	
Stop pump		
Zero the minute counter		
Remove substrate and place in baggie		
Staple baggie and label w/ date, location & filter #		
Remove filter and put in plastic case.	<i>Record used filter #:</i>	
Place new filter	<i>Record new filter #:</i>	
Place new substrate		
Calibrate pump to 3L/min		
Check flow rate	<i>Record flow rate:</i>	
Turn pump on	<i>Record start time:</i>	
Return pump and impactor back to sampling location		
Take used bag with filter to ASFZ office	<i>Before you leave! Check all cable connections.</i>	
NOTES:		

Equipment placement

Air sampling equipment was deployed at the beginning of each of the four sampling periods and removed at the end of each period. Equipment was replaced in the same window at each site unless access to that window was no longer available, as was the case at PS 15 and PS 34 (see Table III-1, *Equipment location* for details).

Our project team designed custom equipment installations for each of the ten sites. Equipment was placed just inside windows, allowing for access to outdoor air and protection against rain and vandalism. Rigid sampling boxes were outfitted to securely hold sampling pumps, PMI's and Sidepaks. Boxes were custom outfitted to connect samplers with outdoor air through general purpose PVC tubing. Aethalometers were connected to outdoor air through customized window openings.



Sampling box at St. Emeric's containing sampling pump (black) connected to a PMI and a Sidepak (blue).

Sampling pumps and PMI's were placed at all ten sites. A Sidepak was placed at each of three sites: the AFSZ office, PS 20 and St. Emeric's. An Aethalometer was placed at the AFSZ office and at PS 20. Table III-1 shows which samplers were placed at each location.

Three ozone monitors were deployed to three different sites during the 4th period, the summer period. These monitors were placed at the AFSZ office, PS 184 and the NYCHA Community Center.

Table III-1 describes the location of equipment at each site, including the type of room, the direction in which the window faced, and floor level.



Aethalometer (L) and sampling box (R)
Installation at PS 20.



PS 184 sampling installation
seen here from outside.

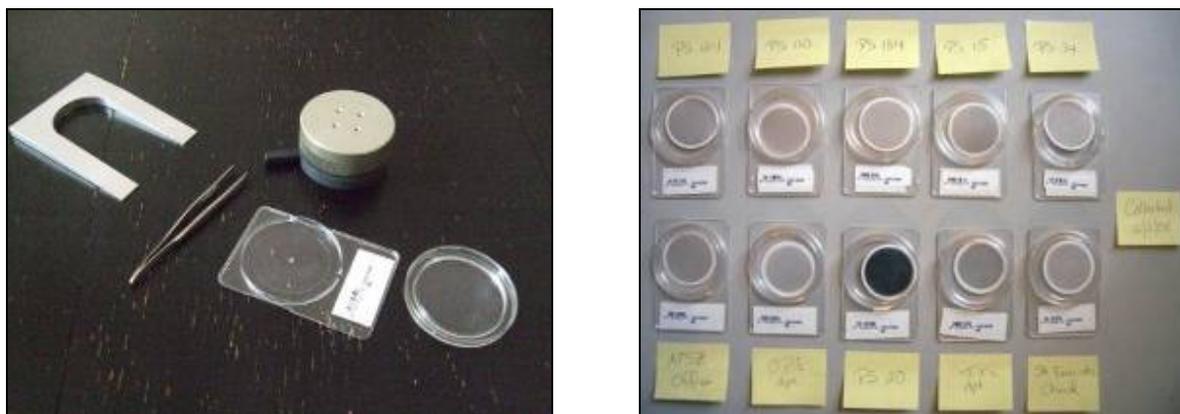
Fieldwork protocol

During the four 4-week sampling periods (fall: Nov/Dec, winter: Feb/Mar, spring: May/June, and summer: July/Aug) assigned team members visited each site once per week, equipped with a toolkit of necessary materials.

During each site visit team members collected filters and placed new filters into the PMI's (Figure III-4). Sampling pumps and Sidepaks were re-calibrated and cleaned to maintain flow rates. Real-time data was downloaded each week from the Aethalometers and Sidepaks to a laptop computer.

PVC filters were placed in the PMI's during the first three weeks of each period for PM_{2.5} gravimetric analysis. Quartz fiber filters were placed the fourth week of each period for PM_{2.5} gravimetric and carbon analysis. Collected filters (Figure III-3) and a chain-of-custody form for tracking the filters were sent to Galson Laboratories in East Syracuse, NY for analysis (see Table III-2, *Analysis method*)

Figure III-3. Air filter extraction materials (L) and collected air filters (R) from the week of November 25, 2008.



Gravimetric and Carbon Analysis

Gravimetric PM_{2.5} was determined using pre-weighed PVC filters and a modified NIOSH 0600 method. NIOSH method 0600 consists of sample collection and weighing. For this study, the 2.5 micron impactor was used instead of the 4 micron cyclone to collect the sample. The laboratory employed the same weighing methods. The limit of quantitation stated by the laboratory was 100 micrograms collected on the filter. This was achieved for all samples where the pump functioned.

Galson Laboratories, at the request of the project team, initiated the use of pre-weighed quartz filters to allow gravimetric PM_{2.5} to be measured in the same filters which were analyzed for elemental carbon, organic and total carbon using NIOSH method 5040. NIOSH method 5040 is a chemical analysis method - evolved gas analysis - which is much more sensitive, with a lower limit of quantitation than gravimetric. The limit of quantitation stated by the laboratory was 4 micrograms collected on the filter. This was achieved for all samples where the pump functioned.

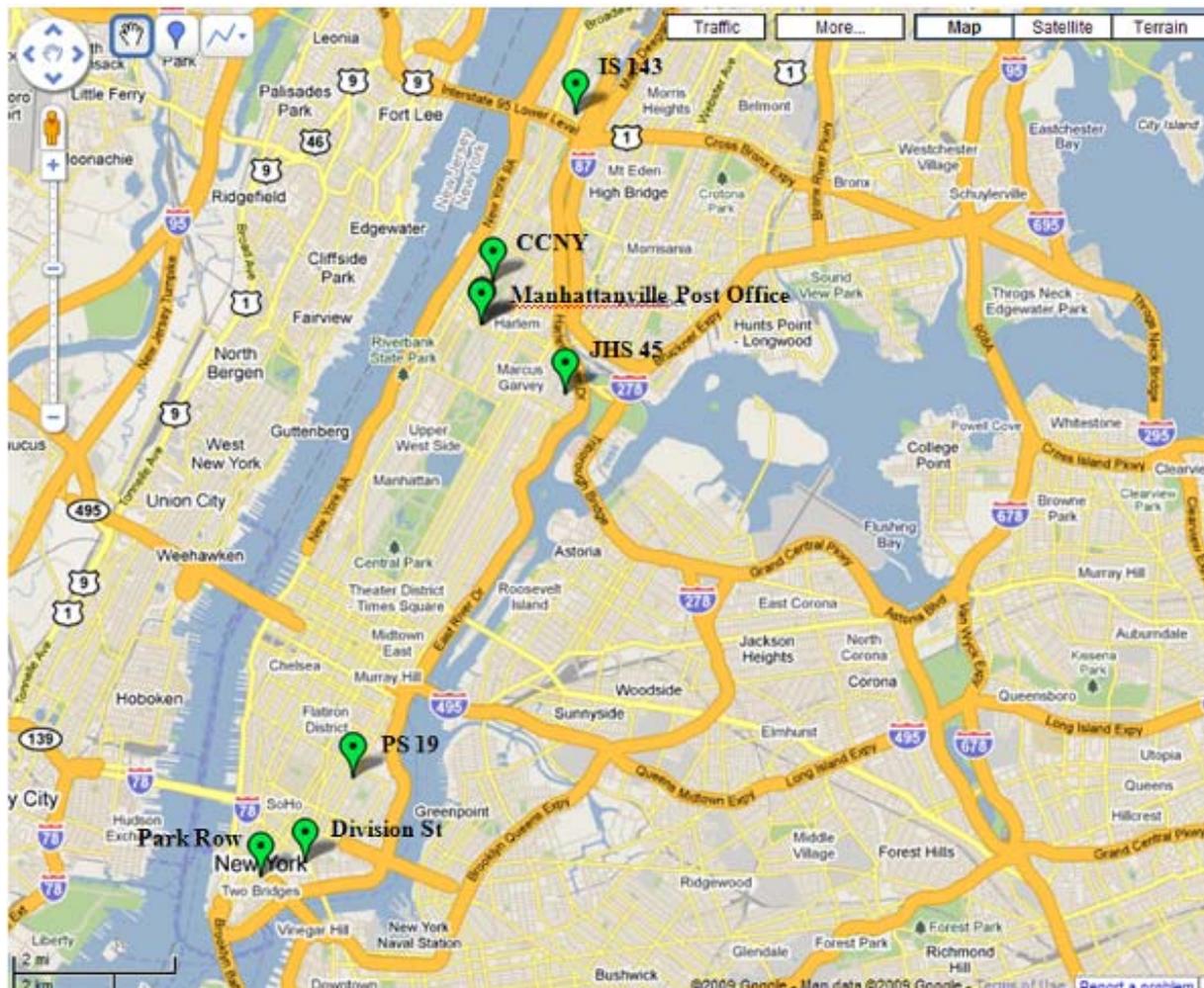
Downloading of Department of Environmental Conservation PM_{2.5} and Meteorology Data

Real time, hour-by-hour air pollution and meteorology data for a large network of monitoring sites are available on line from the New York State Department of Environmental Conservation (DEC). <http://www.dec.ny.gov/airmon/index.php> , Figure III-4. Seven sites measuring PM_{2.5} are located in Manhattan. These locations are shown in Figure III-5. We identified the sites closest to the measurement sites established for this project. For the fall and winter campaigns, the DEC sites identified as Division Street (same location as the PS 124 site where our equipment was deployed) and Park Row (Pace College) were taken as representative. Starting in February, a third site, PS 19 came on line, also located in CB3. The nearest site for weather data (temperature, humidity, barometric pressure, wind speed, and wind direction) was located at the New York Botanical Garden.

Figure III-4. Sample screenshot for downloading PM_{2.5} data from the DEC website. This is the screen for PS 124 located on Division Street. On November 10, 2009, exposure peaked at about 45 ug/M³ at about 10 am, declining to 15 ug/M³ by 4 pm.



Figure III-5. Locations of seven DEC monitoring sites in Manhattan. The study collected and averaged data from Park Row, Division Street (PS 124) and PS 19.



