HEI

STATEMENT

Synopsis of Research Report 180

HEALTH EFFECTS INSTITUTE

Ultrafine Particles and Other Air Pollutants In and Around School Buses

BACKGROUND

Children are considered particularly susceptible to the effects of outdoor particulate matter (PM). Some evidence suggests that the smallest particles in the complex mixture of PM — ultrafine particles, defined by having a diameter of 0.1 µm or less — have properties that may make them particularly toxic. Accurately assessing exposures to ultrafine particles, of which a major source is vehicle emissions, is considered a key research need. Dr. Yifang Zhu, who was a recipient of HEI's Walter A. Rosenblith New Investigator Award, and her colleague Dr. Qunfang Zhang assessed levels of ultrafine particles and other pollutants in and around school buses powered by diesel engines and identified factors contributing to these levels, including an evaluation of two retrofit devices.

APPROACH

Zhu and Zhang measured levels of ultrafine particles and other pollutants, such as $PM_{2.5}$ (PM with an aerodynamic diameter $\leq$ 2.5 µm) and black carbon, in and around school buses in four sets of tests: (1) on-road; (2) during idling; (3) before and after retrofitting with a diesel oxidation catalyst, a crankcase filter system, or both; and (4) before and after operating a high efficiency particulate air (HEPA) filter air purifier inside the cabin. Each set of tests comprised several conditions: for example, windows open or closed, air conditioner on or off, and buses idling in different positions relative to each other. Air pollutants were measured simultaneously inside the cabin as well as directly outside the cabin or close to the tailpipe, except for the on-road tests in which only the in-cabin levels were measured. Measurements were made in small sets of buses (model years 1990–2006) in Texas and California.

MAIN RESULTS AND INTERPRETATION

In its independent review of the study, the HEI Health Review Committee considered that the retrofit and idling tests in particular provided useful information. Tailpipe concentrations of ultrafine particles were significantly reduced (by 20% to

What This Study Adds

- Zhu and Zhang's study adds to the small number of studies assessing air pollutants including ultrafine particles in and around school buses. In a small sample of U.S. diesel-powered school buses evaluated under different conditions, the investigators measured levels of ultrafine particles and other air pollutants inside the bus, directly outside the bus, or close to the tailpipe.
- Retrofitting buses with a diesel oxidation catalyst, a crankcase filtration system, or both substantially reduced tailpipe concentrations of ultrafine particles, black carbon, and fine particulate matter during idling. However, retrofitting did not reduce in-cabin levels of the measured pollutants, indicating that factors other than the vehicle's self-pollution — in particular, ambient levels including emissions from nearby vehicles — were more important in influencing in-cabin concentrations.
- Assessment of in-vehicle pollutant levels remains an important area of study. This study demonstrates the importance of including measurements of ambient air pollution concentrations in future in-vehicle studies.

This Statement, prepared by the Health Effects Institute, summarizes a research project funded by HEI and conducted by Drs. Yifang Zhu and Qunfang Zhang at the University of California–Los Angeles. The complete report, *Characterizing Ultrafine Particles and Other Air Pollutants In and Around School Buses* (© 2014 Health Effects Institute), can be obtained from HEI or our Web site (see next page).

94%) in idling school buses after retrofitting with a diesel oxidation catalyst and/or a crankcase filter system. Black carbon and $PM_{2.5}$ were also reduced close to the tailpipe, on average by 64% and 47%, respectively, but only the reduction in black carbon was statistically significant. However, while the buses were idling or driving, in-cabin concentrations of the measured pollutants were not reduced after the buses were retrofitted. Similar results were found in the idling test: close-to-tailpipe ultrafine particle concentrations were greatly influenced by the bus' own engine (they were 7- to 26-fold greater than with the engine off), whereas in-cabin concentrations were affected only when the wind blew from the back to the front of the bus, especially with nearby buses idling together (producing up to a 5.8-fold increase). Thus, factors other than the vehicle's self-pollution — in particular, ambient levels including emissions from nearby vehicles — were more important in influencing in-cabin concentrations. The use of a HEPA air purifier and the air conditioner also substantially decreased in-cabin levels of ultrafine particles and $PM_{2.5}$.

A strength of the study was that in many of the tests (idling, retrofit, and HEPA air purifier tests) air pollutants were measured simultaneously inside as well as directly outside the cabin and with identical equipment. In addition, the same buses were tested before and after retrofit devices were installed. However, because of certain design decisions, the Committee concluded that some study results were open to interpretation and thus some conclusions should be considered cautiously. One major reason was that, in the on-road tests, no measurements of ambient concentrations were conducted, and therefore this particular test had limited value overall. In addition, the Committee expressed concern about the absence of an adjustment for varying ambient levels in the retrofit analyses, because it prevented reliable conclusions from being drawn about the effectiveness of the two retrofit devices in reducing in-cabin levels of ultrafine particles and $PM_{2.5}$.

For future studies, the Committee would make the following additional recommendations: (1) collect detailed data on other pollutants — in particular nitrogen dioxide, black carbon, and carbon monoxide — as well as data on traffic intensities; (2) use a standard dilution system when measuring tailpipe concentrations; (3) use a more common alignment of buses (that is, not perpendicular), and account for local fluctuations in wind direction or the possible effects of wind speed when studying idling buses; (4) within available resources, test a larger number of buses, with engines of varying ages, and in different seasons.

CONCLUSIONS

The HEI Health Review Committee concluded that the study by Zhu and Zhang adds to the small number of studies assessing air pollutants including ultrafine particles in and around U.S. school buses. Since a substantial fraction of at least some children's daily exposure may come from bus transfer locations or waiting areas where multiple buses are idling, the reduction in tailpipe concentrations after retrofitting could reduce children's overall exposure to air pollutants and contribute to overall cleaner outdoor air. Further reductions in children's exposure could also be achieved by reducing idling time, increasing the distances between buses during driving and idling, increasing the distances between buses and other vehicles, and avoiding high-traffic roads.

This study holds important methodologic lessons for future in-vehicle studies, since it highlights the importance of including measurements of ambient air pollution concentrations. In-vehicle studies remain an important area of future research because in-vehicle exposure may contribute substantially to a person's average exposure to pollutants such as ultrafine particles, in spite of the fact that time spent in vehicles makes up only a relatively small amount of a person's day. Additional studies are needed to estimate the relative contributions of in-vehicle microenvironments to air pollutant exposures, but also the assessment of the contributions of other microenvironments in which children and adults spend most of their time (such as home, work, and school) is particularly important.

HEALTH
EFFECTS
INSTITUTE

101 Federal Street, Suite 500
Boston, MA 02110, USA
+1-617-488-2300 phone
+1-617-488-2335 fax

pubs@healtheffects.org
www.healtheffects.org

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