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EMISSIONS FROM SCHOOL BUSES INCREASE POLLUTION LEVELS INSIDE THE BUS

The Bulk of Scientific Studies Suggest that Self-Pollution is Real

Recent studies show that air pollutant levels inside school buses can be greater than the ambient levels outside the bus. The elevated levels are attributed to emissions from the bus itself that intrude into the bus cabin, a process sometimes called "self-pollution." Factors that affect the amount of these emissions entering the bus include wind speed and direction, whether windows are opened or closed, age and condition of the bus. A smaller number of studies question whether school bus self-pollution actually occurs to any significant extent, typically attributing pollution inside a school bus to other vehicles on the road. The existing evidence is summarized in the attached review.

On balance, there is strong evidence that school bus self-pollution is a real phenomenon. Five independent research teams using different methods have documented the effect for many buses in numerous locations. By comparison, the studies with negative results examined fewer components of the engine's emissions and consequently failed to fully characterize the problem.

Where the Pollutants Come From

There are two sources of emissions that contribute to the self-pollution effect: the engine crankcase and the tailpipe. The crankcase on most diesel engines is vented to the air, which results in emissions of volatilized engine oil, as well as unburned fuel and exhaust gases that leak through or "blow-by" the piston rings. The relative strengths of the crankcase and the tailpipe are not well established; however, Donaldson estimates that the crankcase accounts for 10-25% of an engine's total particulate emissions.[1]

The Clean Air Task Force's measurements of in-cabin pollution levels show that observed ultrafine particles (<1μm), black carbon and PAH originate from the tailpipe while the majority of the observed PM2.5 mass comes from the crankcase.

Solutions

Commercially available technologies can effectively remove nearly all of the emissions that contribute to elevated pollution levels inside school buses. Crankcase filtration systems, which trap oil mists and reroute crankcase emissions back to the engine air intake, can reduce particulate emissions by more than 90%. Diesel particulate filters (DPF) have been verified by EPA to reduce tailpipe particulate emissions by 85% or more while diesel oxidation catalysts (DOC) can achieve reductions in the 25% range.

These devices can also dramatically improve air quality inside school buses and outside of schools. The Clean Air Task Force found that a crankcase filter and a DPF, used in tandem, can reduce all the key diesel pollutant levels[2] inside school buses down to ambient levels.

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[1] See, e.g., "Contributors to Diesel Engine Emissions," www.donaldson.com/en/exhaust/support/datalibrary/007341.pdf
[2] PM2.5 mass, number ultrafine particles, black carbon and PAH

Summary of studies of air pollution inside school buses

- Hill, L.B., Zimmerman, N.J., and Gooch, J., "A Multi-City Investigation of the Effectiveness of Retrofit Emissions Controls in Reducing Exposures to Particulate Matter in School Buses," 2005; available at www.catf.us/publications/view/82.

Investigates the causes of school bus self-pollution and documents the reductions in particulate matter pollution inside school bus cabins retrofit with various emission control devices. Identifies the tailpipe as the source of ultrafine particles, black carbon, and particle-bound PAH in the bus cabin, and crankcase emissions as the dominant source of in-cabin levels of PM2.5. A diesel particulate filter effectively removes the ultrafine particles, black carbon and PAH, while a closed-crankcase filtration device effectively removed PM2.5. When combined, the two control devices nearly eliminate all measured particle species.

- Marshall, J.D. and Behrentz, E., "Vehicle Self-Pollution Intake Fraction: Children's Exposure to School Bus Emissions," Environmental Science and Technology, 2005, p. 2559

Using data from Fitz *et al.*, this paper finds that the fraction of pollution inside a school bus attributable to the bus itself is "substantial." Concludes that reducing emissions from school buses, even if doing so was much more expensive per gram *emitted* than for an average vehicle, "it would still be less expensive per gram *inhaled*, which is a better proxy for health effects. Calls for research to identify the mechanism of self-pollution.

- Ontario Public Health Association, "School Buses, Air Pollution & Children's Health: Improving Children's Health and Local Air Quality by Reducing School Bus Emissions," 2005; available at www.opha.on.ca/resources/schoolbus.pdf.

Section B provides a good survey and synthesis of previous work on the issue. Among other things, concludes that "While children may only spend a few hours per day on school buses, the high levels of exposure encountered on-board school buses can add considerably to their daily and annual exposures to air pollutants such as [diesel particulate matter] and PM2.5."

- New Brunswick Lung Association, "Exposure of School Children to Diesel Exhaust from School Buses, 2005 (As reported in OPHA, 2005)

Average exposures to PM2.5 on school buses were 5-6 times greater than ambient levels, averaging 32.1 μg/m3. Exposures to PM2.5, PM1.0 and black carbon were found to be approximately three times higher during bus rides than during the average walking commute.

- Ireson, R.G. *et al.*, "Estimation of Particulate Matter Concentrations in a School Bus Using a Fuel-Based Tracer – A Sensitive and Specific Method for Quantifying Vehicle Contributions," Transportation Research Record, No. 1880, pp. 21-28, 2004 (a longer version is also available: California EnSIGHT, "Estimated Concentrations of Diesel Particulates Inside a School Bus Based on Tracer Added to its Fuel," prepared for International Truck and Engine Corporation, 2003; available at www.greendieseltechnology.com/default.asp?archive=fact).