The DEC determines $PM_{2.5}$ by means of a tapered element oscillating microbalance (TEOM) [<http://www.thermo.com/com/cda/product/detail/1,,10122682,00.html>]. The DEC website site provides downloads into an Excel spreadsheet for specified periods. Data are provided on hourly readings.

Data Analysis

DEC hourly $PM_{2.5}$ results were synchronized by the hour for the Park Row, Division Street and PS 19 sites (when PS 19 became available). Because every site didn't operate all the time, results were averaged to achieve a consistent time series. For comparison with gravimetric results, the DEC average was calculated over the same time period as the samples were collected. Except for week 1, there was little difference between the contemporary DEC sites over the comparison period.

For evaluation of Sidepak time series, DEC meteorology data were also synchronized with PM_{2.5}.

For each week's campaign, the mean and confidence interval (CI)² of PM_{2.5} or carbon results were calculated. The ratio of our gravimetric PM_{2.5} readings to the DEC's PM_{2.5} readings for the week was calculated for each sampling site, and the mean and confidence interval of these ratios was calculated for each week over the 10 sites, and for all 18 weeks at each of the 10 sites.

Data Cleaning and Smoothing of Direct Reading Instrument Downloads.

Sidepak data were extracted using Trak-pro software supplied by TSI. Trak-pro provides output into an Excel spreadsheet. The Aethalometer writes results directly to a memory card in Excel format.

For both the Sidepaks and Aethalometers, the one minute readouts exhibited "spiking" and some corrupted readings. Corrupted readings consisted of date and time results displaced into the PM column, or other scrambling. Corrupted readings were detected using the Excel data filtering function, and were edited where the problem was apparent, or deleted. The source of spiking could not be determined. The data were smoothed by replacing each minute reading with the 5 minute moving average of the previous samples after data cleaning above.

Humidity correction for Sidepaks

Sidepaks are reported to give erroneously high mass readings under high humidity conditions. This arises from absorption of water into aerosol particles, increasing their size, and altered light scattering properties and thus their apparent weight. A published correction factor was applied,

$CF = 1 + 0.25\left(\frac{RH}{1 - RH}\right)^2$, where RH is expressed as a decimal fraction. {Ramachandran G 2003

#74780} The humidity correction result would be Corrected = Sidepak reading/ CF. As RH approaches 100%, the correction factor gets very large. This was taken into account for Sidepak comparisons

Data management for direct reading instrument data.

Analysis spreadsheets for the multiple campaigns were compiled as follows. Downloaded individual Sidepak and Aethalometer time series were cleaned for anomalous entries. The Sidepak and Aethalometer time series were then smoothed by calculating 5 minute moving averages, preserving the one minute granularity but reducing noise. These time series were then synchronized in a single spreadsheet. The DEC PM levels and meteorology were available in one hour intervals. These were also synchronized by attributing the one hour result to each minute over the interval from the direct reading instruments. Sidepak data were corrected for humidity using the contemporary humidity values from DEC. This eventually yielded a time series for three Sidepaks, two Aethalometers (both minute by minute and 5 minute moving averages) and the DEC hourly data for each weekly campaign,

² A confidence level for an interval determines the probability that the confidence interval produced will contain the true parameter value. A common choice for the confidence level is 0.95. A 95% confidence interval covers 95% of the normal curve -- the probability of observing a value outside of this area is less than 0.05.

Statistical tests (paired t-test, correlation)

For gravimetric sampling results, the mean and confidence intervals were calculated for each site over the 18 weeks, and for each week over the ten sites, using Excel functions.

Gravimetric results averaged for each week were compared to the DEC weekly average using a two tailed t-test with discordant pairs deleted.

Time series of each result were plotted. Scatter plots for correlation of Sidepaks with each other, Aethalometers with each other, and of each with the DEC data were drawn, and the correlation coefficients and significance were calculated using the Excel data analysis pack.

Ozone monitoring

Knowing that ozone is highest in warm months we chose to sample levels at three sites during the summer campaign only. Our intention was to run real time meters for one full month. The ozone meters we chose to use (Aeroqual S500) were rented from Ozone Solutions, Inc, 451 Black Forest Road, Hull, IA 51239. Though informed of the nature of our project, the company did not inform us that these instruments are not optimal for outdoor atmospheric observations and have a fairly wide range of error (.1 - .5ppm). This makes it difficult to discriminate differences between sites when the permissible attainment threshold is .75 PPM. The specifications for these instruments are in Table III-3.

Table III-3. Specifications for Aeroqual S500 ozone meters used in project

Sensor Heads	Low	High	Leak
Measurement range	0.000 - 0.500 ppm	0.50 -20.00 ppm	0.00 -50.00 ppm
Accuracy	< 0.008 ppm (0 - 0.100 ppm)± 10% (0.100 – 0.500 ppm)	± 10% (0.20 -2.00 ppm)± 15% (2.00 -20.00 ppm)	± 20%, 15 seconds after Reset
Resolution	0.001 ppm	0.01 ppm	0.01 ppm
T90 Response	< 60 seconds (T90)	< 35 seconds (T90)	< 10 seconds
Sensor type	Gas-sensitive semiconductor		
Operating temperature range	-5°C to 50°C; 23°F to 122°F (sensor head and base unit)		
Relative humidity limit	95% maximum (sensor head and base unit)		

We tested the ozone monitors at the AFSZ office and noticed that the three detachable heads gave very different readings. With such low correlations at the same location we asked for replacement sensors. The company shipped three additional heads that we tested in various combinations with the first set of heads to assess which correlated best with one another and with ambient levels downloaded from local DEC sites.

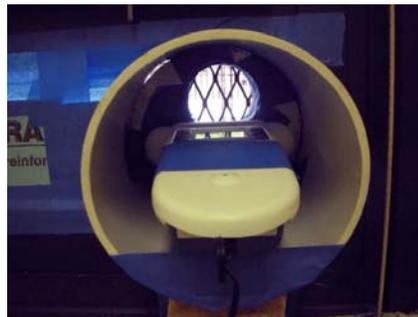


The 3 Aeroqual ozone monitors, plus 3 extra sensor heads, used for the project.

It took us more than three weeks from the start of the test period to get three sensors that ran in reasonable correlation with one another. We then installed them at three of our ten sites, alongside our other air monitoring equipment at the AFSZ office, PS 184 and the NYCHA Community Center. Each was placed inside a 6-inch PVC tube with the sensor head near the external end of the tube so that it could draw air from the immediate external environment and be protected from rain.



Sampling box (L) and ozone monitor (R) installed at PS 184.



Close up of an ozone monitor installation.

Before the instruments had to be returned we were able to get simultaneous readings from all three sites from August 9 to August 12. These data were compared with data from 4 DEC sites that monitor ozone in New York City, IS 52 (650 Academy Street, Inwood), New York Botanic Garden, CCNY, and Queens College.

IV. RESULTS

Gravimetric Samples

Weekly gravimetric and weekly average DEC $PM_{2.5}$ values are shown in Table IV-1.

There were 180 site-week sample opportunities for $PM_{2.5}$ gravimetric. Among these, 26 cells in Table IV-1 are blank. During week 14, samples were only analyzed for carbon but not $PM_{2.5}$ due to a laboratory error, accounting for 10 missing values. For the July campaign, the PS 110 site was found to be unavailable at the time of first placement and an alternative site nearby could not be found to deploy the equipment, accounting for 4 missing values. Two samples, (PS 15, week 16) and PS 34, week 18) were discarded because pump the run duration was very short, giving anomalous high readings. For other spoiled samples, reasons for no result were a pump not running for an unknown period, or a clearly spurious result such as a negative value for weight. For the first sampling week, a sample was collected at PS 188, but construction began at this site and it was replaced by PS 15, nearby. The PS 188 sample is included in the PS 15 averages because of the proximity of the two sites.

Table IV-1. Weekly average PM_{2.5} filter samples sorted by distance from northeast corner of CB3.
Red= greater than 35 ug/M3, **Orange**= 15 ug/M3 to 35 ug/M3, **Blue**= lowest reading for a week's campaign

Weekly Averages Sorted by Distance from Northeast Corner													
site id	7	5	6	8	10	2	9	4	3	1			
Site	St. Emeric's Church	PS 34	OP's apt	JK's apt	AFSZ office	PS 15	PS 20	PS 110	PS 184	PS 124	10 site weekly average	DEC	Lower
Distance	0.1	0.1	0.2	0.3	0.4	0.5	0.8	0.9	1.3	1.5			
Floor level	1	6	1	6	1	1	1	1	1	1			
Week 1 11/12/08	9.1	7.3	11.0	5.1	9.8	12.0	12.0	9.1	8.4	12.2	9.6	7.4	8.2
Week 2 11/18/08	8.8		7.3	13.0	9.8			8.5	7.9	10.0	9.3	8.1	7.9
Week 3 11/25/08	9.7	8.6	7.6	12.0	12.0	12.0	16.0	12.0	12.0	14.0	11.6	10.9	10.1
Week 4 12/2/08	9.2	10.0	13.0	14.0	14.0	13.0	9.5	11.0	11.0	14.0	11.9	11.4	10.7
Week 5 12/10/08	9.0	7.6	8.8	9.3	10.0	8.6	9.7	7.5	8.9	9.4	8.9	10.3	8.4
Week 6 12/17/08	12.0	9.9		13.0	9.9	13.0	14.0	9.0		13.0	11.7	13.3	10.4
Week 7 2/11/09	15.0	9.4		55.0	12.0	12.0	13.0	15.0	9.9	12.0	17.0	8.2	7.6
Week 8 2/18/09	7.7	11.0	13.0	12.0	11.0	13.0	23.0	9.1	10.0	18.0	12.8	10.5	10.0
Week 9 2/25/09	14.0	25.0	12.0	12.0	12.0	13.0	13.0	12.0		18.0	14.6	10.7	11.7
Week 10 3/4/09	14.0		15.0	18.0	13.0		12.0	15.0	14.0	16.0	14.6	17.0	13.3
Week 11 5/13/09	11.0	11.0	9.6	15.0	13.0	27.0	16.0	12.0	14.0		14.3	8.6	10.9
Week 12 5/20/09	14.0	15.0	17.0	13.0	16.0	16.0	19.0	16.0	16.0	14.0	15.6	11.4	14.5
Week 13 5/27/09	11.0	11.0	20.0	14.0	11.0	13.0	14.0	14.0	19.0	12.0	13.9	9.3	11.9
Week 14 6/3/09												9.7	
Week 15 7/29/09	15.0	55.0	24.0	22.0	20.0		19.0		21.0	30.0	25.8	13.4	15.2
Week 16 8/5/09	12.0	26.0	16.0		12.0	17.0	14.0		15.0	16.0	16.0	9.4	12.9
Week 17 8/12/09	20.0	48.0	17.0	23.0	22.0	6.5	26.0		27.0	28.0	24.2	17.0	16.1
Week 18 8/20/09	18.0		23.0	23.0	14.0	15.0	25.0		25.0	17.0	20.0	10.7	12.6
18 Week Average	12.3	18.2	14.3	17.1	13.0	13.7	16.0	11.6	14.6	15.9	14.8	11.0	13.7
Lower	10.7	10.2	11.6	11.3	11.4	7.3	13.4	10.0	11.6	13.0	12.5	9.7	
Upper	14.0	38.5	16.9	25.2	14.7	32.9	18.5	13.1	17.6	18.7	19.7	12.2	

Thus, 163 gravimetric filter samples for PM_{2.5} were available for analysis. Sample readings greater than 35 ug/M³ are highlighted in red. These were 10th Street apartment week 7, and PS 34 weeks 15 and 17. Weekly samples between 15 ug/M³ and 35 ug/M³ are highlighted in orange. There were 50 samples in this range. The lowest reading for a week's campaign is highlighted in blue.

