

Airborne Concentrations of PM_{2.5} and Diesel Exhaust Particles on Harlem Sidewalks: A Community-Based Pilot Study

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Residents of the dense urban core neighborhoods of New York City (NYC) have expressed increasing concern about the potential human health impacts of diesel vehicle emissions. We measured concentrations of particulate matter ≤ 2.5 μm in aerodynamic diameter (PM_{2.5}) and diesel exhaust particles (DEP) on sidewalks in Harlem, NYC, and tested whether spatial variations in concentrations were related to local diesel traffic density. Eight-hour (1000–1800 hr) air samples for PM_{2.5} and elemental carbon (EC) were collected for 5 days in July 1996 on sidewalks adjacent to four geographically distinct Harlem intersections. Samples were taken using portable monitors worn by study staff. Simultaneous traffic counts for diesel trucks, buses, cars, and pedestrians were carried out at each intersection on ≥ 2 of the 5 sampling days. Eight-hour diesel vehicle counts ranged from 61 to 2,467 across the four sites. Mean concentrations of PM_{2.5} exhibited only modest site-to-site variation (37–47 $\mu\text{g}/\text{m}^3$), reflecting the importance of broader regional sources of PM_{2.5}. In contrast, EC concentrations varied 4-fold across sites (from 1.5 to 6 $\mu\text{g}/\text{m}^3$), and were associated with bus and truck counts on adjacent streets and, at one site, with the presence of a bus depot. A high correlation ($r = 0.95$) was observed between EC concentrations measured analytically and a blackness measurement based on PM_{2.5} filter reflectance, suggesting the utility of the latter as a surrogate measure of DEP in future community-based studies. These results show that local diesel sources in Harlem create spatial variations in sidewalk concentrations of DEP. The study also demonstrates the feasibility of a new paradigm for community-based research involving full and active partnership between academic scientists and community-based organizations. **Key words:** diesel exhaust, Harlem, outdoor air pollution, PM_{2.5}, urban. *Environ Health Perspect* 108:213–218 (2000). [Online 21 January 2000]

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Residents of densely developed urban neighborhoods face a range of environmental risks both indoors and outdoors. Among the outdoor factors of greatest concern to residents of the Harlem neighborhood of New York City (NYC) is the complex mixture of toxic air pollutants emitted in and around the city by mobile sources (e.g., cars, trucks, and buses). Mobile source emissions are of special concern both because of their ubiquitous nature and because emissions occur at ground level in urban street canyons where human activity is greatest. The seemingly disproportionate concentration of diesel emission sources in underprivileged urban neighborhoods such as Harlem, and the potential impacts that diesel exhaust particles (DEPs) may have on human health, has in recent years led both to a community-based movement aimed at reducing diesel emissions and a concurrent scientific research agenda directed at understanding the relationships among sources, concentrations, exposures, and human health.

The human health effects of airborne particulate matter (PM) have been examined in numerous recent epidemiologic studies (1–6), several of which highlight the special health significance of particles ≤ 2.5 μm in

aerodynamic diameter (PM_{2.5}). PM_{2.5} particles are potentially more harmful than larger particles because they can reach deeper into the lower respiratory tract of the lungs. In addition, because they are products of fossil fuel combustion, PM_{2.5} often contains high concentrations of several toxic substances, including acid sulfates, soluble metals, and organic compounds such as polycyclic aromatic hydrocarbons.

DEPs are an important constituent of PM_{2.5} in NYC. DEP aerosols consist of chain aggregates of roughly spherical nuclei composed largely of elemental carbon (EC). DEPs have large surface areas, ranging from 30 to 100 m^2/g , on which a wide range of organic compounds are adsorbed (7). Nearly all DEPs fall within the PM_{2.5} size range, with mass median diameters ranging from 0.05 to 0.3 μm . Because diesel engines burn fuel more efficiently than conventional spark ignition gasoline engines, they offer better fuel economy. Nonetheless, diesel engines emit 10 times more particles per mile than conventional gasoline engines and 30–70 times more than engines equipped with catalytic converters (8).

