Quantification and characterization of In Vehicle Exposure on city roads in Kanpur, India: Passenger Car vs. School bus

Manish Agrawal[1*] and Anubha Goel[2]

[1, 2] Department of Civil Engineering, IIT Kanpur, Kanpur, UP, 208016, India
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*Presenting author email: amanish@iitk.ac.in

In vehicle exposure is now recognized as a significant contributor to total daily exposure to pollutants (Bigazzi and Figliozzi, 2012). Measurements inside cars near roadside in Portland, Oregon suggested that PM10 concentrations inside the vehicles exceeded outdoor concentration values by 3–5 times (Geiss *et al* 2010). A study conducted in three wheeled auto-rickshaws in New Delhi, India (Apte *et al* 2011) reports higher levels inside the vehicle than ambient air of fine, ultrafine, and black carbon particles. They have estimated one's exposure during a daily commute by auto-rickshaw in Delhi. For average daily commute (1.9 h d-1 for auto-rickshaw users), the time-integrated exposure is ~$530*10^3$ particles cm^{-3} h d^{-1}, which is more than entire day ultrafine particle number concentration exposures for California residents (~$330*10^3$ particles cm^{-3} h d^{-1}).

This preliminary study conducted on inner city roads in Kanpur (UP), India aims to examine in vehicle exposure caused to school going children during transport to school by bus and passenger cars.

Table 1. Comparison between exposure levels recorded in car and school bus during different time of day.

S. No.	PPAHs (ng/m^3) PAS (10s, 1 lpm)		Black Carbon (µg/m^3) AE51 (30s, 100 lpm)		$PM_{2.5}$ (pt/m^3) OPC (1 min, 1.3 lpm)	
	Average	Max.	Average	Max.	Average	Max.
Morning	210 **(313)**	1368	53.3 **(106)**	178.5	$1.5*10^9$ **(52)**	$2.1*10^9$
Afternoon (Car)	562 **(359)**	5705	140.3 **(119)**	158.5	$8.6*10^8$ **(60)**	$2.6*10^9$
Afternoon (School Bus)	312 **(707)**	1892	125.8 **(234)**	420.7	$4.8*10^8$ **(117)**	$6.6*10^9$
Evening	367 **(530)**	6197	105.3 **(145)**	702.8	$1.2*10^{*9}$ **(72)**	$1.9*10^9$

Sampling was conducted on two consecutive Thursdays: 26th February 2015 (passenger car), and 5th March, 2015 (school bus carrying children). Measurements were conducted for Particle bound PAHs (PPAHs using PAS); Black carbon (BC using AE51) and particles (using OPC, Optical Particle Counter). Sample interval time and flow rate for the instruments are noted in Table 1. Instruments were held at breathing zone level on passenger seat of car and in middle seat of school bus. In the school bus & car, only driver window was open and all the rest were closed during sampling. The route covered by both vehicles and experiences heavy traffic throughout the day. Traffic comprises all vehicle types, 2W, 3W and 4W, includes heavy vehicles as well. Car was driven thrice a day on the same route during the peak traffic hours in morning (8 to 10 AM), afternoon (12 to 2 PM) and evening (6 to 8 PM). Bus route was covered 2 times in the bus (6 AM to 8 AM & 12 noon to 2 PM). Levels observed are noted in Table 1, and represent data collected during time spent in covering the whole route. The averages are based on the number of data points (noted in bracket) during the day.

As expected, the results are in keeping with traffic flow pattern at different times of the day. Average values for PPAHs & BC, for which diesel is a major source, follow the same trend and were highest in the afternoon. This can be attributed to emissions from heavy duty vehicles, which use only diesel, and are allowed to travel at that route in day time. Only few heavy duty vehicle were seen in morning and evening time. The highest maximum recorded levels occurred in evening for PPAHs and BC. Both average and maximum recorded levels rose steadily during the day for PPAHs. The fact that PAHs are highly toxic and recognized as human carcinogens by International Agency for Research on Cancer (IARC), WHO (Mastrangelo *et al* 1996), makes this observation alarming.

Measurements in school bus in the afternoon reveal average levels lower than those recorded in car. Interestingly, the highest level recorded for PM2.5 and BC are 2.5 times higher in the bus. The trend is opposite for PPAHs; highest level is 3 times higher in cars than in bus. This suggests that exposure levels to children are markedly lower in a school bus than in a passenger car. One possible reason is the difference in volume of seating space in car and bus. Factors influencing indoor-outdoor ventilation rate, such as vehicle ventilation conditions, nature of traffic followed, etc. which in turn impacts levels inside the vehicle, needs further examination. This will aid efforts to fully assess exposure of children to toxic air pollutants during time spent commuting to and from school.

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