Weekly averages for filter samples

The average gravimetric filter result across all sites and weeks was 14.8 ug/M³ (95% CI = 13.7, 18.5).

For site specific weekly averages, 6 weeks exceeded 15 ug/M³. The highest result was observed on week 16, when the result was 25.8 ug/M³ (95% CI = 15.2, 55.0) All four weekly campaigns in the summer exceeded 15 ug/M³ and the sample exceeding 35 ug/M³ was collected in week 16.

The average exposure in the summer campaign (weeks 15-18) was 21.6 ug/M³ (95% CI = 18.3, 24.8). For the fall, winter and spring campaigns (weeks 1-14), the average exposure was 12.8 ug/M³ (95% CI = 11.8, 13.7). The increased value in summer was highly significant ($p < 10^{-11}$ by t-test.)

Site averages and spatial variation

Four sites exceeded 15 ug/M³ averaged over 18 weeks: PS 34, 18.2 ug/M³ (95% CI = 10.2, 38.5); JK's Apartment, 17.1 ug/M³ (95% CI = 11.3, 25.2); PS 20, 16.0 ug/M³ (95% CI = 13.4, 18.5); and, PS 124, 15.9 ug/M³ (95% CI = 13.0, 18.7). The average value for PS 110, 11.6 ug/M³ (95% CI = 10.0, 13.1) was the lowest of all sites; however, this may have arisen from the absence of sampling from the higher exposure summer campaign because construction precluded sampling.

In Table IV-1 air sampling sites are ordered by increasing distance from the northeast corner of CB3. There was no definite trend of exposure level with distance from that corner. High averages were observed for PS 34 and JK's apartment, close by the northeast corner, but also at the farthest site, PS 124.

There was a suggestion of an effect of elevated readings at higher levels in the northeast corner (PS 34 and JK's Apartment, both on the 6th level) but no statistical test could be run on two observations.

Variability in exposure across the area was also assessed by calculating the ratio of highest to lowest PM_{2.5} value in a week. The largest ratio was 7.5 in week 15, the lowest was 1.5 in weeks 4, 10 and 13. The average was 2.5 (95% CI = 1.8, 3.3). While there was significant spatial variation, no spatial pattern was discernable.

Relationship of gravimetric sampling to DEC monitoring results

Over the whole campaign, weekly gravimetric filter samples were significantly higher than the averages of nearby DEC sites. (14.8 ug/M³ (95% CI = 12.5, 19.7) vs. 11.0 mg/M³ (95% CI = 9.7, 12.2), $p < 0.01$ by two-tailed paired t-test.). The comparison was divided into the fall-winter-spring campaigns, and summer. For summer, the gravimetric filter mean was 21.5 mg/M³ and the DEC mean was 12.6 mg/M³ ($p = 0.007$). For the fall-winter-spring campaign, the mean gravimetric was 12.8 mg/M³, the mean DEC was 10.6 mg/M³ ($p = 0.03$).

Among DEC weekly averages, two exceeded 15 ug/M³. This compares to 6 weeks when the gravimetric results exceeded 15 ug/M³. DEC results were generally higher in the summer campaign with an average of 12.5 ug/M³, compared to the three earlier campaigns, averaging 10.5 ug/M³. This was the same observation as with the gravimetric filter results. Table IV-2 shows the ratio of

gravimetric filter results to the DEC's weekly average. Over an average of all 18 weeks, every site's PM2.5 gravimetric filter average was higher than the DEC's average.

Table IV-2. Ratio of PM_{2.5} Filter Gravimetric to DEC Weekly Average

Ratio of Site Filter Samples to DEC results for week											
site id	7	5	6	8	10	2	9	4	3	1	
Site	St. Emeric's Church	PS 34	OP's apt	JK's apt	AFSZ office	PS 15	PS 20	PS 110	PS 184	PS 124	10 site weekly average
Distance	0.1	0.1	0.2	0.3	0.4	0.5	0.8	0.9	1.3	1.5	
Floor level	1	6	1	6	1	1	1	1	1	1	
Week 1 11/12/08	1.2	1.0	1.5	0.7	1.3	1.6	1.6	1.2	1.1	1.6	1.3
Week 2 11/18/08	1.1	0.0	0.9	1.6	1.2			1.0	1.0	1.2	1.2
Week 3 11/25/08	0.9	0.8	0.7	1.1	1.1	1.1	1.5	1.1	1.1	1.3	1.1
Week 4 12/2/08	0.8	0.9	1.1	1.2	1.2	1.1	0.8	1.0	1.0	1.2	1.0
Week 5 12/10/08	0.9	0.7	0.9	0.9	1.0	0.8	0.9	0.7	0.9	0.9	0.9
Week 6 12/17/08	0.9	0.7		1.0	0.7	1.0	1.1	0.7		1.0	0.9
Week 7 2/11/09	1.8	1.2		6.7	1.5	1.5	1.6	1.8	1.2	1.5	2.1
Week 8 2/18/09	0.7	1.0	1.2	1.1	1.0	1.2	2.2	0.9	1.0	1.7	1.2
Week 9 2/25/09	1.3	2.3	1.1	1.1	1.1	1.2	1.2	1.1		1.7	1.4
Week 10 3/4/09	0.8		0.9	1.1	0.8		0.7	0.9	0.8	0.9	0.9
Week 11 5/13/09	1.3	1.3	1.1	1.8	1.5	3.2	1.9	1.4	1.6	0.0	1.7
Week 12 5/20/09	1.2	1.3	1.5	1.1	1.4	1.4	1.7	1.4	1.4	1.2	1.4
Week 13 5/27/09	1.2	1.2	2.2	1.5	1.2	1.4	1.5	1.5	2.1	1.3	1.5
Week 14 6/3/09											
Week 15 7/29/09	1.1	4.1	1.8	1.6	1.5		1.4		1.6	2.2	1.9
Week 16 8/5/09	1.3	2.8	1.7	0.0	1.3	1.8	1.5		1.6	1.7	1.7
Week 17 8/12/09	1.2	2.8	1.0	1.4	1.3	0.4	1.5		1.6	1.6	1.4
Week 18 8/20/09	1.7		2.2	2.2	1.3	1.4	2.3		2.3	1.6	1.9
18 Week Average	1.1	1.5	1.3	1.5	1.2	1.4	1.5	1.1	1.3	1.3	1.4
Lower	1.1	1.5	1.3	1.5	1.2	1.4	1.5	1.1	1.3	1.3	1.4
Upper	1.2	1.7	1.4	1.8	1.2	1.5	1.5	1.2	1.4	1.4	1.4

The time trend of gravimetric filter and DEC results is shown in Figure IV-1. For 11 weeks, gravimetric average was higher than DEC, while for 2 weeks the DEC was higher. The greatest exceedence over DEC was in the summer campaign. For a spatial analysis the data is organized by distance from the northeast corner of CB3 in Figure IV-2. No trend was observed. The two points circled in blue were 6th floor sites; they were higher but the difference was not significant because of the small amount of data.

Figure IV-1. Time trends of gravimetric filter and DEC data. Blue- gravimetric, Red= DEC.

