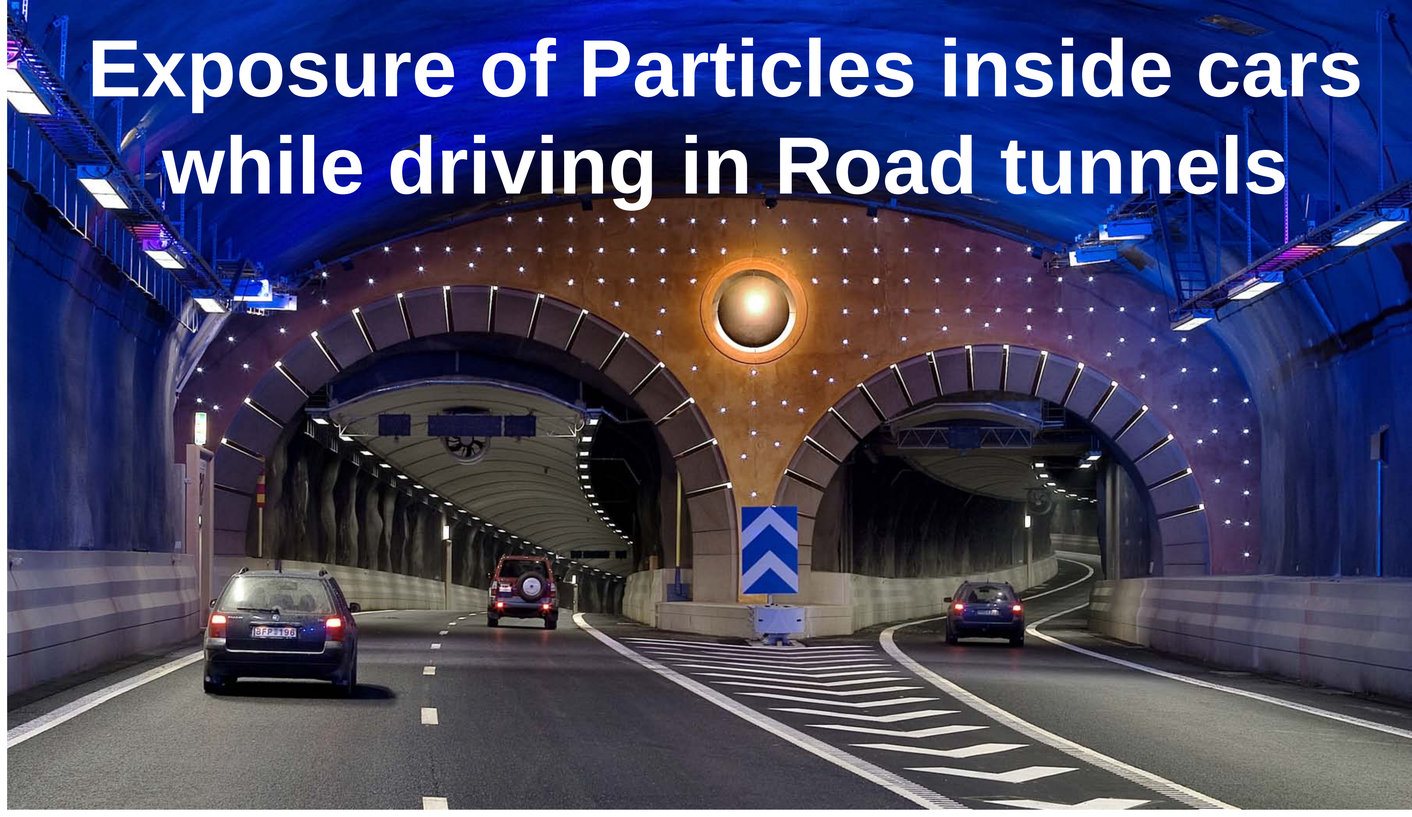
Exposure of Particles inside cars while driving in Road tunnels



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Introduction

A major bypass highway called “Bypass Stockholm” is being prospected passing outside Stockholm. 18 out of 20 km of the passing highway will be constructed as a highway road tunnel, which will be Europe’s longest highway tunnel. The air quality inside the tunnel is important due to the exposure of the passengers driving in the tunnel. A project initiated by the Swedish road administration was initiated in order to study the concentrations of pollutants inside vehicles in relation to the tunnel air and also with the aim to come up with guidelines or limit values for tunnel air.

