STATEMENT

Synopsis of Research Report 158

HEALTH EFFECTS INSTITUTE

Air Toxics Exposure from Vehicle Emissions at a U.S. Border Crossing

BACKGROUND

Motor vehicles and other combustion sources emit many air toxics that are either known or suspected, with sufficient exposure, to cause adverse health effects. Characterization of exposure to air toxics has been challenging, in part, because of the low ambient levels of individual compounds. HEI has had a long-standing commitment to improving methods for measuring selected air toxics and increasing our understanding of exposure and health effects. In 2003 HEI targeted research to identify and characterize so-called hot spots, areas where concentrations of one or more air toxics are expected to be elevated. Dr. John Spengler and colleagues hypothesized that vehicle-related emissions from traffic backed up at the Peace Bridge in Buffalo, New York, one of the nation's busiest border crossings, would result in higher levels of mobile-source air toxics (MSATs) directly downwind. They proposed a study to measure levels of air toxics, including MSATs, upwind and downwind of the plaza adjacent to the Peace Bridge, to examine the relation between traffic at the bridge and pollutant concentrations in ambient air, and to explore geographic patterns of ambient air pollutants in this potential hot spot for mobile-source emissions.

APPROACH

The investigators measured levels of a large number of compounds that might be expected in exhaust from diesel and gasoline vehicles, including volatile organic compounds (VOCs), polycylic aromatic hydrocarbons (PAHs), and nitrogenated PAHs (NPAHs). Their analyses focused on comparing pollutant levels measured at fixed sites on opposite sides of the 17-acre plaza adjacent to the Peace Bridge, which comprised the U.S. Customs Building, a customs inspection and holding area, tollbooths, a duty-free store, the Peace Bridge Authority Administration Building, and parking space. Residential and commercial areas abut the plaza to the east, north, and south, with Lake Erie and the Niagara River to the west.

During pilot studies in July 2004 and January 2005, the investigators sampled air at sites upwind and downwind of the plaza and tested a variety of routes for mobile monitoring in a neighborhood next to the plaza. They collected meteorologic data and bridge traffic counts by vehicle type (cars, trucks, and buses), for all sampling days. Prevailing wind directions were determined from 10 years of weather data from the Buffalo Niagara International Airport, which demonstrated that the wind blows from the west side of the plaza (off Lake Erie) about 45% of the time (lake winds) and from the east on the Buffalo side of the plaza (city winds) about 31% of the time. The investigators established two fixed sampling sites for both continuous monitoring and integrated sampling during the summer 2004 pilot study: one to the southwest of the plaza at the Great Lakes Center (GLC site), which they describe as an upwind site, and the other in front of the Episcopal Church Home (Chapel site) adjacent to the east side of the plaza, which they describe as a downwind site. They also tested routes, equipment, and protocols for mobile monitoring of pollutants around the Peace Bridge plaza area, including the neighborhood of Buffalo directly to the east. The researchers added a third fixed sampling site in this neighborhood (School site) during the winter 2005 pilot study.

After the two pilot studies, Spengler's team conducted two larger-scale sampling campaigns featuring both fixed-site and mobile monitoring components. Samples were collected simultaneously at

This Statement, prepared by the Health Effects Institute, summarizes a research project funded by HEI and conducted by Dr. John Spengler, of the Department of Environmental Health, Harvard School of Public Health, Boston, Massachusetts, and colleagues. The complete report, *Air Toxics Exposure from Vehicle Emissions at a U.S. Border Crossing: Buffalo Peace Bridge Study* (© 2011 Health Effects Institute), can be obtained from HEI or our Web site (see last page). **SPENGLER 158**

all three fixed sampling sites for two weeks in July 2005 and two weeks in January 2006. The research team collected integrated samples at these sites and also from collocated real-time continuous monitors that took measurements every minute.

The mobile monitoring campaign was designed to assess the levels of selected pollutants in the neighborhood adjacent to the Peace Bridge plaza. Staff members wore backpacks containing air monitoring equipment and carried GPS (Global Positioning System) units while walking along one of four designated routes in the neighborhood. Pollutant data and GPS coordinates from the mobile monitoring campaigns were used to create maps showing the spatial distribution of pollutants in the neighborhood east of the Peace Bridge plaza.

