Black carbon, particle number concentration and nitrogen oxide emission factors of random in-use vehicles measured with the on-road chasing method

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ABSTRACT

We used the chasing method (Ježek et al., 2015) in an on-road measurement campaign, and determined emission factors (EF) of black carbon (BC), particle number (PN) and nitrogen oxides (NO_x) from 139 individual vehicles of different types. The results of the chasing campaign represent the first on-road study where BC EF of numerous diesel cars were determined, and provides EFs of BC, NO_x and PN measured for individual vehicles. We gained registration information for measured vehicles. Using the collected data we compared the representativeness of our measured fleet to Eurostat's statistical data on the Slovenian and European vehicle fleet; we demonstrate the effects of vehicle age, engine maximum power and vehicle size, and the contribution of high emitters to the total emissions of the measured fleet.

INSTRUMENTAITON

With our mobile measuring station we were chasing different vehicles on regional roads and highways. We measured increased concentrations of black carbon (Aethalometer AE33), particle number concentration (FMPS) and CO_2 (Carbocap 343) over the background level. The baseline concentrations that were measured before and/or after the chase were subtracted from the measured values. Assuming complete combustion of fuel, where all carbon in fuel burns to CO_2, emission factors were calculated as the amount of pollutant (P – BC, NO_x or PN) emitted per kg fuel consumed (Eq. 1). Carbon fraction w_c was set to 0.87 for both diesel and petrol powered vehicles.

$$EF_P = \frac{\int_{t_1}^{t_2} ([P]_t - [P]_{t_1})dt}{\int_{t_1}^{t_2} ([CO_2]_t - [CO_2]_{t_1})\,dt} \cdot w_c \qquad \text{(Eq. 1)}$$