Both the respirable size and the composition of DEPs raise concerns for human health

impacts of diesel exhaust exposure. There are few data on levels and patterns of human exposures to DEP in urban areas. Data relating spatial variations in source density to variations in ambient DEP concentrations in densely populated urban core neighborhoods are especially lacking. In the case of PM_{2.5}, there are minimal spatial variations within or between urban areas in the northeastern United States (9–11). This reflects the dominant influence of region-wide sulfate aerosols as major drivers of local PM_{2.5} concentrations, especially during the summer months. In contrast, measures of direct vehicle emissions such as nitrogen oxides and black smoke exhibit greater spatial variations, and these variations have been associated with local traffic sources (12–14). The emerging evidence suggests that DEPs and other components of PM_{2.5} for which significant local sources exist are likely to exhibit substantial spatial variability in concentrations within urban areas.

Urban sidewalks serve both as pathways for pedestrian movements and as areas of play and recreation for children of many ages. They also are an important locus for congregation and interaction among adults, including the elderly (15). These uses are especially prevalent in the urban core neighborhoods of NYC. Risks to children, the elderly, and other vulnerable groups from breathing diesel exhaust and other air pollutants on sidewalks are of special concern.

The present study is a part of an ongoing community-based research and outreach partnership between two academic centers at Columbia University in New York (the Center for Environmental Health in Northern Manhattan and the Harlem

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Center for Health Promotion and Disease Prevention) and a community-based organization [West Harlem Environmental Action, Inc. (WE-ACT)]. The study was designed to generate pilot data on temporal and spatial variations in sidewalk concentrations of $PM_{2.5}$ and EC at street level, and to relate these data to measures of diesel emissions on adjacent streets. In addition, the study represents an emerging model of community-based research in which researchers and community representatives work as full partners in the design, implementation, analysis, and reporting of the study.

Materials and Methods

Community background and site selection. Harlem is in the northern half of the borough of Manhattan in NYC (Figure 1) and is at the center of a large sprawling metropolitan region. In recent years NYC been out of compliance with the annual National Ambient Air Quality Standard for $PM \leq 10 \mu m$ in aerodynamic diameter ($50 \mu g/m^3$) (16). Residents of northern Manhattan are predominantly low-income persons of African American and/or Hispanic heritage. Air pollution from diesel exhaust has been of special concern to Harlem residents because of the large volume of diesel truck and bus traffic through the community, and because seven of the eight bus depots in Manhattan are located in northern Manhattan. Nearly 2,000 diesel buses are garaged in Harlem, often in close proximity to schools and housing complexes. Two of the major north/south avenues (Broadway and Amsterdam Avenue) that pass through Harlem are principal truck routes for moving goods in and out of Manhattan.

We selected the four monitoring sites for the present study from a total of eight sites in



Figure 1. Locations of four monitoring sites in the Harlem neighborhood of Northern Manhattan.

Harlem. In summer 1996, these sites were targeted, in response to community requests, for intensive PM monitoring by the New York City Region 2 office of the U.S. Environmental Protection Agency (EPA). All of the monitoring sites were selected jointly by community residents and by scientists from Columbia University and the EPA at community forums. Site selection was driven primarily by concerns about high traffic volumes and other diesel exhaust sources (e.g., bus depots). Additional criteria included the proximity of important receptor sites (e.g., schools, hospitals, and residential complexes) and the need for a control site in a location less impacted by diesel sources.