Results

Table 1. *Range of concentration (average per passage) in the tunnel during the study.*

Component	Range of concentration
PM10, µg/m^3	350-1500
PM2.5, µg/m^3	60-170
Black Carbon, µg/m^3	15-30
Particle number, N/cm^3	140000-180000

Example of time series from Volvo V70

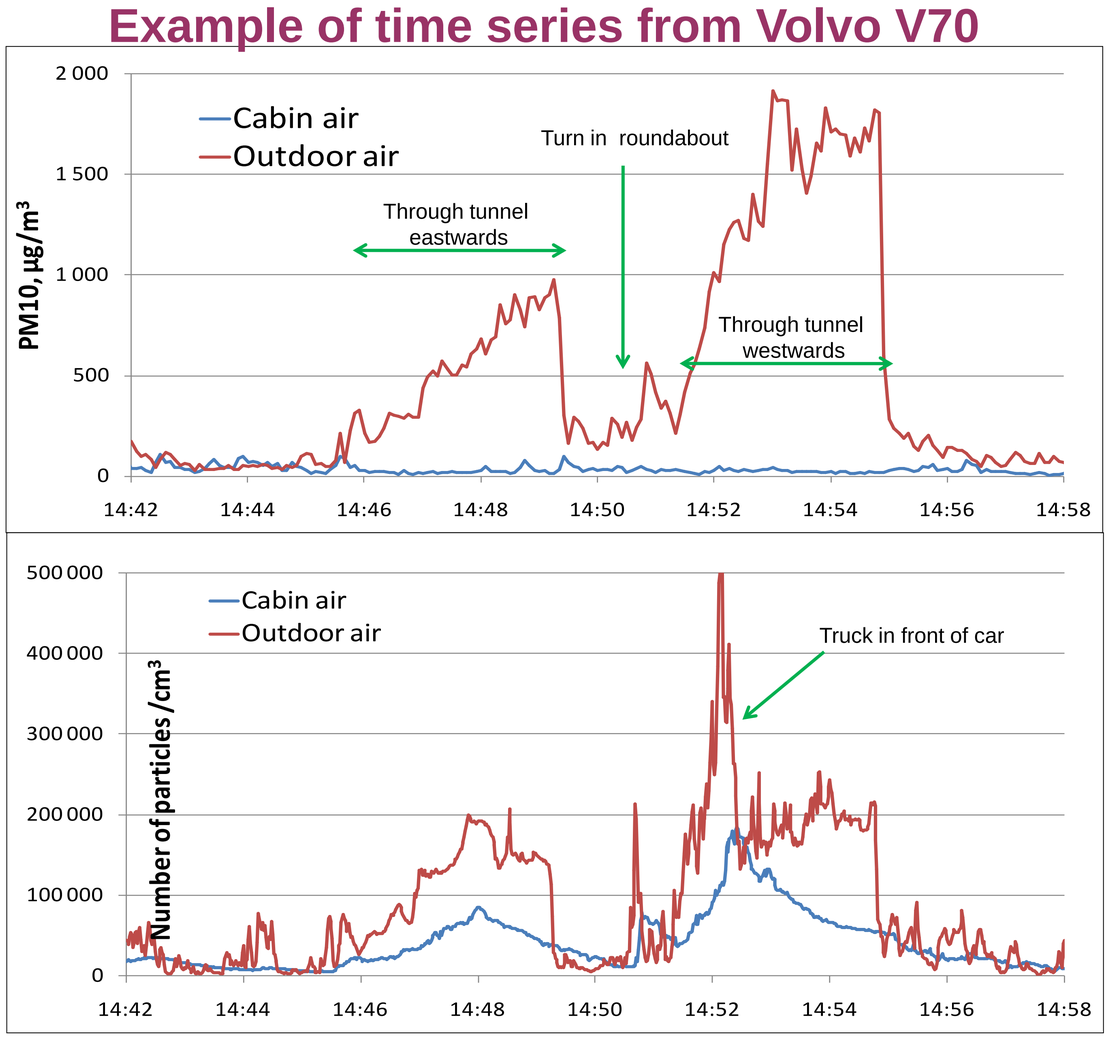

Figure 1. *Example of PM10 and particle number in and outside from one passage with the VOLVO V70.*

Movies from the experiment is available on youtube. Scan the QR-code to the left with your smartphone to be directed to the link.

Method

- Measurements inside and outside of personal cars while driving in 60-70 km/h through a 5 km long highway tunnel outside Stockholm (Södra länken)
- Two identical sets of instruments for measurements of PM10, PM2.5 (Lighthouse 3016-IAQ, 5 sec.), particle number (TSI-P-Trak 8525, 1 sec.) and black carbon (Magee Aethelometer AE51, 1 min).
- Tested with ventilation (air from outside) and recirculation of cabin air
- Three cars: Volvo V70 2011, Saab 95 2004, Ford Focus 2005