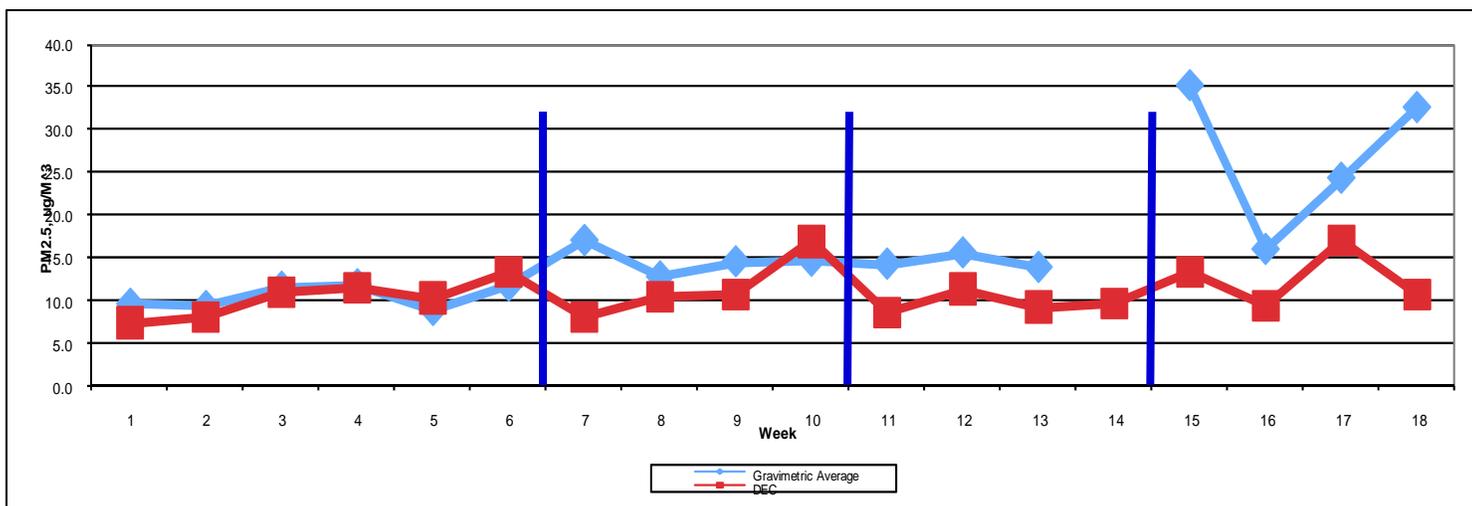
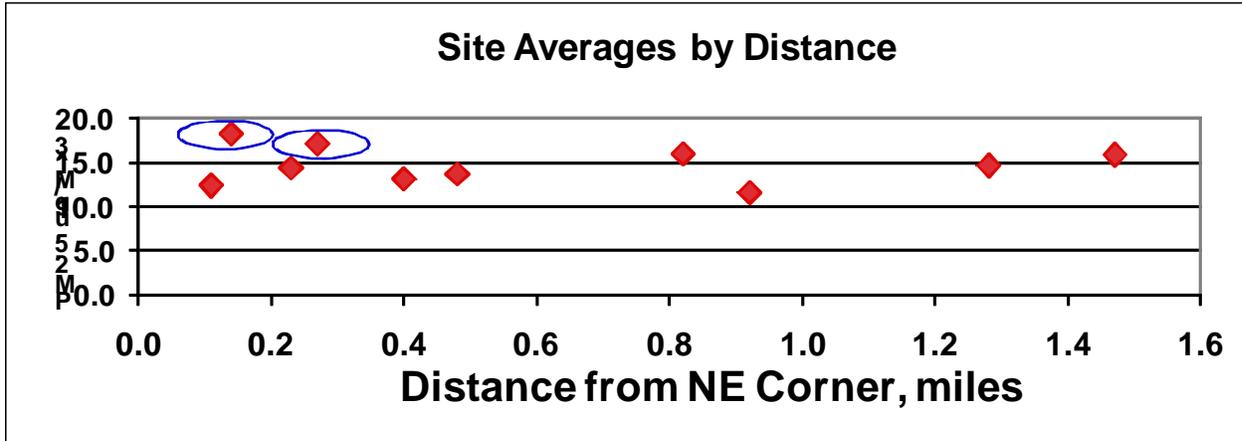
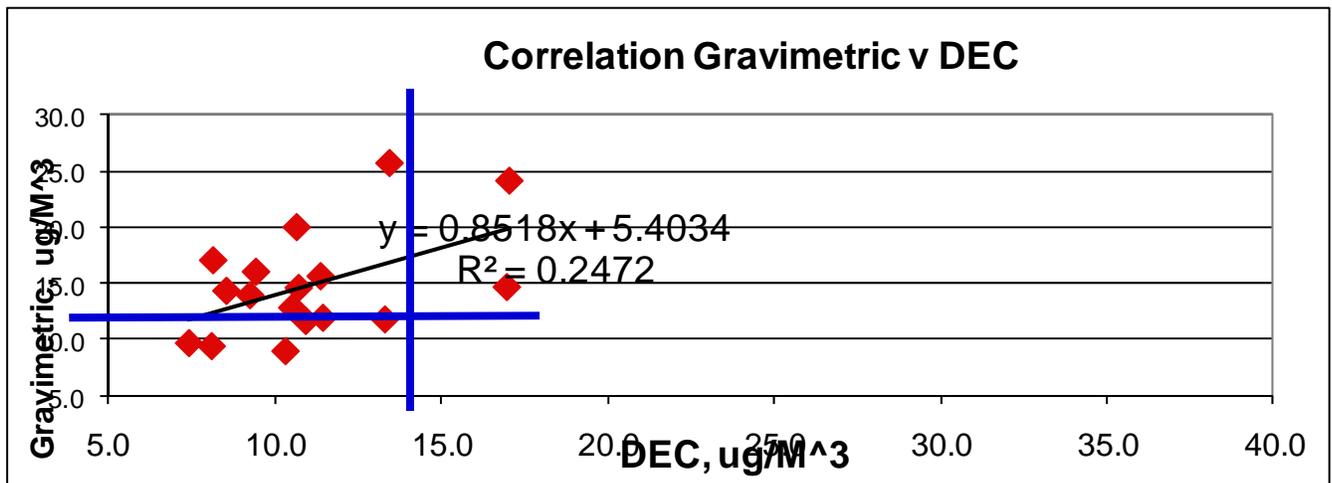


Figure IV-2. Site filter gravimetric averages by distance from the northeast corner.



A scatter plot of gravimetric weekly averages, for all 18 weeks, and DEC is shown in Figure IV-3. Of the 17 paired results, 4 gravimetric results exceeded 15 ug/M³ while the corresponding DEC results were below. One DEC result exceeded 15 ug/M³ while the gravimetric was below, and one result was above by both methods. The regression line Gravimetric = 1.0002 DEC + 5.0621, R² = 0.1358, was not a significant correlation.

Figure IV-3. Correlation of Gravimetric to DEC results. Among Gravimetric filter weekly averages, 11 exceeded 15 ug/M³, among these 2 also exceeded 15 ug/M³ in DEC result



Carbon Samples

Following the study plan, the last week of each four week campaign employed quartz filters which could be analyzed for elemental and organic carbon.³ There was one week of carbon sampling in the fall, winter and spring campaigns. In the summer campaign, an additional week of quartz filter carbon analysis was added, for a total of 5 such weeks.

There were 50 week-site opportunities for carbon sampling. Two samples were lost because of construction at PS 110 during the summer campaign. Results for the two week period at JK's Apartment, when access could not be achieved for the first week, were averaged over the two week period. Four others were lost for diverse reasons, leaving 44 results for statistical analysis.

Elemental carbon

The elemental carbon results are arrayed in Table IV-3. Cells in which the observed value exceeded the upper confidence interval are colored red. Values over the upper confidence limit are meaningfully different than the average. Cells in which the observed value was less than the lower confidence interval are colored blue. Over all weeks and all sites, the mean elemental carbon concentration was 0.98 ug/M^3 (95% CI = 0.88, 1.11). The maximum site-week combination, (or reading at any site for that week) was 2.5 ug/M^3 , the minimum 0.3 ug/M^3 . The highest weekly average was observed in the winter campaign, 1.31 ug/M^3 (95% CI = 0.95, 1.68). The lowest weekly average was the last week of the spring campaign, 0.72 ug/M^3 (95% CI = 0.55, 0.89). The summer campaign also has a similar low value.

The ratio of the highest to the lowest value within the week measures the variation of the level of elemental carbon across the area was the ratio of. These are shown in Table IV-4. Site week combinations and averages greater than the upper confidence limit of the mean are highlighted in red. Those below are highlighted in blue. The mean value was 1.82 (95% CI = 1.04, 2.60) ranging from 8.00 to 1.54.

³ Elemental carbon is non-volatile (and inorganic). It is better known as soot. "Elemental carbon" and "black carbon" differ by how they are measured, but the concentration is fairly similar. Organic carbon is the semivolatile part, ie. some stays as a liquid adsorbed to the surface of the nuclei (often made of EC) while much evaporates off.

Table IV-3. Elemental carbon weekly averages.

Elemental Carbon Weekly Average, ug/M ³													
site ID	7	5	6	8	10	2	9	4	3	1			
Dist	0.11	0.14	0.23	0.27	0.4	0.48	0.82	0.92	1.28	1.47			
Floor	1	6	1	6	1	1	1	1	1	1			
Site	St. Emeric's Church	PS 34	OP's apt	JK's apt	AFSZ office	PS 15	PS 20	PS 110	PS 184	PS 124	Week Average	Lower	Upper
12/16/04	1.1	0.97		0.99	1.2	1.2	0.96	0.78	0.97	1	1.02	0.93	1.10
3/3/05	0.87		0.93	1.1	1.2	2	2.5	0.92	1	1.3	1.31	0.95	1.68
6/2/05	0.57	0.3	0.76	0.67	1.3	0.55	1	0.65	0.56	0.84	0.72	0.55	0.89
8/11/05	0.9	1.6	1.1	0.55	1.2	0.2	1.3		1.6	1.5	1.11	0.79	1.42
8/19/05	0.51		0.85	0.55	0.56	0.72			1.1	0.79	0.73	0.57	0.88
Site Average	0.79	0.96	0.91	0.77	1.09	0.93	1.44	0.78	1.05	1.09	0.98	0.86	1.11
Lower	0.57	0.22	0.77	0.44	0.83	0.32	0.65	0.40	0.72	0.82	0.74		
Upper	1.01	1.69	1.05	1.40	1.36	1.54	2.23	1.17	1.37	1.35	1.25		

Table IV-4. Ratio of highest to lowest elemental carbon result within week.

Elemental Carbon High to Low Ratio Within Week													
site ID	7	5	6	8	10	2	9	4	3	1			
Dist	0.11	0.14	0.23	0.27	0.4	0.48	0.82	0.92	1.28	1.47			
Floor	1	6	1	6	1	1	1	1	1	1			
Site	St. Emeric's Church	PS 34	OP's apt	JK's apt	AFSZ office	PS 15	PS 20	PS 110	PS 184	PS 124	Weekly High/Low		
12/16/04	1.1	0.97		0.99	1.2	1.2	0.96	0.78	0.97	1	1.54		
3/3/05	0.87		0.93	1.1	1.2	2	2.5	0.92	1	1.3	2.87		
6/2/05	0.57	0.3	0.76	0.67	1.3	0.55	1	0.65	0.56	0.84	4.33		
8/11/05	0.9	1.6	1.1		1.2	0.2	1.3		1.6	1.5	8.00		
8/19/05	0.51		0.85		0.56	0.72			1.1	0.79	2.16		
Site Average	0.79	0.96	0.91	0.92	1.09	0.93	1.44	0.78	1.05	1.09	3.78		
Lower	0.57	0.22	0.77	0.44	0.83	0.32	0.65	0.40	0.72	0.82	1.71		
Upper	1.01	1.69	1.05	1.40	1.36	1.54	2.23	1.17	1.37	1.35	5.85		

Organic carbon

Organic carbon results are arrayed in Table IV-5. Site-week combinations and averages greater than the upper confidence limit are highlighted in red. Those below the lower confidence limit are highlighted in blue. The mean value was 5.28 ug/M³ (95% CI = 4.02, 6.53). The highest site was the AFSZ office, averaging 10.88 ug/M³, driven by the highest value, 30 ug/M³ in the winter campaign. That week also displayed the highest weekly average over all sites of 9.01 ug/M³.

Table IV-5. Organic carbon weekly averages.