First on-road BC EF of individual diesel cars

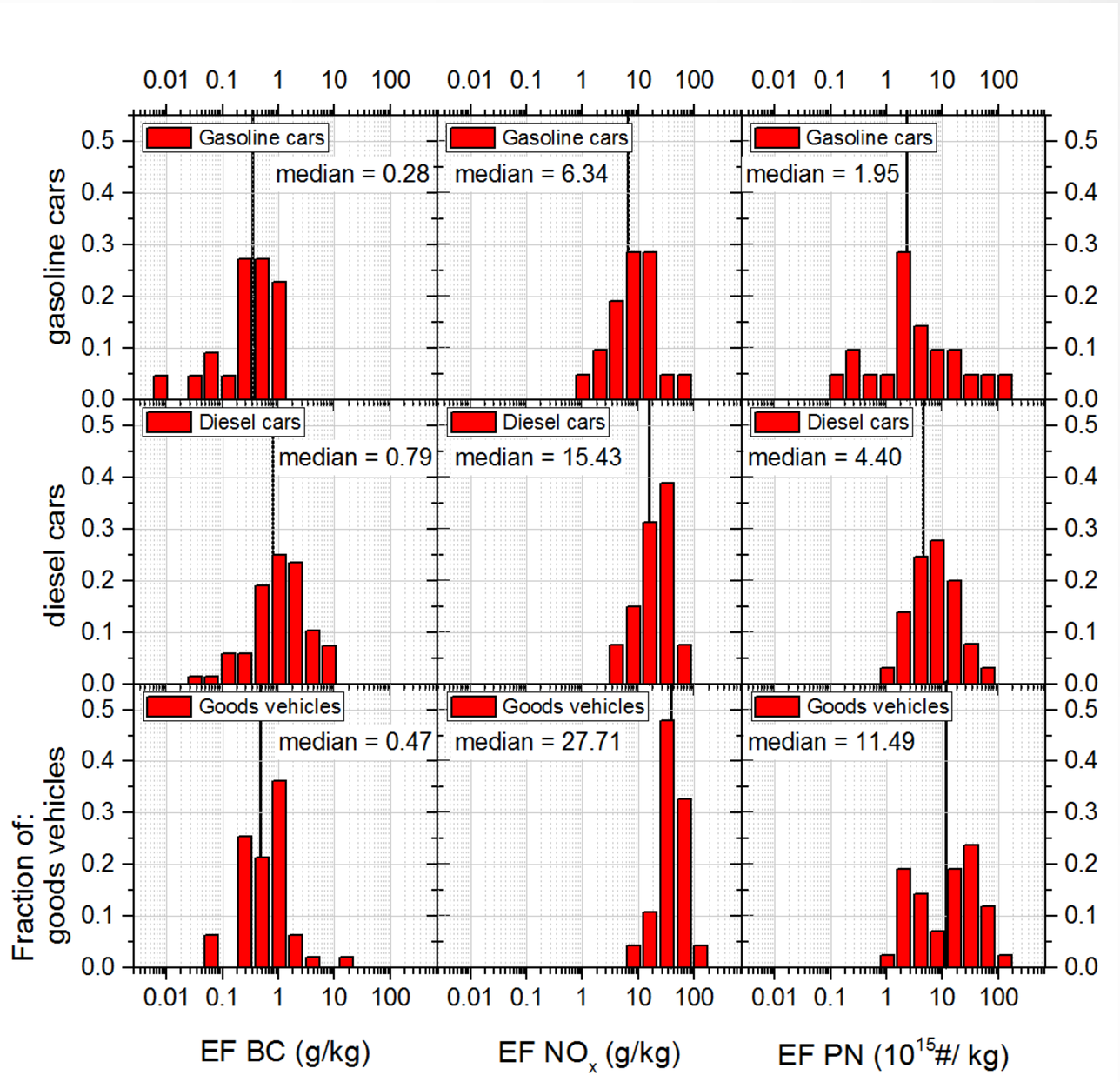

Figure 1: Black carbon (BC), particle number concentration (PN) and NO_x emission factor (EF) distributions for gasoline and diesel cars, light and heavy goods vehicles. Note the EF logarithmic scale.

Contribution of high emitters

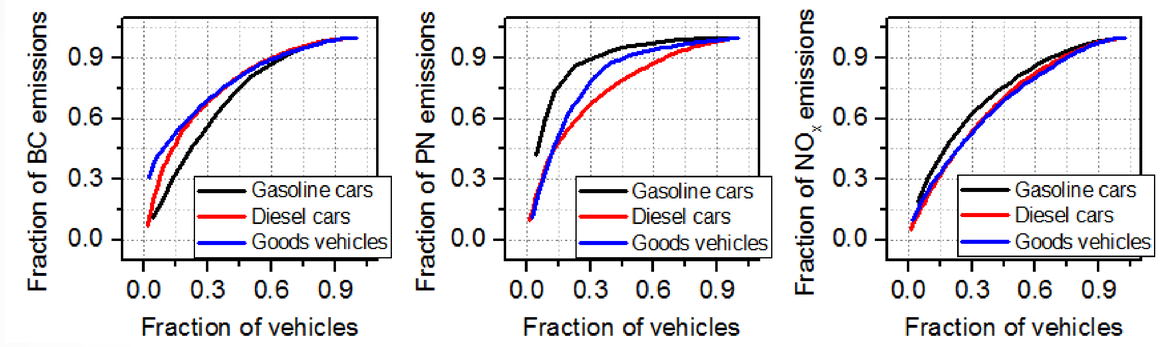

Figure 2: Cumulative distribution of all vehicles emissions. Fractions of vehicles are distributed from highest to lowest emitting vehicles. The result shows that 10% of vehicles contribute about a half of total BC and NO_x emissions.