Statistical analysis, example from Ford Focus

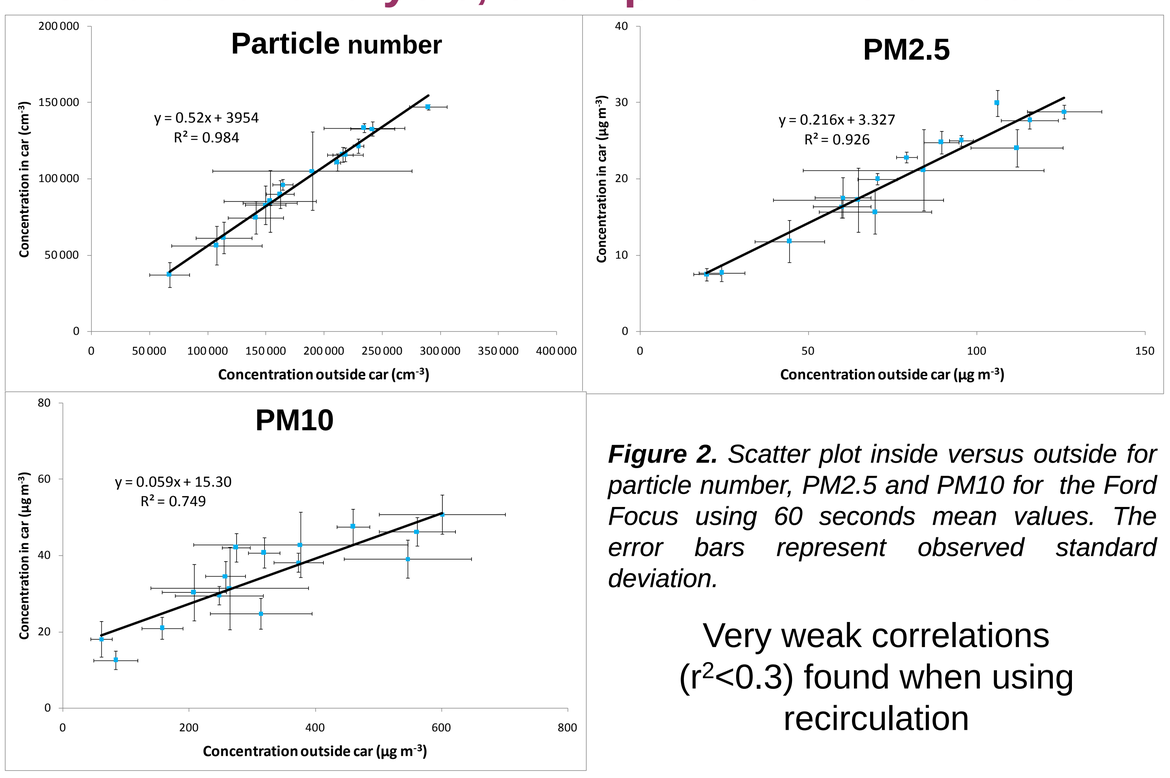

Figure 2. *Scatter plot inside versus outside for particle number, PM2.5 and PM10 for the Ford Focus using 60 seconds mean values. The error bars represent observed standard deviation.*

Very weak correlations (r^2<0.3) found when using recirculation

Table 2. *Statistical summary of all test with ventilation (air from outside).*

Component	Volvo		Ford		SAAB	
	slope	r^2	slope	r^2	Slope	r^2
PM10	0.016	0.51	0.059	0.75	0.041	0.91
PM2.5	0.069	0.39	0.22	0.93	0.14	0.96
Particle number	0.41	0.72	0.52	0.98	0.48	0.96

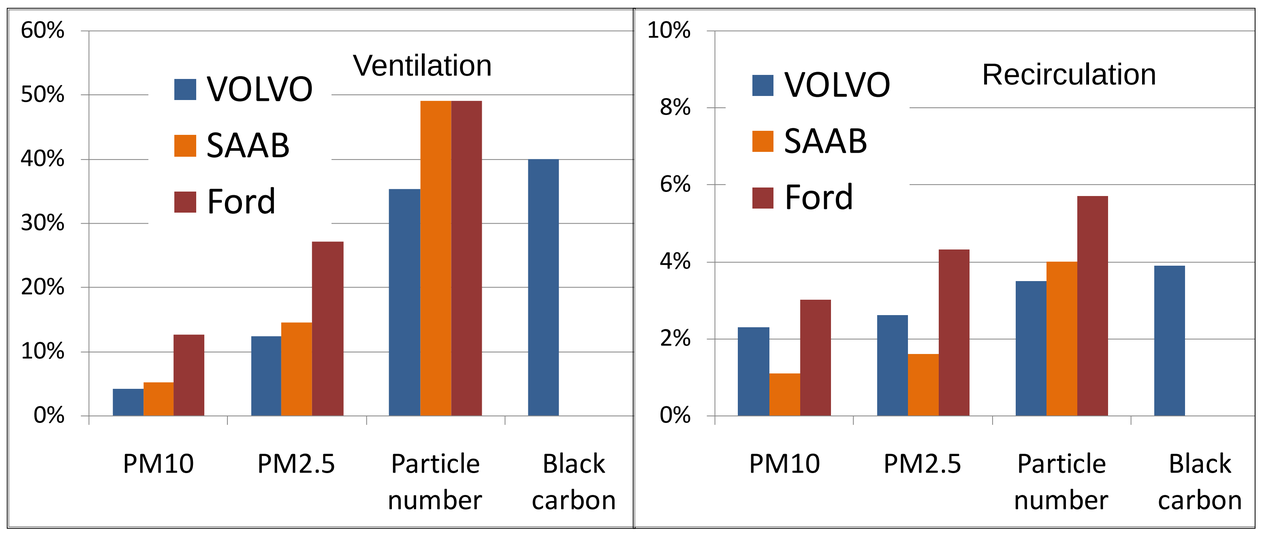

Figure 3. *Average ratio (%) between outdoor and cabin air concentration inside the tunnel.*

Conclusions

- The concentrations in the tunnel were significantly elevated in comparison to outdoor air
- Using the recirculation of the cabin air, was found to be very efficient in reducing the concentration inside the cabin
- Small particles, measured as particle number and black carbon, entered the cabin air to a much larger extent
- Larger particles from road wear (PM10) do not enter the vehicle cabins to a large extent
- Black carbon, particle number or NOx better exposure health indicators in road tunnels than PM10 or PM2.5