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Assessment of Carbonaceous $PM_{2.5}$ for New York and the Region

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Assessment of Carbonaceous $PM_{2.5}$ for New York and the Region

Executive Summary

This report presents a comprehensive assessment of the carbonaceous fraction of ambient fine particulate matter ($PM_{2.5}$) in New York State. Carbonaceous components comprise a significant fraction of ambient levels of $PM_{2.5}$ in many areas in the Northeast, and they may play a critical role in observed adverse human health effects associated with $PM_{2.5}$ exposure. In order to design future policies based on sound scientific and technical knowledge that will reduce carbonaceous $PM_{2.5}$ levels in New York, this project synthesized available and emerging information in three key areas: (1) atmospheric science and emission sources, (2) human health effects, and (3) control technologies and strategies.

In collaboration with its Project Advisory Committee (PAC), NESCAUM staff developed five central questions listed below to help guide the project's overall research and assessment effort. Central findings for each question follow.

1. **DOES CARBONACEOUS PM2.5 CONTRIBUTE SIGNIFICANTLY TO HIGH LEVELS OF AMBIENT $PM_{2.5}$ IN NEW YORK STATE?**

2. **WHAT PROPORTION OF CARBONACEOUS $PM_{2.5}$ PRESENT IN NEW YORK IS DERIVED FROM IN-STATE SOURCES?**

3. **DOES CARBONACEOUS $PM_{2.5}$ PRESENT A PUBLIC HEALTH CONCERN?**

4. **WHAT ARE THE TECHNICAL OPTIONS FOR REDUCING EMISSIONS OF CARBONACEOUS $PM_{2.5}$ FROM SOURCES?**

5. **WHAT ARE THE NEAR-TERM STRATEGIES FOR REDUCING EMISSIONS OF CARBONACEOUS $PM_{2.5}$ FOR NEW YORK AND THE REGION?**

Questions 1 & 2:

AMBIENT $PM_{2.5}$ CARBONACEOUS AEROSOL LEVELS AND IN-STATE CONTRIBUTION

In New York State, ambient measurements of $PM_{2.5}$ indicate that carbonaceous aerosols represent a sizeable fraction of the $PM_{2.5}$ mass, and much of that aerosol comes from in-state sources.

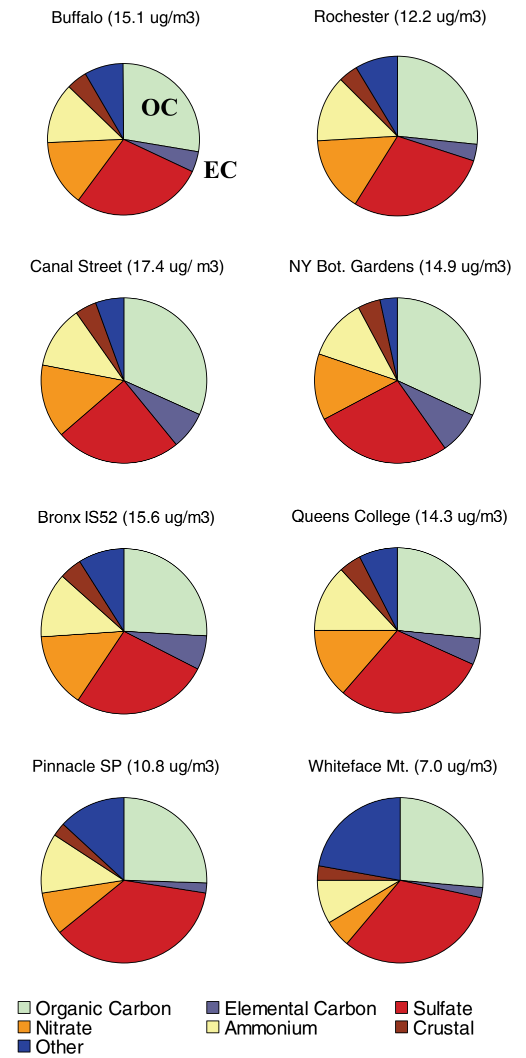


Figure ES-1. Annual Average Fine Particle Species Mass at New York State Speciation Trends Network Sites (data collected 2/00 through 11/05).