Organic Carbon Weekly Average, ug/M ³													
site ID	7	5	6	8	10	2	9	4	3	1			
Dist	0.11	0.14	0.23	0.27	0.4	0.48	0.82	0.92	1.28	1.47			
Floor	1	6	1	6	1	1	1	1	1	1			
Site	St. Emeric's Church	PS 34	OP's apt	JK's apt	AFSZ office	PS 15	PS 20	PS 110	PS 184	PS 124	Weekly Average	Lower	Upper
12/16/04	4.4	2.9		2.3	2.6		2	2.2	3.1	2.8	2.79	2.27	3.31
3/3/05	7.2	13.0	5.2	5.2	30	4.7	6.4	5	6.5	6.9	9.01	4.20	13.82
6/2/05	4.5	4.2	4	3.7	2.7	4.7	3.7	4.2	5.1	4.1	4.09	3.69	4.49
8/11/05	6.7	1.9	7.5	3.7	8.2	6.7	5.6		6.7	5.7	5.86	4.58	7.14
8/19/05	4.2	4.9	4.5	3.7		4.9	4.4		6.2	4.3	4.64	4.12	5.15
Site Average	5.40	5.38	5.30	3.72	10.88	5.25	4.42	3.80	5.52	4.76	5.28	4.02	6.53
Lower	4.15	1.51	3.78	2.82	-1.88	4.30	2.92	2.17	4.22	3.38	3.21		
Upper	6.65	9.25	6.82	4.62	23.63	6.20	5.92	5.43	6.82	6.14	7.35		

A measure of variation of the level of organic carbon across the area was the ratio of the highest to the lowest value within the week. These are shown in Table IV-6. The site week combinations and averages are the same as those in Table IV-6. The ratio of highest to lowest in a week is highlighted in orange. The mean value was 3.19 (95% CI =1.33,5/05). The greatest variation was observed in the winter campaign, 6.38, while the least was seen in the last week of the summer campaign, 1.38.

Table IV-6. Ratio of Highest to Lowest Organic Carbon Result within week

Organic Carbon Ratio High to Low Within Week													
site ID	7	5	6	8	10	2	9	4	3	1			
Dist	0.11	0.14	0.23	0.27	0.4	0.48	0.82	0.92	1.28	1.47			
Floor	1	6	1	6	1	1	1	1	1	1			
Site	St. Emeric's Church	PS 34	OP's apt	JK's apt	AFSZ office	PS 15	PS 20	PS 110	PS 184	PS 124	Ratio High to Low	Lower	Upper
12/16/04	4.4	2.9		2.3	2.6		2	2.2	3.1	2.8	2.20	1.68	2.72
3/3/05	7.2	13.0	5.2	5.2	30	4.7	6.4	5	6.5	6.9	6.38	1.58	11.19
6/2/05	4.5	4.2	4	3.7	2.7	4.7	3.7	4.2	5.1	4.1	1.38	0.97	1.78
8/11/05	6.7	1.9	7.5	3.7	8.2	6.7	5.6		6.7	5.7	4.32	3.04	5.60
8/19/05	4.2	4.9	4.5	3.7		4.9	4.4		6.2	4.3	1.68	1.16	2.19
Site Average	5.40	5.38	5.30	3.72	10.88	5.25	4.42	3.80	5.52	4.76	3.19	1.94	4.44
Lower	4.15	1.51	3.78	2.82	-1.88	4.30	2.92	2.17	4.22	3.38	1.33		
Upper	6.65	9.25	6.82	4.62	23.63	6.20	5.92	5.43	6.82	6.14	5.05		

The ratio of elemental carbon to organic carbon is a measure of variability of composition of PM_{2.5} and its carbon component. Results are arrayed in Table IV-7. Site week combinations and averages greater than the upper confidence limit are highlighted in red. Those below the lower confidence limit are highlighted in blue. The mean value was 0.24 (95% CI = 0.18,0.30). The highest site was the PS34 at 0.42, driven by the highest value, 0.84 in the first week of the summer campaign. The week with the highest weekly average of 0.37 was the fall campaign.

Table IV-7. Ratio of Elemental to Organic carbon weekly averages

Ratio Elemental to Organic Carbon Weekly Average, ug/M ³													
site ID	7	5	6	8	10	2	9	4	3	1			
Dist	0.11	0.14	0.23	0.27	0.4	0.48	0.82	0.92	1.28	1.47			
Floor	1	6	1	6	1	1	1	1	1	1			
Site	St. Emeric's Church	PS 34	OP's apt	JK's apt	AFSZ office	PS 15	PS 20	PS 110	PS 184	PS 124	Weekly Average	Lower	Upper
12/16/04	0.25	0.33		0.43	0.46		0.48	0.35	0.31	0.36	0.37	0.32	0.43
3/3/05	0.12		0.18	0.21		0.43	0.39	0.18	0.15	0.19	0.23	0.15	0.31
6/2/05	0.13	0.07	0.19	0.18	0.48	0.12	0.27	0.15	0.11	0.20	0.19	0.12	0.26
8/11/05	0.13	0.84	0.15	0.15	0.15	0.03	0.23		0.24	0.26	0.24	0.09	0.40
8/19/05	0.12		0.19	0.15		0.15			0.18	0.18	0.16	0.14	0.18
Site Average	0.15	0.42	0.18	0.22	0.36	0.18	0.34	0.23	0.20	0.24	0.24	0.18	0.30
Lower	0.10	-0.03	0.16	0.12	0.15	0.01	0.23	0.11	0.13	0.18	0.17		
Upper	0.20	0.86	0.20	0.33	0.58	0.35	0.45	0.35	0.27	0.30	0.31		

A measure of variation in composition across the area was the ratio of the highest to lowest EC/OC ratio. These are arrayed in Table IV-8. (The site-week values are the same as those in Table IV-7). The column showing the ratio of highest site within week to lowest is highlighted in orange. The high to low ratio averaged 8.11 (95% CI = -1.96, 18.2). The most dramatic variation was observed in the second week of the summer campaign, 28.2 from high to low, driven by a very high ratio observed at PS 34 and a low ratio at PS 15. The least variation was observed in the last week of the summer campaign, 0.16.

Table IV-8. Weekly ratio of high to low elemental to organic carbon ratio.

Ratio Elemental to Organic Carbon Weekly High to Low														
site ID	7	5	6	8	10	2	9	4	3	1				
Dist	0.11	0.14	0.23	0.27	0.4	0.48	0.82	0.92	1.28	1.47				
Floor	1	6	1	6	1	1	1	1	1	1				
Site	St. Emeric's Church	PS 34	OP's apt	JK's apt	AFSZ office	PS 15	PS 20	PS 110	PS 184	PS 124	Weekly High to Low	Lower	Upper	
12/17/08	0.25	0.33		0.43	0.46		0.48	0.35	0.31	0.36	1.92	1.87	1.97	
3/4/09	0.12		0.18	0.21		0.43	0.39	0.18	0.15	0.19	3.52	3.44	3.60	
6/3/09	0.13	0.07	0.19	0.18	0.48	0.12	0.27	0.15	0.11	0.20	6.74	6.67	6.81	
8/12/09	0.13	0.84	0.15	0.15	0.15	0.03	0.23		0.24	0.26	28.21	28.06	28.36	
8/20/09	0.12		0.19	0.15		0.15			0.18	0.18	0.16	0.14	0.18	
Site Average	0.15	0.42	0.18	0.22	0.36	0.18	0.34	0.23	0.20	0.24	8.11	8.06	8.17	
Lower	0.10	-0.03	0.16	0.12	0.15	0.01	0.23	0.11	0.13	0.18	-1.96			
Upper	0.20	0.86	0.20	0.33	0.58	0.35	0.45	0.35	0.27	0.30	18.19			

Ozone

With regard to spatial variation, the readings were very close to one another and statistically insignificant. The averages ranged from .038 to .042. The maximum readings ranged from .068 to .074. Minimum levels ranged from a possibly spurious reading of .000 at the AFSZ office to .018 (Table IV-9 and Figure IV-4).

Table IV-9. Ozone meter measurements for three project sites

	Campos Plaza	AFSZ Office	PS 184
	Meter 1	Meter 2	Meter3
Avg ppm	0.041	0.038	0.042
Max ppm	0.068	0.068	0.074
Min ppm	0.018	0.000	0.018

During the same hours and days the DEC monitors showed similar results (Table IV-10, Figure IV-5). Figure IV-6 shows our ozone meter measurements and NYS DEC's measurements on one graph.

Figure IV-4. Ozone meter measurements in parts per million (ppm) every 2 minutes. Meter 1 (blue) is Campos Plaza, Meter 2 (red) is AFSZ Office, Meter 3 (green) is PS 184.

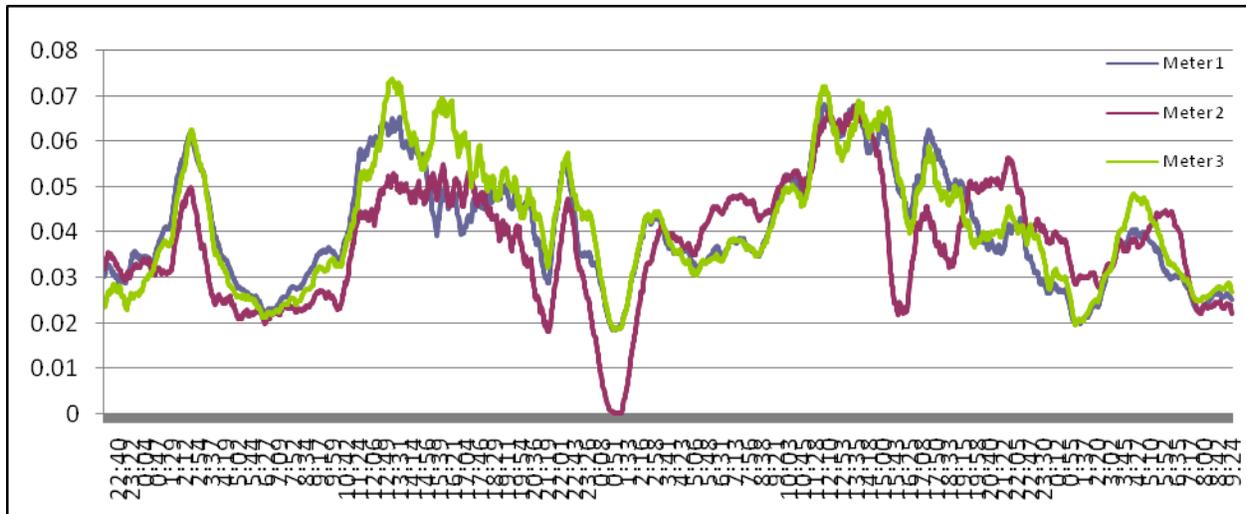


Table IV-10. Ozone measurements at four nearby NYS DEC monitoring stations.