The four sites chosen for the study of sidewalk $PM_{2.5}$ and DEP concentrations were Amsterdam Avenue, the Manhattanville Bus Depot (bus depot), Harlem Hospital, and Edgecombe Avenue. Site 1 (Amsterdam Avenue) was on the northeast corner of 125th Street and Amsterdam Avenue, a busy intersection between two heavily traveled roadways in a residential/commercial neighborhood. Eight bus routes pass through this intersection. In addition, Amsterdam Avenue is a principal truck route for the delivery of goods in and out of Manhattan. Site 2 (bus depot) was on the south side of 133rd Street between Broadway and 12th Avenue. Although traffic volumes are low on 133rd Street, the Manhattanville Bus Depot, on the south side of the street, spans much of the block. The bus depot has ventilation ducts directed toward 133rd Street. Across the street to the north is a junior high school. One block west (upwind) is a major highway and a commuter rail line linking the northern suburbs with lower Manhattan. Site 3 (Harlem Hospital) was on the southwest corner of 135th Street and Lenox Avenue, a busy intersection in a residential/commercial neighborhood with fewer local diesel sources than sites 1 and 2. Adjacent to site 3 on the southwest corner of the intersection is an elementary school; Harlem Hospital and a subway entrance are located on the northeast corner. Site 4 (Edgecombe Avenue) was on the west side of Edgecombe Avenue between 141st and 142nd Streets. This control site was in a quiet residential neighborhood near several schools.

Particle concentration measurements. Monitoring and traffic counting was carried out jointly by staff from Columbia University, WE-ACT, and the University of Wageningen (Wageningen, The Netherlands). Each site was staffed by two to four persons who wore personal particle monitors and, on a subset of days, counted traffic. Although a scientific staff member was present at each site during all sampling events, much of the hands-on work was carried out by members of WE-ACT's Environmental Leadership Training

group (the Earth Crew), a group of 17 paid community interns 14–18 years of age. Before the start of sampling, scientific staff members assigned to each site were trained in the operation, calibration, and proper placement of the personal samplers by N.A.H. Janssen, an expert from the University of Wageningen. The trained scientific staff were responsible, in turn, for oversight of the sampling operations at each site, including the proper physical placement and use by the WE-ACT interns.

At each of the four sites, monitoring for $PM_{2.5}$ and EC was carried out between the hours of 1000 and 1800 on 5 weekdays in July 1996. We chose July because of the availability of summer interns and to avoid the heating season, when coal and oil furnaces emit EC. We chose to monitor on weekdays for consistency in a small study and for the measurement of typical commercial traffic volumes. The 5 monitoring days were scattered over a 13-day span.

Air monitors consisted of 4 L/min battery-operated personal sampling pumps (Gilliam model Gil-Air 5; Gilliam Instrument Corp., W. Caldwell, NJ) attached by flexible tubing to polyethylene filter sampling cartridges (University Research Glassware, Carrboro, NC). The cartridge had an inlet nozzle and a greased impactor plate, which eliminated particles $> 2.5 \mu m$ in aerodynamic diameter from the air stream before collection on the filter.

Pumps were worn at the waist using a belt clip or in a backpack, and the sample cartridge was clipped to the shirt collar. Samplers were worn by study staff, who sat on folding chairs on the sidewalk facing the flow of traffic. Two identical pump/cartridge sampling assemblies were operated simultaneously at each site (worn by separate individuals). One contained a preweighed Teflon filter for gravimetric $PM_{2.5}$ and reflectance analysis and the other contained a quartz fiber filter for EC analysis.

Flow rates were checked by scientific staff with precalibrated rotameters before and after each air sampling event. After sampling, staff members separated cartridges from the tubing and pumps. The cartridges were then capped and placed in resealable bags for hand transport to the laboratory at Columbia University. At the laboratory, the cartridges were disassembled and the filters were removed in a positive-pressure, particle-free hood by a laboratory technician. Teflon and quartz filters were placed in individual sterile petri dishes and shipped to external laboratories for $PM_{2.5}$, EC, and reflectance analyses.

Gravimetric $PM_{2.5}$ analysis procedures. Teflon filters were pre- and postweighed after 24 hr temperature and humidity equilibration

in the laboratories of P. Koutrakis at the Harvard School of Public Health (Boston, MA). A microbalance connected via a serial data port to a personal computer programmed to track mass and tare was used for weighing. In every batch of 10 samples, the zero, span, and linearity of the balance was checked via calibration weights and one filter was randomly chosen for quality assurance purposes and was weighed by a different individual. PM_{2.5} data were expressed in micrograms per cubic meter.