Analysis reveals appreciable spatial and temporal variations in measured carbon aerosols. On an annual basis, organic carbon (OC) constitutes between a fourth and a third of the ambient $PM_{2.5}$ mass, with elemental carbon (EC) contributing as much as 8% of total $PM_{2.5}$ at urban sites (Figure ES-1). Seasonally, contributions range a bit wider, while individual 24-hour measurements can be nearly all carbonaceous. OC levels peak in summertime across the State, driven by increased photochemical activity that also results in increased ozone levels. EC levels, however, tend to be flat with some evidence of wintertime increases at urban sites with abundant local motor vehicle sources.

On average, urban areas experience higher levels of carbon aerosols than more remote regions. For both OC and EC, significant gradients exist across the metropolitan areas. Comparing OC measurements across New York City, the maximum seasonally averaged OC concentrations can be 50% greater than the minimum measured levels. Seasonally averaged EC concentrations at the site with maximum levels can be nearly twice as high as at the site with the minimum. These intra-urban differences offer a lower bound estimate of highly local impacts of carbon aerosol emissions. Local EC contributions reach as high as 85% of monitored EC in urban areas based on regional background levels. Local urban OC contributions generally do not exceed two-thirds of the ambient urban OC levels. The more regional nature of OC is due, in part, to its being both a primary pollutant (e.g., directly emitted) and a secondary pollutant (one formed in the atmosphere), as well as the large diversity of contributing source categories. Uncertainties associated with the relative importance of primary and secondary contributions to OC complicate the ability to accurately describe the emission sources responsible for ambient OC.

QUESTION 3:

PUBLIC HEALTH CONCERNS ASSOCIATED WITH CARBONACEOUS $PM_{2.5}$

A growing number of health studies focusing on the carbonaceous fraction of $PM_{2.5}$ demonstrate that exposure to carbonaceous $PM_{2.5}$ presents a public health concern. Toxicological, clinical, and epidemiological research has, to varying degrees, investigated the potential role of individual carbonaceous constituents, carbonaceous mixtures and surrogates, emissions sources, and different particle size fractions that are rich in carbonaceous $PM_{2.5}$. While health effect studies suggest the toxicity of carbonaceous $PM_{2.5}$, they do not point conclusively to which of its many characteristics are most responsible for eliciting adverse effects. Nor do they rule out other, non-carbonaceous components of $PM_{2.5}$. It is likely that different agents may contribute to adverse health outcomes, and fine carbonaceous particulates may be a significant contributor to some or all of these.

The pervasiveness of carbon-rich combustion sources represents an important exposure risk to populations in New York State. For vehicular source emissions, some studies of populations residing near roadways in major cities find increased risks for a variety of adverse health effects, including respiratory and cardiac effects. Moreover, recent studies in urban settings have shown that “hot-spot” exposures can take place at micro-environmental scales. These include studies near highway corridors, airports, and bus, marine and railroad terminals; studies inside subways, buses, cars, ferries, and trains; and studies close to small nonroad internal combustion engines, such as lawn equipment. A growing number of exposure assessment and measurement studies in Europe, North America, and the New York City area indicate that urban populations can be exposed to high levels of mobile source emissions. Few comparable exposure assessments of rural populations, however, have been undertaken. A limited number of studies have begun to evaluate the effect of mobile source emissions on health in New York State populations.

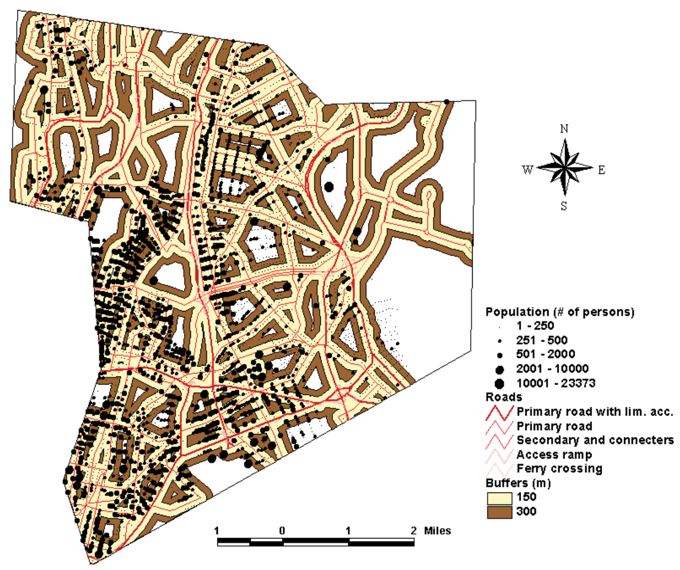


Figure ES-2. Census block-level population living within 150m and 300m of major roads in Bronx County, NY