	IS52	NYBG	CCNY	QC
Avg ppm	0.029	0.029	0.027	0.032
Max ppm	0.064	0.060	0.063	0.078
Min ppm	0.007	0.009	0.006	0.003

Figure IV-5. NYS DEC ozone meter measurements in parts per million (ppm) every hour



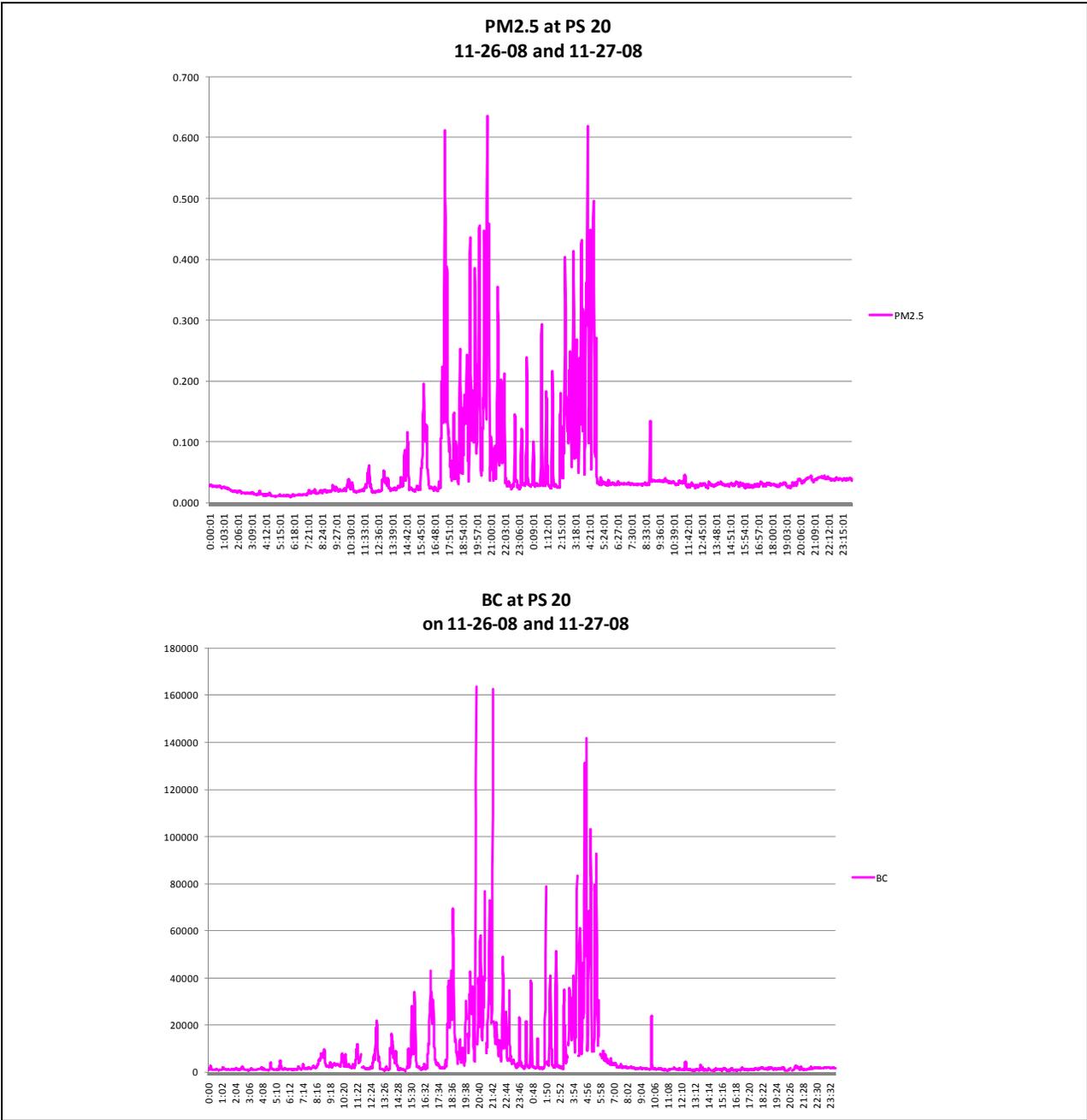
Our observations in the neighborhood did not reveal any significant differences between the three sites selected by the AFSZ project or between those sites and the DEC sites. Two expert advisors in the NYS (Brian Lay, DEC's Bureau of Air Quality Surveillance, and Rob Sliwinski, DEC's Director of the Bureau of Air Quality Planning) both said that they would not expect that we could see meaningful highly local spatial variations in ozone, just regional variations.

Real Time Measurements

Over the 18 sampling campaigns, data were collected for over 198,000 one-minute samples, mostly with 5 instruments running simultaneously at 3 locations. This yielded almost a million data points. These were matched with simultaneous hourly $PM_{2.5}$ and relative humidity values downloaded from the NYS DEC.

The utility of these measurements is illustrated by a unique event observed over the period November 26 and 27, 2008, shown in Figure IV-7, which displays both $PM_{2.5}$ and BC on the same time base. This was a nearly simultaneous surge in both $PM_{2.5}$ and BC at PS20, at a time when there was little movement in $PM_{2.5}$ at AFSZ, St. Emeric's and the DEC, or BC at AFSZ.

Figure IV-7. PM_{2.5} (Sidepak readings) and BC (Aethalometer readings) at PS20 on November 26th and 27th.



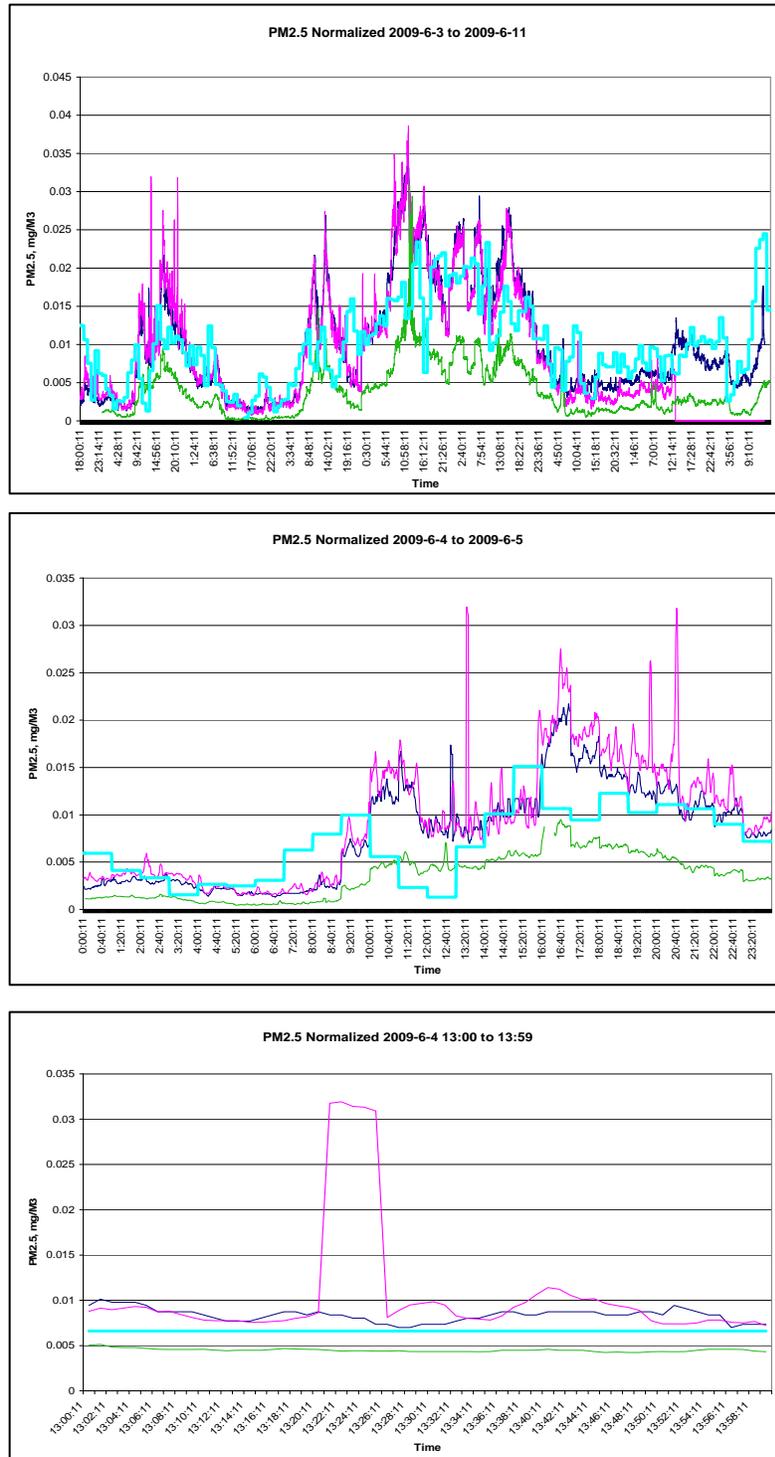
The BC event, recorded on the Aethalometer, began with a modest increase at about 8:45 AM on 11/26, peaked at about 8:30 pm, remained high and surged to another peak at 4:55 AM on 11/27, returned to a more normal level by about 9 AM but then showed a brief spike at 9:55 AM. Almost exactly parallel behavior was seen in the PM_{2.5} results, recorded on the Sidepak. A modest increase at 8:45 AM on 11/26 was followed by a surge to a high point at 8:45 pm, a second surge at 4:15 am, subsiding with a final spike at 8:53 am.

The peak reading for BC was 160 ug/M³. The peak reading for PM_{2.5} was 636 ug/M³, although the absolute magnitude is unreliable for reasons discussed below.

The filters for the campaign starting 11/25 are shown in Figure III-3. The sample for PS 20 is clearly darker than the others. The gravimetric result for that week for PS20 was 16 ug/M³, the highest for that week, but not the highest for the entire period. The Aethalometer average for that week for PS20 was 2.8 ug/M³, which was the highest for the entire observation period; the AFSZ office average was 1.1 ug/M³.