RESULTS

Spengler and colleagues discuss most of their results by comparing sites that were predominantly upwind and downwind of the Peace Bridge plaza. By considering both the prevailing wind direction and the wind direction measured during the sampling campaigns, they were able to draw inferences about the likelihood that these measurements were related to the volume and composition of traffic traversing the Peace Bridge plaza. Approximately two thirds of the sampling days were classified as having lake-wind conditions that resulted in the GLC site being directly upwind, the Chapel site being directly downwind, and the School site being less directly downwind of the plaza.

The investigators compiled a wealth of comparative data on several different classes of MSATs — VOCs and carbonyls, elements, PAHs, and NPAHs — and measurements from continuous sampling of particulate matter (PM) $\leq$ 10 µm and $\leq$ 2.5 µm in aerodynamic diameter (PM_{10} and $PM_{2.5}$, respectively), ultrafine particles (UFPs, defined as particles < 0.1 µm in aerodynamic diameter), particle-bound PAHs (pPAHs), and gaseous pollutants. For PM_{10} and $PM_{2.5}$, and for the fraction of elemental carbon (EC) present in the collected $PM_{2.5}$, the mean daytime levels were highest at the Chapel site (typically downwind of the plaza), and higher at the residential School site than at the upwind GLC site.

The investigators created summary categories for selected VOCs and chlorinated compounds. In weekday 12-hour samples, overall mean and median levels of benzene, toluene, ethylbenzene, and xylenes (BTEX) were highest at the neighborhood School site, followed by the Chapel site, and then the GLC site. Overall mean and median levels of a summary category of five chlorinated compounds were very similar across the three sites. Median daytime benzene and formaldehyde levels were lowest by far at the GLC site. Overall mean and median daytime acetaldehyde levels were highest at the GLC site, nearly as high at the School site, and much lower at the Chapel site. Acetone levels for all daytime samples were slightly elevated at the GLC site.

Spengler's team analyzed fixed-site $PM_{2.5}$ samples for 28 different elements, of which only six — calcium, chromium, manganese, iron, copper, and antimony — varied considerably across the three fixed sampling sites. Mean daytime weekday levels of these were, on average, higher at the Chapel site than at the other sites. The authors suggest that the higher concentrations of these elements at the Chapel site were related to emissions from traffic at the Peace Bridge plaza.

The researchers also noted important contrasts in levels of PAHs and NPAHs across the three fixed sampling sites. Concentrations of all but a few of the PAH compounds were higher at the Chapel site when the site was downwind of the city of Buffalo (rather than downwind of the bridge), implying that regional combustion and urban infrastructure contributed more PAHs than the emissions from traffic at the Peace Bridge plaza. Low-molecular-weight PAHs, however, were consistently highest at the Chapel and School sites. Comparison of median concentrations of 14 NPAHs at the GLC and Chapel sites under lake-wind conditions showed that some were notably higher at the downwind Chapel site, indicating that traffic at the Peace Bridge plaza was a potential local source for these compounds.

In results from 600 hours of continuous measurement at each of the three fixed sampling sites, mean UFP counts were substantially higher at the Chapel site, followed by the School and GLC sites. The relative differences in UFP counts between the sites were similar in winter and summer, with all three sites recording higher counts in the winter. Concentrations of $PM_{2.5}$ were relatively uniform at the three sites, indicating that $PM_{2.5}$ levels in the

study area may be dominated by regional air pollution patterns. For both 10-minute average and 12-hour average concentrations of PAHs in $PM_{2.5}$, the highest mean concentrations were at the Chapel site, followed by the School and GLC sites. These results indicate an enrichment of PAHs at the Chapel and School sites, since the levels of PAHs in $PM_{2.5}$ varied across the sites while the levels of $PM_{2.5}$ did not.

During the mobile monitoring campaigns, UFP and pPAH levels were measured under different wind conditions at different times of day. Sampling results under city-wind conditions indicated that busy intersections, high-traffic roads, and neighborhood combustion sources are likely to have contributed to the UFP and pPAH levels measured by the mobile monitoring staff. Under lake-wind conditions, mobile monitoring results showed a general increase in concentrations of UFPs and pPAHs with decreasing distance from the Peace Bridge plaza.

