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CHARACTERIZING THE RANGE OF CHILDREN'S POLLUTANT EXPOSURE DURING SCHOOL BUS COMMUTES

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BACKGROUND

- The ARB has declared diesel exhaust particulate to be a toxic air contaminant
- 70% of school buses in CA powered by diesel engines
- Children may be exposed to high concentrations of diesel particles and gases during bus commutes, at school bus stops, or at loading/unloading zones
- Some children spend up to 3 hours a day on school buses
- Inadequate data concerning children's in-vehicle exposure on diesel school buses in CA

OBJECTIVES

- Characterize the range of exposures experienced by children during school bus commutes, especially in potentially high exposure conditions
- Identify factors that lead to higher exposure
- Evaluate the direct exposure benefits of alternative fuel types and improved bus emission control technologies

APPROACH

- On-board measurements with 10 second time resolution
- State-of-the-art instruments for all relevant particles and gases (two instruments for each pollutant)
- In-use buses and bus routes

Selection of School and Route

- Brentwood Science Magnet School (BSMS) in WLA
- 85% of students commute on 19 school buses; 85 minutes and 23 miles on average one way; a wide range of distance and congestion scenarios
- Urban route 1 (U1). Residential streets plus I-10 and I-405 freeways
- Urban route 2 (U2). Exclusively on surface streets
- Rural/suburban route (RS)

Selection of Buses

BUS TYPE	CODE	YEAR
Conventional Diesel High Emitter	HE2	1985
Conventional Diesel High Emitter	HE3	1975
Representative Conventional Diesel	RE1	1988
Representative Conventional Diesel	RE2	1993
Particle Trap-Outfitted Diesel	TO1	1998
Compressed Natural Gas	CNG	2002

Measurements

REAL TIME	INTEGRATED	OTHER PARAMETERS
CO	Filter-based PM2.5 Mass	Date and Time
Elemental Carbon	Filter-based PM10 Mass	Relative Humidity
NO_2	Gaseous Aldehydes and Ketones	Wind Speed and Direction (AQMD)
PM2.5 Mass	Gaseous Hydrocarbons	Temperature
PM10 Mass	SF_6 Tracer Gas	Location (GPS)
Particle Counts	PM Elements	Speed
Particle-phase PAH		Traffic Documentation
VOC		
Ultra-fine Particle Counts		