EC analysis. The quartz filters were analyzed for EC by Sunset Laboratory, Inc. (Forest Grove, OR) according to the method of Birch and Cary (17). The sample filter was heated in an oxygen-free helium atmosphere to first remove and measure all organic carbon and then to oxidize and measure the remaining EC. After all of the carbon was oxidized from the sample, a known volume and concentration of methane was injected into the sample oven, thus calibrating each sample to a known quantity of carbon. Based on the flame ionization detector response and laser transmission data, the quantities of organic carbon and EC were calculated for each sample. EC data were expressed in micrograms per cubic meter.

Reflectance analysis. After postweighing to determine PM_{2.5}, we sent the Teflon filters to the University of Wageningen for reflectance analysis. The blackness of the PM_{2.5} filter deposit was measured using a reflectometer (EEL model 43; Diffusion Systems Ltd., London). Blank filters were used to set reflection to 100%. The reflectance of each sampled filter was measured 3 times to document homogeneity. The absorption coefficient (abs coeff) was calculated using the following formula (International Organization for Standardization, Geneva, Switzerland; ISO9835):

$$\text{abs coeff (per meter)} = 0.5A \times \ln(\text{RO}/\text{RF})/V,$$

where A = loaded filter area; RO = reflection of field blanks (in percent); RF = reflection of sampled filters (in percent); and V = sampled volume of air (in cubic meters). We used the average of three readings to calculate the absorption coefficient, which was then multiplied by 10^5 to make the readings more comprehensible. The reflectance data

were expressed as absorption coefficient of the sample filter.

Traffic counting. Traffic was counted by project staff for an 8-hr period at each site on at least 2 air monitoring days using traffic-counting boards. Each counting board was equipped with four manually operated digital counters to enable simultaneous counts of diesel buses, diesel trucks, cars, and pedestrians. Counting was carried out in 15-min active periods alternating with 15-min rest periods from 1000 to 1600 hr and in continuous 15-min blocks from 1600 to 1800 hr. The two study staff assigned to each traffic-counting location took turns counting for the 15-min blocks. Total 8-hr counts were estimated by summing the 1600–1800 hr counts with twice the 1000–1600 hr counts. These daily counts were then averaged across days at each site.

Staff members were trained in traffic-counting methods by a traffic engineer. During two training sessions at a busy intersection in Harlem, staff members were instructed in the use of counting boards, the proper traffic lanes and directions to be counted, and the identification of heavy-duty diesel vehicles (trucks and buses) as distinct from cars and light-duty trucks. We assumed that all buses were diesel powered (during the study period, all NYC buses used diesel fuel). All trucks larger than pickup trucks, including delivery trucks and 18-wheel tractor-trailer trucks, were counted as diesel trucks. Vans and sport utility vehicles were counted as cars.

At the two 4-way traffic intersection (sites 1 and 3), two teams of Earth Crew members sat on diagonal corners to count traffic in all directions. One team of two individuals counted traffic moving from west to east and north to south; the other team counted traffic from east to west and south to north. Counting at sites 1 and 3 occurred on 3 separate days. At sites 2 and 4, which were mid block rather than at intersections, a single team of counters counted traffic in both directions. Counting at sites 2 and 4 occurred on 2 separate days.

No direct validation of identified traffic counts (i.e., the type of vehicle) was available for the study. Total visual traffic counts (buses + trucks + cars) were validated using an automatic traffic counter for 3 hr on

1 day at sites 2 (bus depot), 3 (Harlem Hospital), and 4 (Edgecombe Avenue). For automated counting, pneumatic tubes were laid across the road and were connected to an automatic data logger.

