Clean Air Task Force Methodology -- Conroe ISD School Bus Study, March 2006
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Approach

This investigation, conducted by Clean Air Task Force, for Environmental Defense, was designed to investigate the presence of diesel exhaust particles inside the cabins of conventional and retrofit buses along actual school bus routes in the Conroe Texas Independent School District.[1]

The study design required a school bus, with the windows closed, to follow a single representative school bus route, provided by the Conroe fleet manager, approximately 45 minutes in duration and with sixteen bus stops. The bus route was light suburban, in the affluent Woodlands area in the Houston area. Few other vehicles were observed on the route, thereby enhancing our ability to detect bus self-pollution and reducing confounding. Buses of approximate fleet average age and mileage were requested from the fleet manager.

Prior to the run, the school bus was inspected for obvious rear door leaks and, if found, was sealed with duct tape. The school bus was preceded by a car equipped with a full suite of monitoring equipment, and was located approximately 50 to 100 feet in advance of the bus at most times. The car was operated with windows down in order to measure pollutant levels in the air in front of the bus, as a control. Each run began with a 10 minutes idle, first with door open, then with door closed. At each stop, one minute in duration, measurements of wind direction relative to the bus outside of the bus, were recorded. Wind direction and magnitude was recorded in order to investigate the influence of tailpipe (rear winds) or engine crankcase emissions (front winds) on self polluting exhaust entering the cabin, based on the results of earlier studies. Notes were taken on other sources of nearby pollution that could affect the bus.

Four particulate matter parameters were measured inside the cabin of the bus: 1) fine particulate matter ($PM_{2.5}$), 2) ultrafine particles, 3) black carbon, and 4) particle-bound PAH. Three parameters were measured inside the car: 1)$PM_{2.5}$, 2) ultrafine particles and 3) black carbon. Data is reported in "net" concentrations. Net concentrations represent the contributions of diesel pollution to the interior; an average value (constant) for ambient outdoor air is subtracted from the raw data. Occasionally this results in a false net negative value which should be read as *no contribution from self pollution or external sources*.

In the bus, monitoring instruments were situated at the middle of the bus (7 rows behind the driver). Sample inlets were placed at a height approximately level with the top of the seat—where children breathe. In addition, an additional $PM_{2.5}$ monitor was placed in the front seat to the right of the driver. In the lead car, inlets were positioned in windows or cars were operated with windows open.

Raw PM2.5 and ultrafine data was smoothed into rolling 10-second averages of the original 1-second data and is reported in 10 second intervals. Raw black carbon data was recorded and reported in 1 minute intervals. Raw PAH data was recorded and reported in 10 second intervals. Subsequently, as noted above, an average ambient concentration for the run, as determined from the lead car data, was subtracted to result in net contribution of the pollutant to the cabin air. All data is reported as 'net" after ambient subtracted. In some graphic treatments, potential external PM influences and wind directions are noted.

$PM_{2.5}$ Measurements

Particulate matter mass was measured using the TSI Dust Trak equipped with a $PM_{2.5}$ impactor.[2] Data was logged in 1-second intervals using a 10 second time constant, and the data later smoothed to 10-second intervals in post-processing. Two or more Dust Traks (#2,3,5) were located in the bus (front middle and duplicate), and one Dust Trak (#1) in the lead car. Dust CATF2 (mid-bus) and CATF 1 (car) were equipped with a Nafion Tube diffusion dryer assemblies, attached to the instrument inlet. The dryer tube was used to mitigate the effects of humidity, based on the method of Chang et al (2001).[3] The two other Dust Traks, sampling in the front (CATF3) and middle of the bus (CATF5), were operated *without* the Nafion tube dryer. Despite zeroing the instruments, measurements from CATF 5 diverged strongly from CATF 1 and appeared to produce erratic data. Therefore CATF 5 data is not used in the analysis.

Ultrafine Particle Measurements

Ultrafine particles were measured using a TSI PTrak, a continuous monitoring condensation particle counter that measures the number of ultrafine particles (0.02-1.0 microns) in a cubic centimeter of ambient air.[4] PTraks were located in the middle of the bus and in the lead car. PTrak data was collected in 1.0 second intervals and smoothed to 10 second intervals in post-processing. The instruments were zeroed daily using a HEPA filter.

Black Carbon Measurements

Black carbon measurements were made using portable single channel Aethalometers™ [5] set up for collecting data at maximum sensitivity using a flow rate of 5 liters per minute with a 60 second logging interval. A BGI Inc $PM_{2.5}$ cyclone was attached to the inlet in each instrument. Despite criticisms in the literature (e.g. Borak, 2003[6] and Cohen, et al (2002)[7] appear unfounded as we found the portable units to provide stable measurements. Contrary to those comments, the Aethalometers used were not sensitive to vibrations experienced on school bus routes we traveled as reported in those studies.

Particulate PAH Measurements

Particle-bound PAH measurements were collected using a portable Ecochem analytics PAS 2000CE. Data was recorded in 10 second intervals. Data was not collected in the first run of the study involving the retrofitted DPF-Spiracle-ULSD bus due to an electronic instrument malfunction. A fuse replacement arrived subsequent to that bus run. Stable PAH measurements were observed and recorded in the first run of the conventional bus, the DPF-ULSD equipped bus, and Spiracle bus. However, in the second run of the Conventional bus (the last run of the study), field observations of instrument behavior and post-experiment analysis of data suggest abnormal erratic behavior likely affected by sharp vibrations inside the bus. As a result, PAH data from the second run in the conventional bus is not used in the analysis and should be discarded.

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[1] A "conventional" style school bus is typically used to mean a yellow school bus with the engine extending out in front of the cab. Conversely, a "transit" style bus is a flat-faced bus where the engine is either under the front of the cabin floor adjacent to the driver or in the rear of the bus. Nearly all of the buses tested in this study were 'conventional" style.

[2] http://www.tsi.com/exposure/products/dusttrak/dusttrak.htm

[3] Chang et al (2001) Laboratory and Field Evaluation of Measurement Methods for One-Hour Exposures to O3, $PM_{2.5}$, and CO; Journal of the Air and Waste Management Association, vol. 51, pp. 1414-1422.

[4] http://www.tsi.com/iaq/products/PTrak/PTrak.shtml

[5] http://www.mageesci.com/

[6] Borak et al (2003) Comparison of NIOSH 5040 method versus Aethalometer to monitor diesel particulate in school buses and at work sites. AIHA Journal vol. 64 p.260-268.

[7] Cohen et al (2002) Observations on the suitability of the Aethalometer for vehicular and workplace monitoring. Journal of the Air and Waste Management Association vol. 52, p. 1258-1262, November 2002