3
4
5

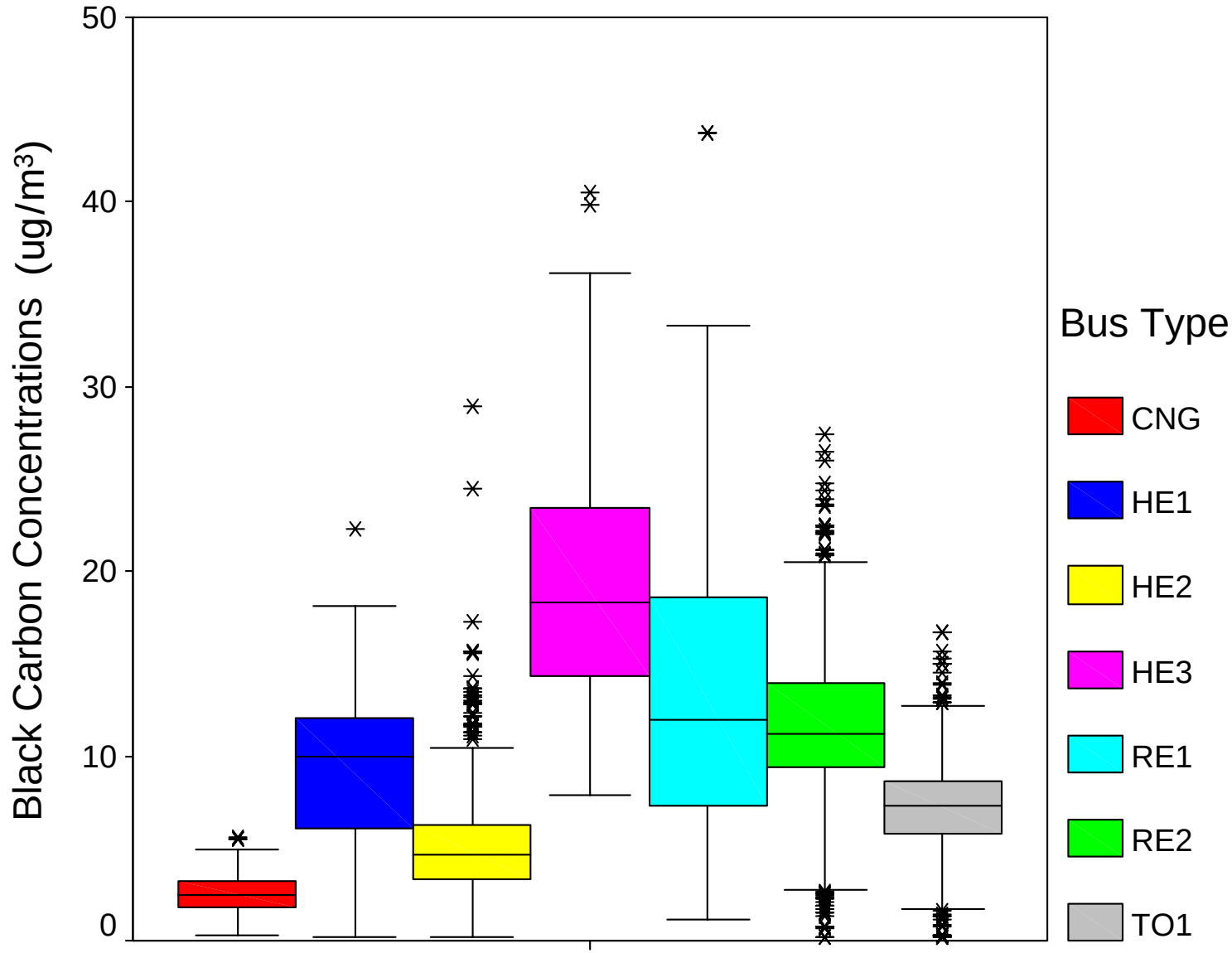
RESULTS

Average Concentrations Inside the Cabin During School Bus Commutes [1,2]

	Windows Closed (morning)			Windows Open (afternoon)[3,4]		
	CNG Bus	Trap-Outfitted Diesel Bus	Conventional Diesel Buses	CNG Bus	Trap-Outfitted Diesel Bus	Conventional Diesel Buses
Black Carbon (ug/m^3)	2.5 ± 0.1	7.2 ± 0.2	12.5 ± 0.3	3.5 ± 0.4 (1.2 ± 0.2)	4.2 ± 0.3 (1.9 ± 0.2)	5.9 ± 0.3 (8.6 ± 1.9)
PAH (ng/m^3)[5]	64 ± 3	201 ± 7	219 ± 5	119 ± 18 (27 ± 16)	105 ± 12 (20 ± 4)	87 ± 7 (106 ± 26)
NO_2 (ppb)	34 ± 0.4	42 ± 0.4	76 ± 1	39 ± 1 (37 ± 3)	86 ± 2 (78 ± 6)	77 ± 1 (64 ± 6)
Formaldehyde[6] (ug/m^3)	4.8	2.2	1.4	1.2	1.0	1.0

[1]Includes bus commutes on urban route one only. [2]The number of buses tested in each category included: one CNG bus; one particle trap-outfitted diesel bus; five conventional diesel buses. [3]With windows open, concentrations inside bus were dominated by outside sources, thus reducing the influence of the bus type. [4]Numbers in parenthesis represent mean concentrations during periods of the commute when the bus was idling in residential neighborhoods with windows open, and no other diesel vehicles were present. Includes selected afternoon runs on HE2, RE1, RE2, TO1 and CNG. [5]Measurements of PAH inside conventional diesel buses may be biased low due to the instrument's maximum setting during these commutes. [6]Confidence intervals are not presented for HCHO because of small sample size.

Black Carbon Concentrations by Bus Type (Windows Closed)