Influence of vehicle age

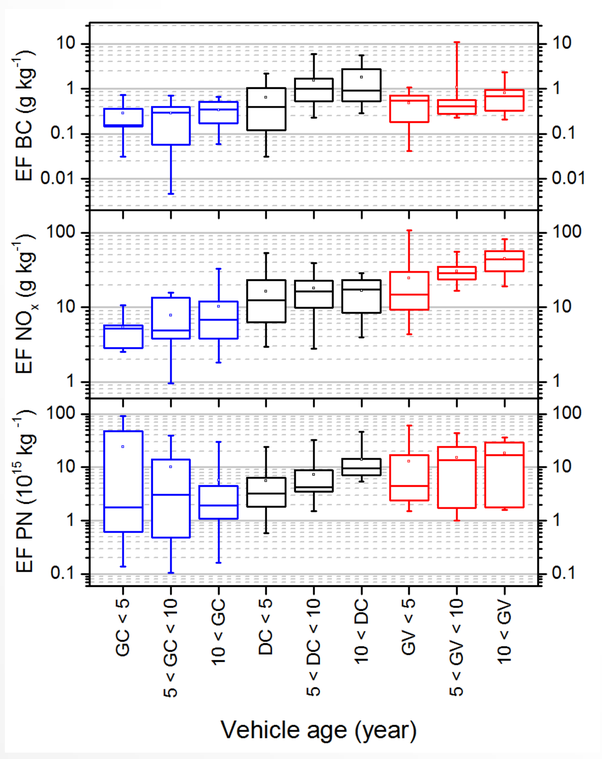

Figure 3: BC and NO_x EF according to different vehicle categories and age (in years) group subcategories: gasoline passenger cars (GC, blue), diesel passenger cars (DC, black), and goods vehicles (GV, red). Note the EF logarithmic scale.

Influence of vehicle power and mass

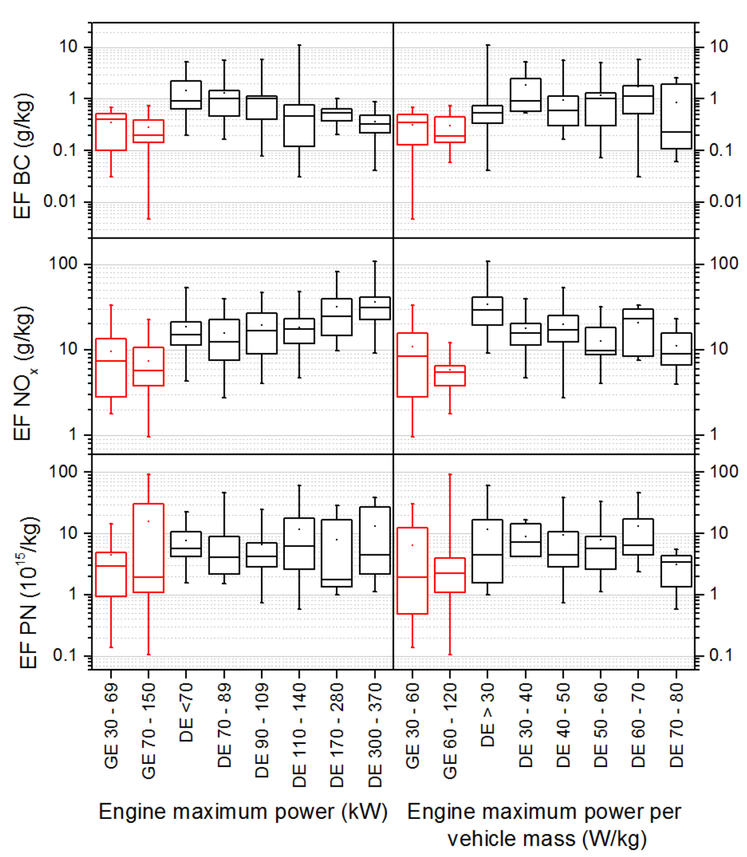

Figure 4: BC and NO_x EFs according engine power (left) and size (right); red boxes for gasoline engines (GE) and black boxes for all diesel engines (DE) regardless of their vehicle category. Note the EFs are on logarithmic scale.

Vehicle fleet composition inter-comparison

Table 1: Passenger car fleets according to their age, at the end of the year 2011.

		10 years or over	From 5 to 10 years	From 5 to 2 years	Less than 2 years
Europe	Total	42%	28%	19%	11%
Slovenia	Total	39%	34%	18%	9%
	Gasoline	50%	25%	15%	9%
	Diesel	18%	48%	23%	11%
This study	Total	27%	47%	29%	7%
	Gasoline	50%	25%	17%	8%
	Diesel	16%	49%	29%	6%

CONCLUSION

The main result of this study are the first reported BC EF for individual diesel cars measured in real driving conditions. We found good agreement with the results of previous studies that used the on-road measurement methods. The median BC EF of diesel cars that were in use for less than 5 years was reduced by a 60% compared to those in use for 5 – 10 years, but there was no decrease in median BC EF of the goods vehicles. PN and NO_x EF of goods vehicles were reduced by 52% and 67%, respectively.

The methodology used in this study is a relatively simple and efficient approach for monitoring emissions of the in-use vehicle fleet, and investigating the effectiveness of emission reduction measures. Real world measurements are important because individual vehicle emissions depend not only on the vehicle type approval at the time it is put on the market, but also on their maintenance and the driving conditions.

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REFERENCE

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