For this report, a screening-level analysis of residential population proximity to, and traffic volume on, major roads in selected New York State counties was conducted. The analysis demonstrated that a large number of residents in rural, suburban, and urban (Figure ES-2) counties live within a distance of 150 and 300 meters of highly traveled major roads. The correspondence between high traffic volume—as determined by vehicle miles traveled and average annual daily traffic counts—and densely populated neighborhoods indicates that elevated exposure to mobile sources may occur in any size community, including cities such as Albany and Buffalo, as well as along busy roadways in more rural areas.

Residential wood combustion in New York represents another important source category for carbonaceous aerosols based on the emissions inventory, especially in rural locations. Although a large body of health studies indicates that wood smoke inhalation presents a health risk to exposed populations, wood combustion exposure assessment, measurement, and health studies conducted within New York State and in the Northeast region are limited. Studies of other areas that have large wood combustion contributions, however, provide evidence that wood smoke is a potential exposure concern in New York State. Residential wood combustion emissions may pose a seasonal exposure risk to populations, especially during wintertime in areas where terrain and meteorology contribute to poor dispersion of pollutants under conditions that are common in many parts of the Northeast.

Questions 4 & 5:

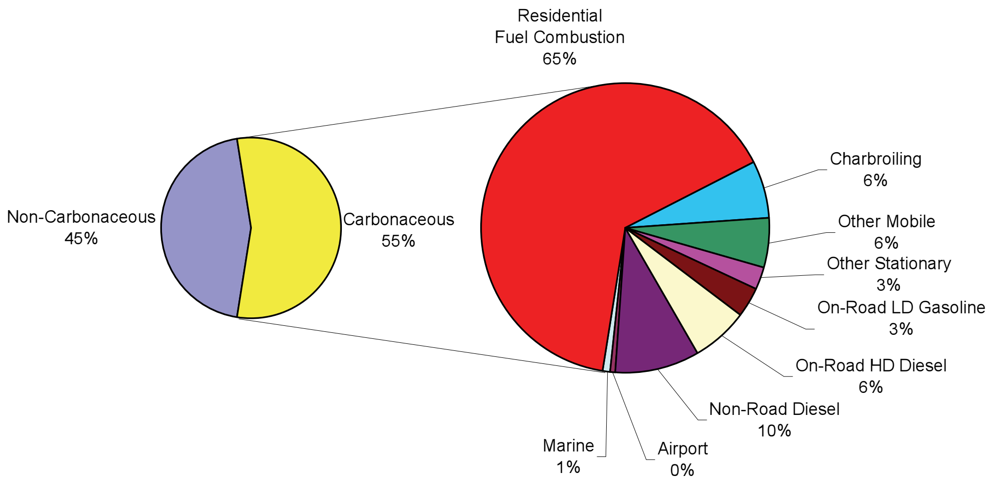
TECHNICAL OPTIONS AND NEAR-TERM STRATEGIES FOR REDUCING EMISSIONS OF CARBONACEOUS $PM_{2.5}$ IN NEW YORK STATE AND THE REGION

Many source categories contribute to the overall emissions of primary carbonaceous $PM_{2.5}$ emissions in the State. The relative proportions, however, vary substantially in urban, suburban, and rural areas. This report estimates emissions from seven major source sectors including five mobile source sectors (nonroad equipment, heavy-duty trucks, light-duty vehicles, airports and marine ports) and two stationary source sectors (residential fuel combustion and commercial cooking), and then evaluates specific control measures considered most promising. The sectors were chosen based on their contributions to the inventory of carbonaceous $PM_{2.5}$ emissions.

Figure ES-3 shows that the carbon fraction is 55% of the primary PM2.5 emissions in New York State. Residential fuel (almost all wood) combustion, diesel sources, and commercial cooking are major contributors. Relative contributions of source sectors, however, are quite different in the urban New York nonattainment area (NAA) as compared to rural areas. For example, whereas more than half of carbonaceous PM2.5 in New York NAA is from onroad and nonroad mobile sources, almost all (>90%) of carbonaceous $PM_{2.5}$ emissions in rural counties are attributed to residential wood combustion. These statewide differences have implications for optimum selection of strategies to reduce emissions.