Statistical analysis. Simple descriptive statistics were tabulated and plotted to examine the spatial and temporal variations in street-level PM_{2.5} and EC. To assess the relative magnitude of spatial and temporal variations in PM_{2.5} and DEP concentrations, data were analyzed by two-way analysis of variance (ANOVA) with site and day as the two main effects.

Results

Cumulative 8-hr traffic counts for trucks, buses, cars, and pedestrians at the four sites are summarized in Table 1 and plotted graphically in Figure 2. Average total diesel vehicle counts (trucks + buses) varied markedly across intersections, from lows of 61 and 102 diesel vehicles at sites 4 (Edgecombe Avenue) and site 2 (bus depot), respectively, to 2,467 vehicles at site 1 (Amsterdam Avenue). An intermediate level (927 vehicles) was observed at site 3 (Harlem Hospital). Truck and bus counts correlated closely with one another across sites (Figure 2); however, truck counts always exceeded bus counts. Together, diesel trucks and buses represented between 4 and 12% of all motor vehicles observed at the four intersections. In addition, car and pedestrian counts tended to correlate with diesel counts, demonstrating that locations with more vehicle traffic of all kinds also had more exposed pedestrians. To validate the traffic counts, automated total vehicle counters were installed for 3 hr at each of three sites. The correlation between the hourly counts by the two methods was

Table 1. Mean and range across days of daily 8-hr weekday traffic counts at four sites in Harlem.

Site, location	Days (n)	Diesel trucks	Buses	Cars	Pedestrians
1, Amsterdam Avenue and 125th Street (heavy traffic)	3	1,403 ± 34	1,064 ± 67	18,375 ± 1,473	11,158 ± 1,752
2, West 133rd Street (bus depot)	2	75 ± 1	28 ± 4	2,302 ± 112	421 ± 120
3, East 135th Street (Harlem Hospital)	3	526 ± 80	401 ± 43	14,229 ± 225	16,760 ± 2,620
4, Edgecombe Avenue (control)	2	47 ± 4	14 ± 0	1,411 ± 190	1,320 ± 240

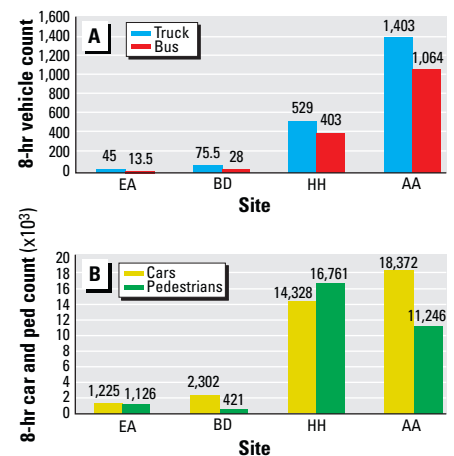


Figure 2. Average 1000–1800 hr weekday traffic counts at four sites in Harlem: (A) heavy-duty trucks and buses, (B) cars and pedestrians (ped). Abbreviations: AA, Amsterdam Avenue; BD, bus depot; EA, Edgecombe Avenue; HH, Harlem Hospital.

0.995. The percent differences between counts were within ± 5% for 8 of 9 hr. For the one outlier, the visual counts were 16% high.

Table 2 displays 8-hr concentrations of PM_{2.5} and EC collected at each site on each day of sampling, as well as averages by site and by day. Average PM_{2.5} concentrations exhibited modest variations across sites, ranging from 36.6 and 38.6 µg/m³ at sites 3 (Harlem Hospital) and 4 (Edgecombe Avenue), respectively, to 45.8 and 47.1 µg/m³ at sites 1 (Amsterdam Avenue) and 2 (bus depot). There was little association between PM_{2.5} concentrations and proximity to local diesel traffic (Figure 3). Variations across days in mean PM_{2.5} concentrations were more pronounced than were spatial variations; daily means ranged from 26.5 µg/m³ on day 5 to 53.5 µg/m³ on day 4. A two-way ANOVA showed that 73% of the variation in PM_{2.5} concentrations was explained by the day effect (i.e., temporal variations), whereas only 14% was explained by the site effect (i.e., geographic variations).