The value of 1 minute granularity is shown in Figure IV-8 [chart time base], which contracts from one week (duration of gravimetric sampling) to one day to one hour (duration of DEC samples). For the purpose of this illustration, the Sidepak values were scaled to the DEC value so that all four series would appear on the same chart. On the one hour time scale, PM_{2.5} measured at PS20 increased 3 fold for 6 minutes, while measurements at AFSZ and St. Emeric's were level and the DEC value was level because that data is an hourly gravimetric average.

Figure IV-8. PM_{2.5} values during one week (top), one day (middle) and one hour (bottom) for our 3 sites and the average of 3 DEC sites.



■ = AFSZ office; ■ = PS 20; ■ = St. Emeric's; ■ = DEC

PM_{2.5}

Generally, the Sidepak proved useful for measurement of temporal variation in PM_{2.5}, but proved unreliable for absolute measurement or spatial variation. This is partly because of the very strong effect of humidity on the instrument's readings, and because a stable correction factor to either co-located gravimetric or DEC could not be achieved.

Results of humidity correction

An example of the distribution of humidity readings is displayed graphically in Figure IV-9. Humidity values were truncated at 95% because application of the correction formula would drive results to zero at higher values. At 80% humidity, the correction factor was approximately two-fold. The distribution of humidity by week is shown in Table IV-11. The fraction of minutes with humidity over 95% ranged from 2% during the week of 2 December, up to 46% during the week of 3 June, with an average of 18%. The fraction of minutes exceeding 80% humidity ranged from 15% for the weeks of 18 November and 11 February, up to 78% during the week of 3 June, for an average of 44%. For the week displayed, 46% of minutes equaled or exceeded 95% relative humidity, and 78% exceeded 80%. At 80% relative humidity, the Sidepak correction is two-fold.

Figure IV-9. Humidity trends over one week. For this week, 46% of minutes equaled or exceeded 95% relative humidity, and 78% exceeded 80%.

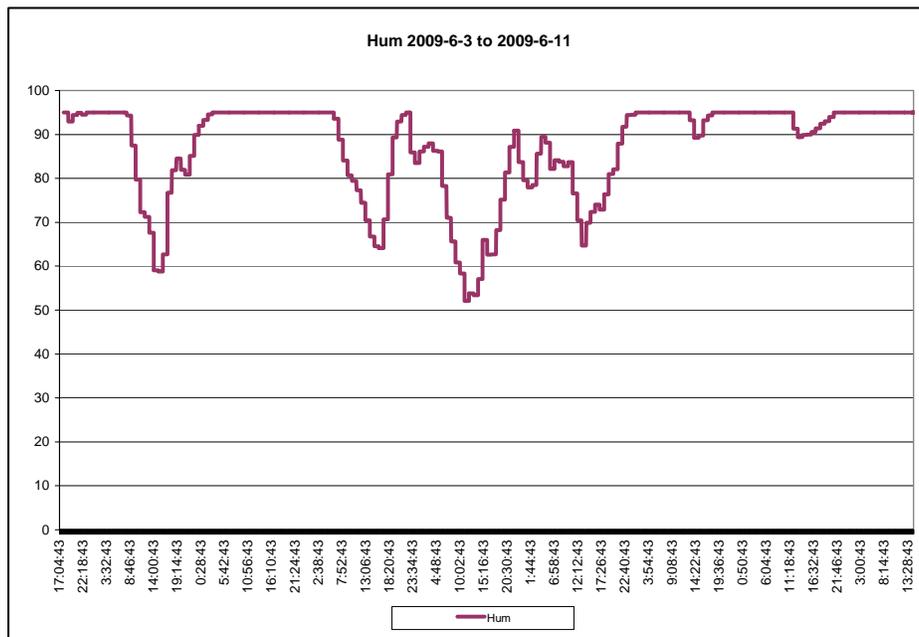


Table IV-11. Number and Fraction of Sampled Minutes Where Humidity Exceeded 95% and 80%.

	Total	>95	>80	>95	>80
	minutes			fraction	
12-Nov	8989	2880	4800	0.32	0.53
18-Nov	10700	340	1554	0.03	0.15
25-Nov	10512	1260	2717	0.12	0.26
2-Dec	11114	240	1920	0.02	0.17
10-Dec	10512	3852	6652	0.37	0.63
17-Dec	10290	3210	6240	0.31	0.61
11-Feb	10556	420	1620	0.04	0.15
18-Feb	9840	1020	1980	0.10	0.20
25-Feb	10760	1320	3300	0.12	0.31
4-Mar	10080	240	3960	0.02	0.39
13-May	10440	2040	4960	0.20	0.48
20-May	10440	504	2280	0.05	0.22
27-May	10560	2640	5048	0.25	0.48
3-Jun	11340	5160	8880	0.46	0.78
29-Jul	10020	3902	6692	0.39	0.67
5-Aug	19660	840	4740	0.04	0.24
12-Aug	12118	2640	6718	0.22	0.55
20-Aug	10404	2880	7026	0.28	0.68
Total	198335	35388	81087	0.18	0.44

Comparison of Sidepak to gravimetric

Table IV-12 displays the Sidepak, co-located gravimetric sampling, and ambient air monitoring results at the three sites. Sidepak readings were corrected for relative humidity based on hourly weather data downloaded from the NYS Department of Environmental Conservation (DEC). Results are in mg/M³. The DEC particle values were the average of those at Division Street, Park Row and PS 19 (when available). Averages were used because each site was not available for each hour. The same Sidepak instrument was deployed at each site, except that the instrument at the AFSZ site malfunctioned, and a different instrument was used for the weeks of August 5, August 12 and August 20 (highlighted in gold in Table IV-12 through IV-15). The substitute instrument gave widely anomalous results and was therefore not used for the analysis. Gravimetric results were not available at any site for the week of 3 June, and for PS20 for the week of 18 November, and the Sidepak at St. Emeric's lost power for the week of 17 December (highlighted in yellow in Table IV-12).

Table IV-12. Comparison of Sidepak, co-located gravimetric sampling, and ambient air monitoring results at 3 sites.

Week begins	AFSZ			PS20			StE			DEC
	Uncorr	Corr	Grav	Uncorr	Corr	Grav	Uncorr	Corr	Grav	
12-Nov	0.0110	0.0040	0.0098	0.0320	0.0120	0.0120	0.0250	0.0110	0.0091	0.0080
18-Nov	0.0038	0.0026	0.0098	0.0160	0.0120		0.0250	0.0110	0.0088	0.0080
25-Nov	0.0083	0.0056	0.0120	0.0450	0.0290	0.0160	0.0180	0.0130	0.0097	0.0110
2-Dec	0.0070	0.0060	0.0140	0.0280	0.0190	0.0095	0.0180	0.0130	0.0092	0.0110
10-Dec	0.0050	0.0020	0.0100	0.0190	0.0030	0.0086	0.0060	0.0030	0.0090	0.0110
17-Dec	0.0080	0.0020	0.0099	0.0280	0.0050	0.0140			0.0014	0.0130
11-Feb	0.0051	0.0032	0.012	0.0234	0.0157	0.013	0.0180	0.0133	0.015	0.0084
18-Feb	0.0047	0.0027	0.011	0.0490	0.0122	0.023	0.0180	0.0108	0.0077	0.0105
25-Feb	0.0081	0.0048	0.012	0.0226	0.0140	0.013	0.0157	0.0088	0.014	0.0109
4-Mar	0.0106	0.0068	0.013	0.0489	0.0325	0.012	0.0121	0.0081	0.014	0.0170
13-May	0.0038	0.0015	0.013	0.0437	0.0197	0.016	0.0360	0.0125	0.011	0.0087
20-May	0.0040	0.0026	0.016	0.0318	0.0279	0.019	0.0322	0.0219	0.014	0.0112
27-May	0.0059	0.0030	0.011	0.0401	0.0196	0.014	0.0372	0.0186	0.011	0.0093
3-Jun	0.0114	0.0037		0.0408	0.0154		0.0376	0.0134		0.0098
29-Jul	0.0058	0.0023	0.02	0.0665	0.0263	0.019	0.0490	0.0194	0.015	0.0137
5-Aug	0.0264	0.0121	0.012	0.0398	0.0195	0.014	0.0721	0.0403	0.012	0.0091
12-Aug	0.5330*	0.2740*	0.022	0.0680	0.0370	0.026	0.0550	0.0310	0.02	0.0170
20-Aug	0.1250*	0.0530*	0.014	0.0320	0.0150	0.025	0.0430	0.0200	0.018	0.0110

Table IV-13 displays the ratio of uncorrected and corrected Sidepak weekly average to co-located gravimetric results. For AFSZ location, weeks of 5, 12 and 20 August used a substitute instrument. No co-located gravimetric data at any site were available for the week of 3 June because of a laboratory error. At PS20 location, the gravimetric sample for the week of 18 November was lost due to pump malfunction. For the St. Emeric's location, the Sidepak for the week of 17 December was lost due to instrument becoming unplugged. Cells highlighted in yellow indicate these missing values.

Comparison of Sidepak averages to co-located gravimetric

Excluding the three weeks with an alternative instrument at AFSZ, summary statistics were calculated for the ratio of uncorrected and corrected Sidepak values to co-located gravimetric. The ratio of Sidepak to co-located gravimetric results is displayed in Table IV-13.

Table IV-13. Ratio of corrected and uncorrected Sidepak weekly average to co-located gravimetric results.

Week begins	AFSZ		PS20		St E	
	UnCorr	Corr	UnCorr	Corr	UnCorr	Corr
12-Nov	1.12	0.41	2.67	1.00	2.75	1.21
18-Nov	0.39	0.27			2.84	1.25
25-Nov	0.69	0.47	2.81	1.81	1.86	1.34
2-Dec	0.50	0.43	2.95	2.00	1.96	1.41
10-Dec	0.50	0.20	2.21	0.35	0.67	0.33
17-Dec	0.81	0.20	2.00	0.36		
11-Feb	0.43	0.26	1.80	1.21	1.20	0.89
18-Feb	0.43	0.25	2.13	0.53	2.34	1.40
25-Feb	0.67	0.40	1.74	1.08	1.12	0.63
4-Mar	0.81	0.52	4.08	2.71	0.86	0.58
13-May	0.29	0.12	2.73	1.23	3.27	1.14
20-May	0.25	0.16	1.67	1.47	2.30	1.56
27-May	0.54	0.28	2.86	1.40	3.38	1.69
3-Jun						
29-Jul	0.29	0.11	3.50	1.38	3.27	1.29
5-Aug	2.20	1.01	2.84	1.40	6.01	3.36
12-Aug	24.23	12.45	2.62	1.42	2.75	1.55
20-Aug	8.93	3.79	1.28	0.60	2.39	1.11
Average	0.55	0.29	2.49	1.25	2.43	1.30
SD	0.25	0.13	0.72	0.62	1.29	0.67
CI	0.12	0.07	0.35	0.30	0.63	0.33
Upper	0.68	0.36	2.85	1.55	3.07	1.62
Lower	0.43	0.22	2.14	0.94	1.80	0.97
CV	0.23	0.23	0.14	0.24	0.26	0.25

Comparison of Sidepak averages to DEC

With the exclusion, again, of the three weeks with an alternative instrument at AFSZ, the ratio of Sidepak to DEC results is displayed in Table IV-14.