The technical options and long-term strategies considered in this report cover a range of geographic scales. Local, statewide or regional controls are assessed for organic carbon given its important local and regional-transport components. Elemental carbon emissions in theory represent a more local issue. In practice, however, mobile sources such as construction equipment, heavy-duty trucks, and light-duty vehicles move freely into and out of urban areas. In consideration of the physical movement of sources and the atmospheric transport of source emissions, controls are reviewed for all relevant spatial scales.

Figure ES-3. Total New York State $PM_{2.5}$ and Carbonaceous Detail (2002).



The combined measures evaluated in this report have the potential to reduce carbonaceous $PM_{2.5}$ emissions in the New York NAA by approximately 9,000 tons each year (tpy), equal to approximately one-third of current carbonaceous $PM_{2.5}$ emissions. Given the complexity of atmospheric formation processes of secondary organic aerosols, the emissions of volatile organic compounds (VOCs) from the seven sectors evaluated in this report are not explicitly addressed. Sector selection, however, would not likely differ had detailed information on VOCs been included. Major reductions in the ambient secondary organic fraction of $PM_{2.5}$ could be realized through reductions in motor vehicle and other gasoline engine hydrocarbon emissions. A suite of additional options is outlined in the body of the report.

According to inventory data presented in this report, nonroad engines are the largest source of carbonaceous $PM_{2.5}$ (24%) in the New York NAA. Policy options to achieve reductions from this sector could include the adoption of retrofit requirements similar to those that the California Air Resources Board (CARB) finalized in August of 2007 and would result in a reduction of approximately 1000 tpy of carbonaceous $PM_{2.5}$. To reduce emissions from locomotives, New York State could consider developing a loan fund for installation of anti-idling devices for railroad switchers and locomotives.

Residential fuel combustion represents the next largest $PM_{2.5}$ source in the New York NAA at 19%, with a much greater relative contribution in the rest of the State. A strategy to attain the National Ambient Air Quality Standards (NAAQS) and reduce public exposure to $PM_{2.5}$ should address emissions from this source category. Major options include requiring cleaner-burning wood for fireplaces, establishing controls on outdoor wood-fired boiler emissions, and implementing residential woodstove change-out programs. Together these programs could reduce carbonaceous $PM_{2.5}$ emissions by 2,000 to 3,000 tpy. Extending these programs statewide would produce substantially greater benefit.

Fine particulates derived from charbroiling (largely meat grilling) comprise 18% of the carbonaceous $PM_{2.5}$ emissions in the New York NAA. Approximately 10% of the total comes from chain-driven charbroilers, and 74% from under-fired charbroilers. If restaurants that use chain-driven charbroilers were required to retrofit their equipment with catalytic oxidizers, a reduction of approximately 250 tpy of carbonaceous $PM_{2.5}$ could be realized. The existing rules in the Los Angeles area could be used as a model. The State could also consider a requirement to retrofit under-fired charbroilers with pollution control technologies, which could reduce emissions by an additional 3,000 tpy.

Another important combined category, light- and heavy-duty vehicle emissions, accounts for 20% of New York NAA carbonaceous $PM_{2.5}$ emissions. These emissions exclude road dust, a significant source of PM, and may lead to an underestimation of emissions from this source category. A number of recommendations stand out for heavy-duty vehicles. Approximately 75% of heavy-duty truck $PM_{2.5}$ emissions are from Class-8 trucks and school buses, combined. Retrofitting vehicles with diesel particulate filters would reduce carbonaceous PM2.5 by 1,500 tpy—assuming a high compliance rate. Several local laws in New York as well as the New York State Diesel Emission Reduction Act require retrofitting of vehicles owned by or on contract to the State, municipalities, or counties. County and municipality retrofit requirements could be expanded to other municipalities or counties in the State. CARB's truck retrofit regulations and New Jersey, Connecticut, and Rhode Island's school bus retrofit requirement provide models for privately owned vehicles and for school buses. Last, adopting a requirement similar to California's truck-refrigeration-unit regulation in New York State could significantly reduce carbonaceous $PM_{2.5}$ from this source.