In contrast to PM_{2.5}, a strong spatial gradient was observed across sites in EC concentrations, reflecting the importance of local diesel traffic sources (Table 2). There was a 4-fold difference in mean EC concentrations (1.5–6.2 µg/m³) between the two sites that had the largest contrast in diesel traffic counts (sites 1 and 4). This is shown graphically in Figure 4, which plots mean EC concentrations against total diesel vehicle counts at the four intersections. One outlier on this plot is site 2 (bus depot), which exhibited elevated EC (and PM_{2.5}) concentrations, yet had low traffic counts. This is most likely due to the impact of the adjacent Manhattanville Bus Depot (with ventilation ducts facing towards the site) as well as the West Side Highway, which is one block to the west. Thus, although local traffic on 133rd Street itself was light during the study, the air at the site appeared to be heavily impacted by local diesel and other mobile source emissions.

Variations across days in EC concentrations were much less pronounced than were spatial variations (Table 2). This contrasts

with the pattern observed for PM_{2.5}, where temporal variations were dominant. In a two-way ANOVA (site × day), site-to-site variations explained 76% of the total variation in EC concentrations (i.e., R² = 0.76) and were highly statistically significant. In contrast, variations across days explained only 6% of the total variations in EC and were not significant. The EC:PM_{2.5} ratio (i.e., the fraction of PM_{2.5} represented by EC) varied from 0.064 to 0.11 across the 5 days.

The Teflon filters used to measure PM_{2.5} concentrations were subsequently analyzed by reflectance to determine the absorption coefficient of the particle deposit, a potential surrogate for EC content of the sample. EC analyses were performed on quartz fiber filter samples collected beside the Teflon PM_{2.5} samples using identical sampling equipment for all sampling events. The scatterplot of EC versus absorption coefficient (× 100) for the 20 paired samples (four sites for each of 5 days) indicates a close correspondence between the two measures (Figure 5), with a correlation of 0.95. The regression of EC on absorption coefficient (× 100) yielded a slope of 0.83 µg/m² and a nonsignificant y-intercept. There was no evidence that the relationship varied by site. These results suggest that absorption coefficient can be a surrogate for fine particle EC concentrations in NYC during the summer months.

Discussion

This study demonstrated consistent spatial variations in sidewalk DEP concentrations on the sidewalks of Harlem. These variations appeared to be related to the magnitude of local diesel sources. Spatial variations in sidewalk PM_{2.5}, of which DEP forms a part, exhibited less pronounced spatial gradients, due presumably to the influence of regional sulfate aerosols. The observation of spatial variations in DEP exposures implies that health risks associated with DEPs may also vary across the community as a function of diesel source density.

Although only a small number of sites and days were monitored in this pilot study, these preliminary results suggest that DEP

concentrations are influenced both by vehicular traffic (of which diesel vehicles are assumed to be of special importance) and by point sources such as bus depots, where large numbers of diesel vehicles congregate. These basic patterns reinforce concerns that have been raised by community residents about the predominance of both diesel traffic and bus depots in Harlem and other disadvantaged neighborhoods of NYC.

The average concentrations of EC ranged from 1.5 to 6.2 µg/m³ across the four sites studied; levels that are typical of those reported in other urban areas. We know of no previous studies of sidewalk-level EC concentrations. Annual average outdoor EC concentrations ranged from 3 to 5 µg/m³ across 10 monitoring sites in the Los Angeles, California, basin in 1982 (18). Daily 24-hr average values at the Lenox site in the Los Angeles study (18) ranged from approximately 1 to 17 µg/m³, with late fall and early winter concentrations far exceeding those measured in other seasons. Data collected in 1987 as part of the Southern California Air Quality Study (19) indicated

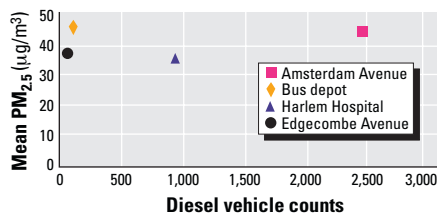


Figure 3. Scatterplot of mean PM_{2.5} concentrations and diesel vehicle counts (heavy duty trucks and buses) at four monitoring sites in Harlem.

