Bus Study Overview with NO_2 Results

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Overview

To investigate the exposures of children who commute to school by diesel school buses, an exposure study was carried out in Spring, 2002. The study measured pollutant concentrations inside five conventional diesel school buses, ages 1975 to 1993, over actual school bus routes in Los Angeles. For comparison, a 1998 diesel bus outfitted with a particulate trap and a 2002 bus powered by natural gas (with no catalyst) were also included. Buses were outfitted with dual sets of real-time instruments to measure black carbon (BC), particle-bound PAHs, PM2.5, fine particle counts, CO, and NO_2, which allowed front versus back and inside versus outside comparisons. Also included were integrated measures of VOCs, aldehydes, and 1,3-butadiene. SF_6 was introduced into each bus's exhaust as a tracer gas to distinguish the bus's own exhaust from that of other diesel vehicles and help quantify the extent of self-pollution (the re-entrainment of the bus's own exhaust). In keeping with observed operating practices, windows were kept closed in the morning, due to cool temperatures, and were kept partially opened in the afternoon. The full report is available at http://www.arb.ca.gov/research/schoolbus/schoolbus.htm

Measurements indicated that for the conventional, uncontrolled, diesel-powered buses, self pollution was a significant contributor to on-board concentrations when windows were closed and ventilation was reduced. For example, concentrations of BC, PAHs, and the tracer gas were several times higher on conventional diesel buses when windows were closed compared to when windows were open. The trap-equipped bus and the CNG-powered bus exhibited much less of an increase in these concentrations when windows were closed. Self-pollution also appeared to increase with the age of the bus.

The high concentrations of pollutants already present on roadways, especially if traffic was heavy, and the direct influence of other vehicles being followed also contributed to high pollutant concentrations on board the buses. For example, concentrations were several times higher on urban routes compared to the rural/suburban route.

NO_2 Measurements

NO_2 was measured with two in-house instruments based on the reaction with Luminol, converted to concentrations via photomultiplier tube. NO_2 and PAN were measured in one-minute intervals. A third instrument, a TEI Model 42, measured NO/ NO_2/NO_x with the Federal Method (chemiluminescence) to calibrate the other two instruments. Measurements were made in the back of the bus at breathing height, and, depending on the run, either in the front of the bus or outside the front door of the bus. NO was not measured.

The following table presents the average NO_2 concentrations on the buses, by bus type, for closed window and open window conditions, along with concurrent ambient concentrations taken from the West Los Angeles and Central Los Angeles AQMD monitoring stations.

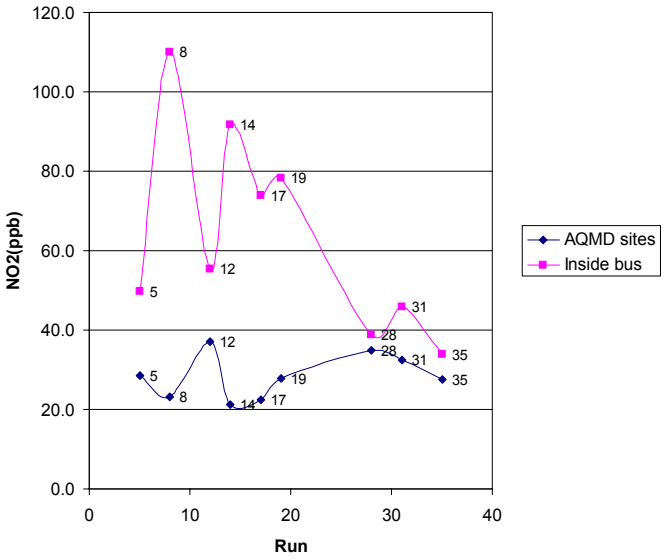
	Bus avg, windows closed (ppb)	Ambient air avg, morning (ppb)	Bus avg, windows open (ppb)	Ambient air avg, afternoon (ppb)
Conventional diesel bus	76 (n=7)	27	77 (n=7)	20
CNG bus	34 (n=1)	28	39 (n=1)	18
Trap bus	42 (n=2)	34	86 (n=2)	30

n = number of runs

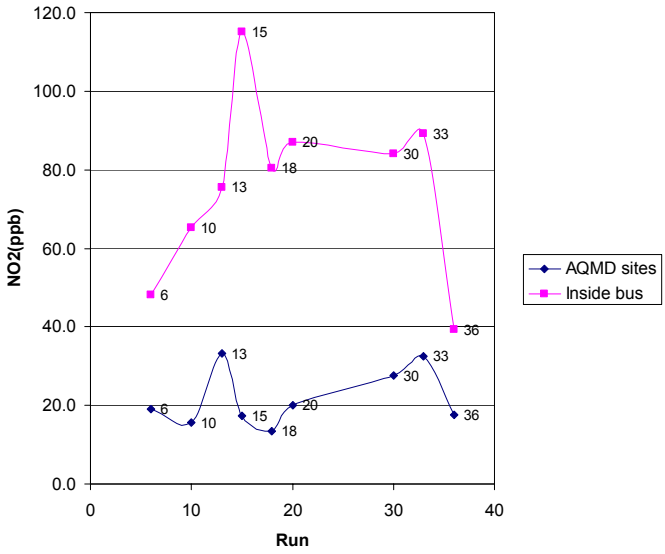
For conventional, uncontrolled diesel buses, NO_2 concentrations were 2 to 3 times higher on-board buses compared to ambient air.

These results are also presented in the following graphs, taken from p. 159 of the final report.

Closed windows, morning



Open windows, afternoon



These graphs show the relatively high bus-to-bus and day-to-day variability in the NO_2 results. In spite of this variability, these graphs show no consistent increase in on-board NO_2 concentrations due to closed windows, unlike BC or PAH concentrations. The higher NO_2 concentrations on board (top lines) were therefore probably due to higher roadway NO_2 concentrations rather than self pollution and closed windows. However, the CNG bus (runs 35 and 36) and runs 28 and 31 for the trap-equipped bus (out of runs 28, 30, 31, and 33) appeared to have on-board NO_2 concentrations closer to ambient concentrations than conventional diesel buses typically did. The exceptions were afternoon runs 30 and 33 of the trap bus, which appeared similar to the conventional diesel buses.

Overall, it appeared the buses were not producing large amounts of NO_2, including the trap-equipped bus, although there is some unresolved uncertainty as to whether the trap was functioning as intended. Based on the amount of self-pollution this study showed can occur on school buses, were trap-equipped

buses to generate large amounts of NO_2, the on-board NO_2 concentrations might be high when windows are closed. (This scenario will be included in our evaluation of exposures.)