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STATEMENT

Synopsis of Research Report 173

Detection and Characterization of Nanoparticles from Motor Vehicles

INTRODUCTION

Ambient nanoparticles, particularly those ≤ 100 nm in diameter, are an important focus of research on the health effects of air pollution. Scientists have hypothesized that these particles may be more toxic than particulate matter ≤ 2.5 µm in aerodynamic diameter because of their physical characteristics and composition. To better identify human exposures and potential health effects associated with nanoparticles, a clearer understanding is needed of sources, atmospheric transport and chemical reactions, concentrations, and composition at the point of exposure.

Earlier research has identified motor vehicle traffic as an important source of nanoparticles. However, little is known about the formation, growth, and change in composition of particles within 100 m of a roadway. Previously, Dr. Murray V. Johnston and colleagues developed an experimental instrument, the nano aerosol mass spectrometer (NAMS), to study individual nanoparticles (< 30 nm) and analyze their major chemical components continuously. For the current investigation, they proposed to study nanoparticles near a major roadway intersection, to test and improve the instrument's performance in a real-world setting, and to assess whether it could aid in identifying motor vehicles' contribution to peak and ambient background nanoparticle concentrations.

The HEI Research Committee members thought the study could both advance the refinement of nanoparticle speciation monitors and demonstrate their usefulness for apportioning vehicle contributions to nanoparticle concentrations in a near-roadway environment.

APPROACH

Johnston and colleagues conducted a field test of the NAMS at a major intersection in Wilmington, Delaware, through which approximately 28,000 vehicles pass daily. Monitoring took place over two- to three-week periods during the summer and winter of 2009. The investigators continuously measured particle number concentrations, size distributions, wind speed and direction, and sulfur dioxide concentrations and compared the results to those of two other methods that analyzed particles over longer averaging times but during the same monitoring period as the NAMS. A direct comparison using speciation data measured over short time intervals was not possible, since few continuous nanoparticle speciation samplers other than the NAMS existed at the time.

The investigators used photographs from traffic cameras in conjunction with air monitoring data to differentiate heavy-duty diesel from gasoline-powered vehicles; to determine whether vehicles were likely to be idling, accelerating, or decelerating; and to assess a vehicle's contribution to nanoparticle levels at a particular moment in time. They used a statistical method, "wavelet decomposition," to differentiate short-term spikes in concentrations, thought to be caused by recent vehicle activities, from longer-term changes in background nanoparticle concentrations that may have reflected regional sources, including traffic. The investigators attributed spikes to nearby sources using wind-direction data and distance to nearby roadway segments. The wind-direction analysis was correlated with traffic-camera images to estimate per vehicle emissions. The investigators then applied the NAMS output to determine major source contributions to spikes and background levels, including distinguishing diesel from gasoline vehicles.

This Statement, prepared by the Health Effects Institute, summarizes a research project funded by HEI and conducted by Dr. Murray V. Johnston at the University of Delaware, Newark, and colleagues. The complete report, *Selective Detection and Characterization of Nanoparticles from Motor Vehicles* (© 2013 Health Effects Institute), can be obtained from HEI or our Web site (see last page).

RESULTS

The investigators found that nanoparticle spikes coincided with the signal timing of the traffic light at the intersection and that the highest-intensity spikes originated from the nearest roadway. In addition, they found that particle sizes tended to increase with greater distance from the likely sources and that greater wind speeds were associated with smaller nanoparticle sizes measured at the monitor, because of decreased time for particle coagulation and chemical reactions.

On average, nanoparticle spikes contributed 15% and 19% to total ambient number concentrations at the intersection during summer and winter, respectively, with contributions as high as 50% during winter. When data from both seasons were combined, spike contributions during the morning rush hour were approximately double those from afternoon and evening time periods. The chemical composition of the spikes indicated that motor vehicles contributed more to spikes, and other sources such as sulfate and nitrate contributed more to the background. When total vehicle emissions were considered, they were found to contribute approximately 60% to wintertime and 49% to summertime total ambient nanoparticle number concentrations. Motor vehicles accounted for approximately 50% of total ambient nanoparticle mass concentrations in winter but only 16% during summer, which was thought to be a result of greater particle formation by photochemistry in summer. The median per vehicle contribution to emissions was 350 particles/cm^3, and the mean was 700 particles/cm^3, with 10% of vehicles contributing 50% of emissions. Using traffic-camera images, the researchers were unable to identify particular vehicle characteristics associated with high-emitting vehicles. However, they determined that diesel and gasoline vehicles each contributed approximately half to fresh nanoparticle mass concentrations during the winter monitoring program, even though gasoline vehicles made up more than 90% of the vehicles observed in the intersection.

INTERPRETATION AND CONCLUSIONS

In its independent review of the study, the HEI Review Committee thought that Johnston and colleagues had conducted a well-designed field study. They demonstrated that they could use the instrument in a real-world setting to study vehicle contributions to spike and ambient background nanoparticle concentrations and to measure the chemical composition of nanoparticles. The study shows that the NAMS can be used to evaluate the potential effects of stop-and-go traffic on human exposures to nanoparticles on or near roadways. The major strength of the NAMS is that it can measure the major chemical components of nanoparticles in real time, which is of interest for a range of research applications. The NAMS may help researchers better characterize emissions and atmospheric transformation of particles, including evaporation and condensation of organic materials; such data will include information useful to health researchers about the specific composition, size distributions, and sources of particles near roadways.

The Committee also noted several weaknesses in the study. First, a suitable comparison method — one that uses short time periods similar to those of the NAMS — was lacking. Comparison with two methods over longer integration periods provided some supporting evidence, but it fell short of a full validation of the NAMS's performance. Second, the iterative wavelet decomposition method to separate nanoparticle counts into spikes and background levels would benefit from further evaluation and comparison with other statistical methods. Third, while the source apportionment analysis was informative, it required data manipulation that substantially reduced the size of the data sample and consequently its information content.

The Committee initially questioned whether the rather narrow particle size range measured by the NAMS (18–24 nm) would be representative of the particle size distributions in the spikes and the background concentrations. The Committee concluded that the limited size range is not likely to have significantly affected most conclusions from the study.

Movement of vehicles after a red light and high-emitting vehicles are the two major sources of spikes in nanoparticle concentrations identified in the study. The investigators concluded that nanoparticle spikes were due more to acceleration from idling than to high emitters in the intersection. The Committee agreed but thought more could have been done with the traffic photos to improve the identification of high emitters.

In summary, Johnston and colleagues demonstrated that the NAMS is a useful new tool for quantifying the chemical composition of nanoparticles at a high time resolution, which can be particularly useful for measuring traffic-related nanoparticles. They demonstrated how the NAMS could be used with other currently available instruments, including particle counters, as well as traffic cameras and meteorologic data, to assess the contribution of local traffic and vehicle types to short-term spikes in nanoparticle concentrations near intersections. Although the NAMS is a complex instrument that requires additional refinement, it is likely to contribute to the development of future nanoparticle speciation monitors.

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