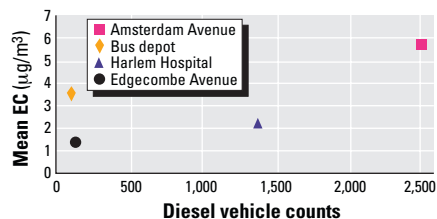


Figure 4. Scatterplot of mean EC concentrations and diesel vehicle counts (heavy duty trucks and buses) at four monitoring sites in Harlem.

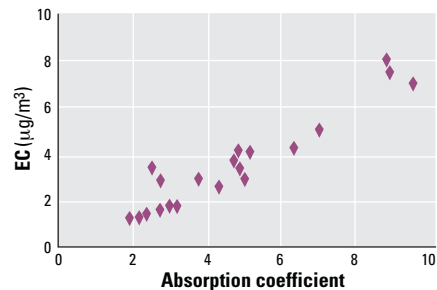


Figure 5. Correlation between co-located EC concentrations, measured on quartz fiber filters, and absorption coefficient, measured on PM_{2.5} filters.

Table 2. Eight-hour average (1000–1800 hr) PM_{2.5} and elemental carbon concentrations (µg/m³) at four Harlem sites.

Site no.	Pollutant	July 17	July 18	July 24	July 25	July 29	Mean ± SD
1	PM _{2.5}	40.4	51.7	46.3	58.3	32.0	45.7 ± 10.1
	EC	7.9	7.6	4.9	7.0	3.6	6.2 ± 1.9
2	PM _{2.5}	33.0	47.4	56.2	69.1	29.6	47.1 ± 16.4
	EC	2.8	4.0	4.2	3.3	4.0	3.7 ± 0.6
3	PM _{2.5}	30.5	37.6	49.7	43.1	22.1	36.6 ± 10.8
	EC	3.3	2.7	2.8	1.6	1.3	2.3 ± 0.9
4	PM _{2.5}	33.6	43.4	50.6	43.3	22.4	38.7 ± 10.9
	EC	1.1	1.4	2.4	1.6	1.1	1.5 ± 0.5
Mean ± SD	PM _{2.5}	34.4 ± 4.2	45.0 ± 6.0	50.7 ± 4.1	53.4 ± 12.6	26.5 ± 5.0	42.0
	EC	3.8	3.9	3.6	3.4	2.5	3.4
	–	± 2.9	± 2.7	± 1.2	± 2.5	± 1.5	–

that average EC concentrations in the summer and fall ranged from 0.10 $\mu\text{g}/\text{m}^3$, at a remote site on San Nicholas Island, to 2.6 $\mu\text{g}/\text{m}^3$ in Azusa, a densely populated community on the northeastern downwind portion of the basin. The maximum daily EC concentration measured in 1987 in Los Angeles was 5.4 $\mu\text{g}/\text{m}^3$ (19). Thus, EC concentrations observed in the present study were comparable to these levels observed in the 1980s in Los Angeles.

Spatial variations in sidewalk $\text{PM}_{2.5}$ exposures were less pronounced and less associated with vehicular traffic than were EC concentrations in the present study. Previous studies, have shown that local $\text{PM}_{2.5}$ concentrations in northeastern U.S. cities are dominated by regional sulfate particles during the summer months (9–11). The contributions of local fine particle sources such as diesel exhaust are difficult to discern against the high background levels of regional sulfate aerosol when using a composite particulate metric such as $\text{PM}_{2.5}$. Because EC represents only a portion of the total mass of particles present in diesel exhaust, it is not possible from our data to directly estimate the fraction of $\text{PM}_{2.5}$ that was due to DEP. Cass and Gray (20) estimated that EC represented 59.5% of the mass of DEPs observed in the Los Angeles atmosphere. Assuming that the mixes of diesel sources are roughly comparable in the two cities, we can apply this correction factor to the mean EC concentration observed in the present study to calculate the average total mass of DEP. This exercise yields an estimated average total DEP mass of 5.7 $\mu\text{g}/\text{m}^3$, which is 13.6% of the average $\text{PM}_{2.5}$ mass that we observed.