Table IV-14. Ratio of uncorrected and corrected Sidepak weekly averages to DEC PM_{2.5} for week.

Week begins	AFSZ		PS20		St E	
	UnCorr	Corr	UnCorr	Corr	UnCorr	Corr
12-Nov	1.38	0.50	4.00	1.50	3.13	1.38
18-Nov	0.48	0.33	2.00	1.50	3.13	1.38
25-Nov	0.75	0.51	4.09	2.64	1.64	1.18
2-Dec	0.64	0.55	2.55	1.73	1.64	1.18
10-Dec	0.45	0.18	1.73	0.27	0.55	0.27
17-Dec	0.62	0.15	2.15	0.38		
11-Feb	0.61	0.38	2.78	1.86	2.13	1.58
18-Feb	0.45	0.26	4.66	1.16	1.71	1.03
25-Feb	0.74	0.44	2.07	1.28	1.43	0.80
4-Mar	0.62	0.40	2.87	1.91	0.71	0.48
13-May	0.43	0.17	5.02	2.27	4.14	1.44
20-May	0.36	0.23	2.83	2.48	2.86	1.95
27-May	0.64	0.33	4.32	2.11	4.00	2.01
3-Jun	1.17	0.38	4.17	1.57	3.84	1.37
29-Jul	0.42	0.17	4.86	1.92	3.58	1.42
5-Aug	2.90	1.33	4.38	2.15	7.93	4.44
12-Aug	31.35	16.12	4.00	2.18	3.24	1.82
20-Aug	11.36	4.82	2.91	1.36	3.91	1.82
Average	0.65	0.33	3.41	1.68	2.92	1.50
SD	0.28	0.13	1.08	0.64	1.74	0.90
CI	0.14	0.07	0.53	0.31	0.85	0.44
Upper	0.79	0.40	3.94	2.00	3.77	1.94
Lower	0.51	0.26	2.88	1.37	2.06	1.06
CV	0.22	0.20	0.16	0.19	0.29	0.29

Black Carbon

The following is a comparison of black carbon (BC), gravimetric elemental carbon (EC), and total carbon (TC) at the AFSZ and PS 20 sites. The Aethalometer weekly averages for black carbon (BC), along with co-located and contemporary EC and TC results are shown in Table IV-15.

Table IV-15. Comparison of Aethalometer weekly averages with gravimetric measurements at two sites.

	AFSZ Aethalometer, ug/M3	AFSZ gravimetric EC ug/m3	AFSZ gravimetric TC ug/m3	PS 20 aeth avg ug/m3	PS 20 gravimetric EC ug/m3	PS 20 gravimetric TC ug/m3
13-Nov						
19-Nov						
25-Nov	1.1			2.8		
3-Dec	1.1			1.4		
11-Dec	1.2			1.6		
18-Dec	1.3	1.2	4.0		0.96	4.1
12-Feb	1.0			1.0		
19-Feb	1.0			0.9		
26-Feb	1.6			1.3		
5-Mar	1.6	1.2	8.1	2.8	2.5	9.0
14-May	1.5			1.7		
21-May	1.3			1.8		
28-May	1.4			1.9		
4-Jun	1.6	1.3	5.4	2.2	1.0	6.1
30-Jul	2.1			2.1		
6-Aug	1.5			1.7		
13-Aug	2.3	1.2	6.9	2.5	1.3	8.0
21-Aug	1.7	0.6	4.8	1.8	1.3	7.5
avg	1.46	1.10	5.84	1.83	1.41	6.94
upper	1.64	1.24	6.65	2.12	1.72	7.87
lower	1.27	0.96	5.03	1.54	1.10	6.01

The average Aethalometer BC value over the whole period at the AFSZ office was 1.46 ug/M³ (95% CI = 1.27 to 1.64). The average BC at PS20 was 1.83 ug/M³ (95% CI = 1.54 to 2.12). This difference was significant, p = 0.017 (two-tailed t-test.)

In parallel with overall PM_{2.5} results, the summer campaign Aethalometer samples at AFSZ were significantly higher than the remainder of the year, 1.9 ug/M³ for summer versus 1.3 ug/M³ for rest of year. At PS20 there was little difference in the average, 2.0 ug/M³ for summer versus 1.8 ug/M³ for the rest of year.

Elemental carbon gravimetric averaged 1.1 ug/M³ (95% CI = 0.96 to 1.24) at AFSZ, and 1.41 (95% CI = 1.10 to 1.72) at PS 20. These were not significantly different. For TC, the average at AFSZ, 5.84 (95% CI = 5.03 to 6.65), was marginally significantly less than that at PS 20, 6.94 (95% CI = 6.01 to 7.87)

V. DISCUSSION

The first aim of the project was to demonstrate whether there was meaningful variation in exposure between sites inside of CB3 on a weekly basis. This was established.

For individual sites, the average $PM_{2.5}$ exposure over the whole period varied from $18.3 \text{ ug}/M^3$ (at PS 34) to $13.0 \text{ ug}/M^3$ (at the AFSZ office), a ratio of 1.40. Four sites exceeded the $15 \text{ ug}/M^3$ annual average NAAQS and 6 sites were below. On a weekly basis, the variation was substantially greater. For weekly results, the average ratio of the highest site to the lowest was 2.5 but the range went up to a 7.5-fold difference.

For the various carbon measures, similar ratios were observed. For elemental carbon, the overall ratio of the highest to lowest site was 3.78, but it increased to 8 fold in one week. For organic carbon, the overall ratio of highest to lowest was 3.1 but ranged as high as 6 fold in one week. Carbon data was much more limited than PM. The composition of the carbon exposure, shown by ratio of elemental to organic varied widely.

Variation was influenced by season. Exposures to $PM_{2.5}$ were substantially higher in summer than in the fall, winter and spring campaigns. EC data were too sparse to draw a conclusion on seasonality. Aethalometer readings showed higher BC in summer at one site, but not the other.

The second aim of the project was to examine whether there were consistent differences in exposure at various sites.

There was no consistent gradient in exposure with distance from the northeast corner of the Community Board 3 area. Two of the sites exceeding $15 \text{ ug}/M^3$ were located a short distance from the northeast corner, but two other sites, exceeding the value were more distant.

There was a suggestion that higher elevation in certain locations was associated with increased exposure, but data were too sparse; there were not enough sites to compare height and distance. The lack of a clear increase at ground level across the 10 sites was not expected. Conversely, our mostly street level observations were higher compared to the DEC.

The third goal was to compare local gravimetric results to ambient DEC air monitoring.

The gravimetric filter results observed here were somewhat higher than the averages calculated from ambient air monitoring. The differences were modest in the fall-winter-spring campaigns and meaningful in the summer campaign.

This increase was statistically significant but is based on limited observations, despite the magnitude of the study. An additional concern is that exposure measurements were conducted near the limit of quantitation of the gravimetric filter analytical method.

The fourth goal was to determine whether time variation using real time aerosol monitoring would reveal peak exposures not identified through week long averages.

The time resolved PM_{2.5} data at 3 sites and BC data at two sites revealed multiple and contrasting excursions which were obscured by the long term averaging of gravimetric sampling. These suggested very local sources which might be identified and abated.

VI. CONCLUSIONS

The project has demonstrated intra-site variation in PM_{2.5} and carbon exposure between the 10 sampling sites in CB3. The project also demonstrated very large short time excursions in exposure level not reflected in longer term samples. These peak exposures vary between sites. A spatial trend from northeast could not be confirmed, perhaps because very high exposures were observed at sites remote from that corner of the neighborhood.

What is the health significance of these observations? There is ample evidence that increases of PM_{2.5} within prevailing exposure levels are associated with increased respiratory and cardiovascular illnesses. There is ample evidence that increases in diesel particulate matter - a component of the particle exposures - are associated with increased asthma and other respiratory effects. The particulate matter studies are based on community-wide exposure monitoring of the type conducted by the DEC – rooftop sampling – and daily and yearly average exposures. These exposures may vary 10-fold from day to day, which was observed in the DEC data used in this study. The established EPA standards for particulate matter are based on this data. The EPA is reevaluating the PM standards, and many believe that exposures in compliance with current standards cause adverse health effects.

Health significance can't be drawn from the observation that street level PM_{2.5} generally exceeded ambient community PM_{2.5}.

The rooftop community average exposure to PM_{2.5} is the product of diverse local emissions sources, some major and affecting wide areas, and some smaller and narrower. The presence of “hot spots” at ground level and rapid variation in exposure level suggests local sources. Abatement of these local sources would reduce exposure at the site, and also subtract from the overall community load. In this study, substantial excursions were observed with real time PM and BC monitoring equipment. Further observation could identify the specific activities associated with those excursions, and perhaps reveal abatement opportunities.

Further studies could be improved by three changes in methods. First, now that we have demonstrated the feasibility of gravimetric sampling for PM_{2.5} on quartz filters which permit simultaneous analysis for elemental and organic carbon, that method would be preferred to gravimetric on PVC filters as the major mode of study. The gravimetric and carbon combination yields information on variation of content of the PM_{2.5}, which could be helpful in identifying sources.

Second, higher volume portable pumps and impactors have recently become available. These would reduce necessary sampling time to 1/3, and would permit more reliable gravimetric sampling and shorter sampling periods.

Third, the design assumed that ground level samples would be substantially higher than those at elevation. Sites could be selected with more elevations in mind, to clarify the relationship between $PM_{2.5}$ and elemental carbon levels, and elevation.

Fourth, the drastic effect of humidity on Sidepak results, and the difficulties in standardization, suggest that future work must exploit these instruments for evaluating short term variations rather than extended sampling periods.

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