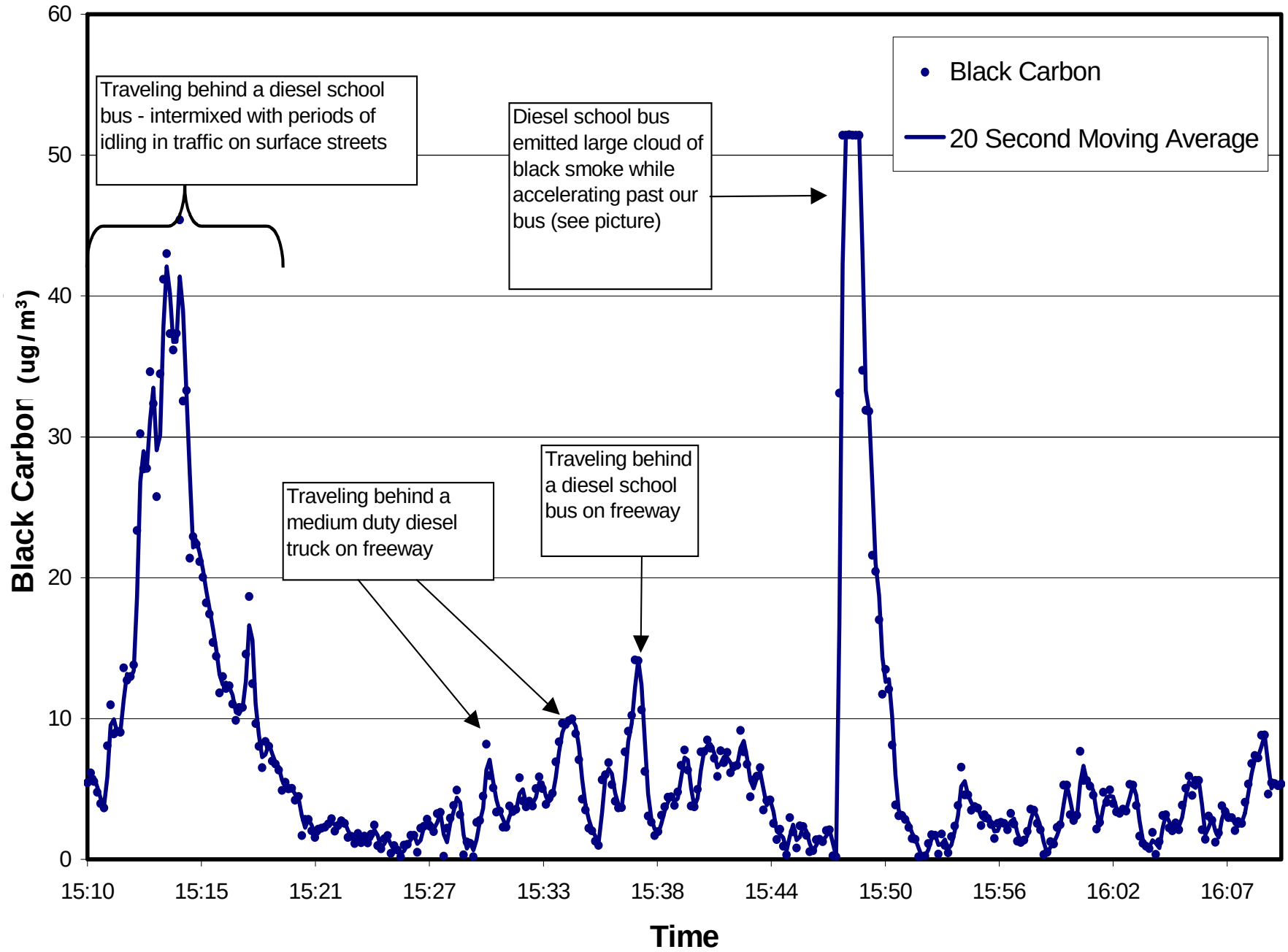
Average Exposures in Three Microenvironments

	Exposure Factors[1]		
	Loading/ unloading zone	Bus stops	Bus commutes
BC (ug/m^3-hr)	0.1	0.2	10
PAH (ng/m^3-hr)	0.8	2	170
NO_2 (ppb-hr)	2	3	90
PC (#/cm^3-hr)	N/A	3	160
$PM_{2.5}$ (ug/m^3-hr)	N/A	1	55
Average time spent in this microenvironment (min)	3	3	76 min[2]

[1] Defined as the mean concentration of a specific pollutant in a given microenvironment multiplied by the time (hours) typically spent by children in that microenvironment

[2] In 0.3 – 0.5 um size range

[3] Average commute time from the first bus stop to the school in the morning and from the school to the last bus stop in the afternoon


Black Carbon
20 Second Moving Average
Traveling behind a diesel school bus - intermixed with periods of idling in traffic on surface streets
Diesel school bus emitted large cloud of black smoke while accelerating past our bus (see picture)
Traveling behind a medium duty diesel truck on freeway
Traveling behind a diesel school bus on freeway
Black Carbon (ug/m³)
60
50
40
30
20
10
0
15:10
15:15
15:21
15:27
15:33
15:38
15:44
15:50
15:56
16:02
16:07
Time

Key Findings

- Bus commutes are more important than bus stops or loading/unloading zones in terms of exposure because children spend much more time commuting and concentrations are higher in bus cabins
- Short-term peak pollutant concentrations inside buses occurred with windows partially opened in close proximity to other diesel vehicles
- Highest mean concentrations occurred for windows closed
- Intrusion of a bus's own exhaust is important for windows closed and when idling (tracer gas study)
- CNG fuel and particle traps reduce pollutant concentrations inside buses

Recommendations for Reducing Children's Exposure During School Bus Commutes

- Phase out conventional diesel school buses and replace with cleaner buses, such as CNG or trap-outfitted diesel
- Assign the cleanest buses to the longest routes
- Instruct school bus drivers to avoid other diesel school buses
- Develop strategies to shorten commute times
- Properly maintain in-use diesel school bus engines to eliminate visible exhaust
- Minimize time spent on sidewalks in front of schools when diesel school buses are arriving or departing
- Instruct school bus drivers to turn off engines immediately on arrival at a school; do not turn engines on until ready to depart

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