To characterize patterns of exposure to locally generated particles in urban areas, it is critical to measure one or more components of fine particles that are specific to the source in question. In the case of diesel exhaust, EC and filter reflectance appear to represent useful surrogate measures of DEP exposure. It has been estimated that the majority of EC emissions in Los Angeles originate from diesel engines (18). Several previous studies have reported strong correlations between EC concentrations and diesel vehicle traffic (21,22). This is likely to hold true for NYC and other northeastern United States cities during the summer months, when no combustion of oil or coal for space heating occurs. The strong association between EC concentrations and local diesel sources in our study provides support for this idea.

Studies on the health effects of diesel exhaust have until recently focused primarily on cancer outcomes (23). However, in recent years, attention has begun to focus on understanding the noncancer respiratory effects of DEPs and their possible role in the

acute or chronic health effects of airborne PM. There is emerging experimental evidence of irritant and/or immunologic effects of diesel exhaust on the respiratory system (24–29). In addition, recent epidemiologic studies have demonstrated associations between residential proximity to traffic sources and adverse respiratory outcomes, including asthma hospitalizations among children (30), increased respiratory symptoms (31–33), and diminished lung function (12,13). Exposure assessment in these studies has included self-reported traffic volumes on residential streets (e.g., high, medium, or low), quantitative data on traffic volumes collected by local agencies, and, occasionally, air monitoring data at selected locations. Because of the limitations of the exposure data, it is not always possible to uniquely implicate diesel exhaust as distinct from other forms of motor vehicle exhaust in the observed respiratory health effects. However, in one recent study in The Netherlands (13), chronic respiratory symptoms and lung function decrements in children were associated with local truck traffic density and with black smoke concentrations in schools, whereas no such associations were observed for car traffic, suggesting a specific effect of diesel exhaust. In addition, recent experimental studies (24–29) highlight the role of DEPs in enhancing inflammatory and allergic responses in the respiratory system.

NYC is one of four metropolitan areas that lead the United States in an annual increase of asthma mortality among individuals 5–34 years of age (34). An investigation of small area variations in asthma hospitalizations in NYC revealed that several sections of Harlem are among those with the highest rates (35). The possible role of diesel exhaust in these alarming asthma statistics has been a prominent concern of Harlem residents in recent years. The present study demonstrated spatial variations in diesel exhaust exposures within Harlem, but did not address whether exposures in Harlem exceeded those in other areas in NYC or elsewhere, nor did it address whether the observed variations in Harlem were associated with variations in asthma rates.

An interesting result of this study was the high degree of correlation between EC concentrations measured analytically on quartz fiber filters and the simple reflectance-based absorption coefficient measurements of the Teflon filters used for $\text{PM}_{2.5}$ analysis ($r = 0.95$) (Figure 5). These results suggest that absorption coefficient may be a surrogate for fine particle EC concentrations in NYC during the summer months. A similarly high correlation of 0.96 was found between EC and black smoke in a recent comparison study conducted in Berlin (36).

In addition to providing new scientific data on patterns of exposure to DEPs in an urban setting, the present study also demonstrated the feasibility of an emerging model of community-based research that addresses environmental health problems in underprivileged communities. In this study, researchers and community representatives worked as full partners in the design, implementation, analysis, and reporting of the data. The study also provided a mechanism for training young people from the community in research methods applied to environmental health problems. It is hoped that this model for community-based research will find application in other settings where there is a natural intersection between community health concerns and public health research needs.

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