For light-duty vehicles, the State could consider encouraging replacement of older (pre-1997) vehicles with newer vehicles. Older vehicles emit half of passenger-car $PM_{2.5}$ emissions. California's Voluntary Accelerated Vehicle Retirement initiative could provide a model for such a program. Improved maintenance is another potential approach to reduce vehicle $PM_{2.5}$. Programs in California and Spokane, Washington could provide models for New York State. Both early retirement and improved maintenance would address emissions of primary carbonaceous $PM_{2.5}$, as well as hydrocarbons, and their associated secondary $PM_{2.5}$ production potential. Adoption of congestion pricing -currently being considered by New York City and State - could reduce light-duty vehicle exhaust $PM_{2.5}$ emissions by approximately 15% in addition to emissions associated with brake, tire, road wear, and road dust.

Mobile sources operating at airports and marine ports emit approximately 5% of carbonaceous $PM_{2.5}$ in the New York NAA. One approach to reduce emissions would be to require electrification or a Best Available Control Technology (BACT) retrofit of ground service equipment, using the CARB Ground Service Equipment regulation as a model. Two other CARB rules require emissions reductions from harbor craft and cargo handling equipment and could be adopted by New York State. These programs taken together could eliminate approximately 300 tpy of carbonaceous $PM_{2.5}$. The strategies provide a suite of options from which policy makers may choose. They do not target a specific level of $PM_{2.5}$ reduction.

Analysis of measurement and emissions data presented in this report show that substantial sources of carbonaceous $PM_{2.5}$ exist in New York and they contribute to the overall $PM_{2.5}$ concentrations. The strategies described in the report, if implemented, would reduce overall carbonaceous emissions significantly in New York. They would reduce exposure to $PM_{2.5}$ and would assist the State in meeting federal air quality standards. In addition to considering implementation of the above strategies, policy makers might place a high priority on reducing $PM_{2.5}$ exposure from mobile sources that carry passengers.

The emission control strategies recommended here rely on current information on emissions inventories, ambient measurements, and health effect studies. Although a considerable body of knowledge exists, substantial gaps remain. Further research should be conducted to identify the relative toxicity of specific $PM_{2.5}$ components or combinations of components, and other parameters beyond particle mass such as particle size (including ultrafine particles), surface area, or number. Laboratory and in situ studies of atmospheric chemistry and gas-particle partitioning behavior should continue. Applications of the emerging real-time analytical instrumentation will provide key information that should be rapidly incorporated into next-generation air-quality models, which will improve their ability to assess $PM_{2.5}$ carbon-based control strategies.

Enhancements to current emissions inventories are required to improve assessments in the future. These inventories serve multiple needs of the air quality and public health communities, both as a direct indicator for source importance and as a resource for modeling studies. Inventories often lack specificity and accuracy, especially with respect to elemental and organic carbon components. They fail to characterize fully an emission source's magnitude, temporal variation, and chemical composition, in part because they were not constructed to provide that data or collection of such data represents a high hurdle. In addition, demonstration projects are needed to assess the real-world reductions that can be achieved with various control strategies.

Expanded spatial and temporal ambient measurements will also greatly improve understanding of the atmospheric behavior of carbonaceous $PM_{2.5}$ and its health implications. Current monitoring networks may not adequately represent total population exposure, and may not therefore be a good predictor of population risk. Daily (24-hour) and annual-averaged ambient air quality data collected at central-site locations for regulatory compliance in rural and urban areas may not reflect real and potentially meaningful population exposures to $PM_{2.5}$ sources rich in carbonaceous material. Unfortunately, the current regulatory system suffers from a lack of data. Indications of health effects exist, but the measurements are too sparse in time and space to characterize them properly; yet funding for measurements will not materialize until the true nature of the health effects is known and can justify the expenditure.

This report synthesizes current understanding of sources of fine particulate carbon pollution, atmospheric processes, analytical methods, and health effects. It describes current emissions inventories, including how they need to be improved. It reviews the control technologies currently available and suggests which of those are cost-effective for reducing carbonaceous $PM_{2.5}$. The project's findings should benefit policymaking efforts to improve ambient air quality that will bring social benefits in the form of improved health for residents throughout New York State.

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