Estimated that less than 1% of the PM2.5 pollution inside a school bus (0.22 μg/m3 out of an average of 72 μg/m3) came from its own exhaust by measuring the amount of an iridium tracer added to the bus's diesel fuel that was collected on a filter inside the cabin. Coupled with measured background concentrations of PM2.5 in a lead vehicle that were 30-40% greater than those measured in the study bus, the authors conclude that the diesel particulate levels inside the bus are not from the bus's engine but from other sources. Since the lead vehicle was roughly 5 minutes ahead of the bus, it is unclear how well the ambient air in the immediate vicinity of the bus was characterized. There is no discussion of the possible influence of crankcase emissions, a notable omission since other studies note that the crankcase is responsible for the bulk of PM2.5 mass detected inside bus cabins, which was relatively high in this study (72 μg/m3 on average). The selection of an urban bus route with high background PM2.5 levels may have confounded the influence of self-pollution.

- Fitz, D.R., Winer, A.M., *et al*., "Characterizing the Range of Children's Pollutant Exposure During School Bus Commutes," Final Report to the California Air Resources Board, 2003; available from www.arb.ca.gov/research/schoolbus/schoolbus.htm

On average 0.03% (range 0.02 – 0.29%) of a bus's exhaust can penetrate the cabin, as determined through the use of an SF6 tracer metered into the engine exhaust. The relative amount of exhaust inside the bus was higher with the windows closed. The tracer concentrations measured inside the cabin correlated reasonably well with black carbon. Conventional buses exhibited higher concentrations of black carbon and PAH than one outfitted with a particulate trap.

- California Air Resources Board, "Characterizing the Range of Children's Pollutant Exposure During School Bus Commutes," ARB Staff Interpretive Summary of Study Results, 2003; available at www.arb.ca.gov/research/schoolbus/summary.pdf

Compares the average black carbon concentrations measured by Fitz *et al*. in school buses (9.2 μg/m3) to concentrations measured in a different study in passenger cars in Los Angeles (5.9 μg/m3). From these values, CARB staff estimates a 34% increase in the daily exposure to black carbon. Predicts increases in the risk of cancer, asthma hospitalization, and lower respiratory symptoms.

- Borak, J. *et al*., "Comparison of NIOSH 5040 Method versus Aethalometer to Monitor Diesel Particulate in School Buses and at Work Sites," AIHA Journal, **64**, p. 260, 2003; available through www.aiha.org/Content/AccessInfo/joeh/joeh.htm. (Performed under contract to International Truck and Engine Corporation.)

Measured black carbon (1.0-1.2 μg/m3) with an aethalometer and, simultaneously, time-weighted average elemental carbon (< 1.0 μg/m3 to 1.9 μg/m3) with the NIOSH 5040 Method inside 3 school buses on an automotive test track. Questions the effectiveness of aethalometers on moving vehicles because they were found to be sensitive to movement and vibration, potentially causing negative black carbon readings, and suggests the instrument's usefulness would be limited in moving vehicles (such a problem was not observed by the CATF). Because no measurements of PM2.5 mass were made, study does not address the contribution from the crankcase.

- Fitz, D., "Evaluation of Emission Control Equipment in a School Bus Application, Final Report," Prepared for Donaldson Company, 2003

Measured condensation particle counts and levels of PAH, VOC and CO inside the cabin of a school bus traveling on a rural route and under stationary idling conditions, in both cases with and without a second bus in front. The stationary idling tests showed that interior concentrations of particles in the trailing bus were reduced when the leading bus used control devices, after adjusting for background levels. Specifically, the reduction in particle counts due to a particulate trap were 96% and roughly 60% due to a diesel oxidation catalyst – crankcase filter combination. The use of a crankcase filter in conjunction with the particle trap further reduced particle counts. The tests on moving buses appeared inconclusive because background levels were not measured. The effect of crankcase filters may have been underestimated due to the lack of PM2.5 measurements.

- Wargo, J., "Children's Exposure to Diesel Exhaust on School Buses," Environment and Human Health, Inc., 2002; available at www.ehhi.org/reports/diesel.

Based on results of personal PM monitors worn by students during a school day, estimates that levels of particulate matter in and around school buses can be up to 5-10 times higher than background levels. Also made PM2.5 and black carbon measurements inside empty school buses during a simulated bus route and while idling. The highest PM2.5 levels detected within buses exceeded 100μg/m3 during 7 of 27 bus runs.

- O'Neill, D., "A Representative Sample of Fairfax County Public Schools Buses Found to be Free of Significant Diesel Exhaust," Fairfax County Public Schools Department of General Services, 2001; available at www.fcps.edu/fts/safety-security/publications/busexhaustreport.pdf.

Measured PM10, elemental carbon (EC) and organic carbon (OC) on 12 buses over roughly 90 minute routes. All of the EC measurements and 8 of 12 PM10 measurements were below the relatively high detection limits of 4-5 μg/m3 and 51-65 μg/m3, respectively. The four positive PM10 readings ranged from 120-200 μg/m3. OC levels ranged from 50-130 μg/m3. The authors rely on the lack of detectable EC to conclude that there was no evidence that the bus's exhaust contaminated the cabin, instead attributing the observed OC to gasoline vehicle traffic. There is no discussion of the high PM10 and OC levels, which could be the result of crankcase emissions.

- Solomon, G.M. *et al.*, "No Breathing in the Aisles: Diesel Exhaust Inside School Buses," Natural Resources Defense Council, 2001; available at: www.nrdc.org/air/transportation/schoolbus/sbusinx.asp

Measured PM2.5 and black carbon inside 4 school buses in Los Angeles. Reports that diesel exhaust particulate levels inside the buses (derived from the black carbon measurements) ranged from 8-19 μg/m3, which was 10-400% higher than the levels measured inside a passenger car driving directly ahead of the bus.