The authors performed a source apportionment analysis using principal component analysis to analyze the data for individual elements and positive matrix factorization for the site-specific PAH measurements from the winter 2005, summer 2005, and winter 2006 sampling campaigns. The principal component analysis indicated that measured levels of elements associated with traffic emissions were higher at the Chapel site when it was downwind of the Peace Bridge plaza. Positive matrix factorization analyses, which divided the PAHs into light, medium, and heavy profiles based on their molecular weight, demonstrated relatively higher levels of the light PAHs at the upwind GLC site, higher levels of the medium PAHs at the downwind Chapel and School sites, and relatively uniform distribution of the heavy PAHs at all three sites.

Overall, to assess the plausibility of a relationship between traffic at the Peace Bridge plaza and levels of airborne pollutants at the Chapel and GLC sites on either side of the plaza, Spengler's team compared measurement data obtained with lake winds and with winds blowing over the city of Buffalo toward the lake. Pairing samples by sampling period and calculating the ratio of measured levels at the Chapel site to those at the GLC site, the authors ranked the results in terms of EC reflectance (EC-r). The Chapel-to-GLC ratios for EC-r were highest with lake-wind events, which would enrich levels of EC-r at the downwind Chapel site if they were the result of mobile-source emissions at the plaza. Based on these comparisons and their overall results, the investigators suggest that the traffic at the plaza was a source for the higher levels of compounds measured at the Chapel site.

INTERPRETATION

In its independent review of the study, the HEI Review Committee considered the methods that Spengler and his research team used to measure a large number of pollutants in a variety of ways to be sound and generally well implemented. The sampling campaigns were very well conducted, and the data were of high quality overall. The mobile monitoring scheme using GPS units and real-time measuring equipment carried in backpacks was innovative and successful. However, the investigators' source apportionment analysis was exploratory and inconclusive, owing to the relatively small number of samples available for analysis.

The investigators made some important innovations and contributions to study design for research intended to identify potential hot spots, particularly for emissions from traffic and roadway sources. The study demonstrated that a concentration of mobile-source emissions, combined with relatively consistent meteorologic conditions, could result in an area of elevated pollutant concentrations that shifts with changing wind conditions. Thus the results indicate that wind speed and wind direction should be considered in the selection of sampling sites in any study attempting to characterize measured pollutant levels surrounding a putative hot spot.

Whether a hot spot can be defined as a particular location with elevated concentrations of pollutants arising from a local source, as it is in this study, or whether it should be more broadly defined as an area where levels of pollutants are excessively high in general (compared with a standard level or with levels reported in the literature), is debatable. The Review Committee had two reservations regarding the investigators' conclusion that the study area constituted a hot spot. First, while differences in methods, instruments, and other conditions make it difficult to compare results across studies, the MSAT levels reported in this study were not high relative to levels measured at other U.S.

locations. The authors note this in their comparison of the measurements for a variety of elements and compounds with those in the 2006 TEACH (Toxics Exposure Assessment Columbia and Harvard) studies in New York City and Los Angeles and the 2005 RIOPA (Relationships of Indoor, Outdoor, and Personal Air) study in Houston and Los Angeles. Second, though meteorologic conditions will affect pollutant levels at any location, the Committee noted that the elevated concentrations near the Peace Bridge were particularly dependent on wind direction: the neighborhood to the east did not generally experience higher pollutant levels for the 55% of the time (40% in the summer) when the wind was not blowing from the Peace Bridge plaza.

The Review Committee decided that differences of interpretation in the definition a hot spot should not detract from the research effort by Spengler and his team and their excellent job of characterizing and investigating an area with potentially high emissions of MSATs.

CONCLUSIONS

Although the levels of MSATs in the area near the Peace Bridge in Buffalo may not be high relative to those in other locations in the United States, these data contribute to our understanding of how traffic emissions may result in elevated levels of air toxics in a local area. Spengler and colleagues devised a study design and sampling program for characterizing concentrations of air toxics in an area of potentially high emissions that included some important and innovative features. They selected a good location for a study of traffic-related emissions by targeting a somewhat geographically isolated source of potentially high emissions for intensive sampling and analysis. Finally, their mobile monitoring program for measuring pollutant levels in a local neighborhood is technically sound and economical, and thus will be valuable for studies of fine variations in pollutant concentrations in relatively small geographic areas.

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