Analysis of In-Vehicle Black Carbon Exposure and Trip Characteristics Using GPS Logs and Diaries

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Summary

In this study we measured in-vehicle exposure to black carbon. It was found that several traffic and road characteristics influence exposure: BC concentrations in vehicles are related to speed, timing of a trip, degree of urbanization, road type, and traffic intensities.

Introduction

Global Positioning Systems (GPS) are being used more frequently in health research. To limit respondent burden, and because of technical problems with the development of miniaturized air quality sensors; exposure is determined afterwards by linking GPS traces with air pollution models or nearby monitoring stations. In-vehicle exposure may however be not only related to yearly averaged outdoor concentrations.

The aim of this research is to investigate whether the levels of in-vehicle Black Carbon (BC) concentrations are influenced by trip duration, hour of the day, traffic intensities, and spatial parameters like degree of urbanization or road type.

FIGURE 1: µ-Aethalometer and PDA with electronic diary and GPS

TABLE 1: Technical specifications of the devices

	Time base	Tech Specs
GPS receiver	1-sec	GPS receiver integrated in PDA (Personal digital assistant, type MIO 168, weight 147 g, 4 hours run time on single battery charge if in use, 12 GPS channels)
Electronic diary	5-min	Custom designed software *PARROTS* installed on PDA
Micro-aethalometer AE51	5-min	Flow rate 100 mL/min, weight 280 g, 24 hours run time on single battery charge

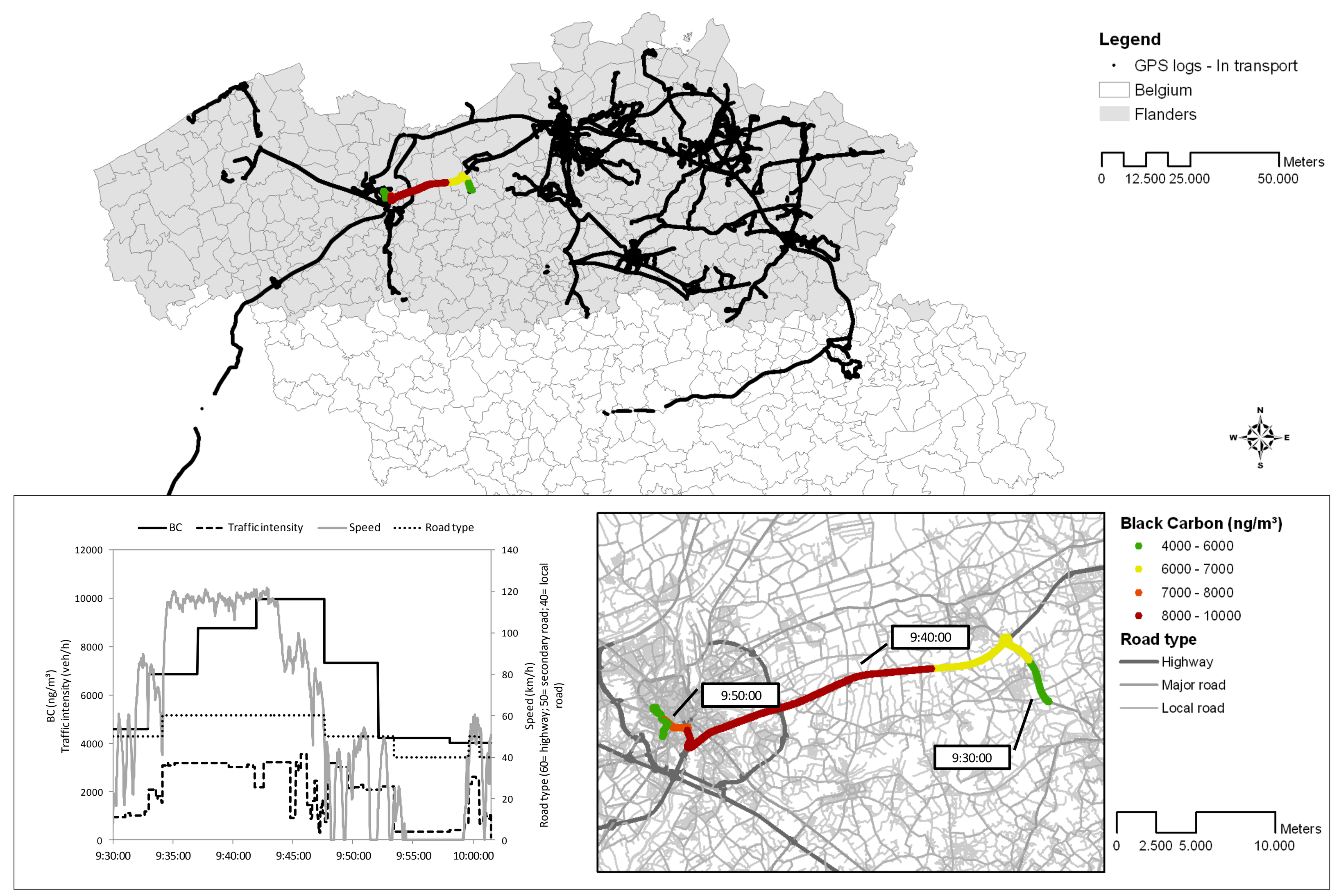


FIGURE 2: Top: Overview of all GPS logs captured by 62 volunteers. Bottom: excerpt of a single car trip illustrating the different temporal resolution between GPS waypoints and BC measurements.

Materials and methods

Personal exposure to BC is measured with a portable aethalometer (microAeth® Model AE51), worn by 62 individuals for 7 consecutive days. During the sampling, participants were urged to meticulously keep track of their executed activities by reporting them in an electronic diary fitted with a GPS (figure 1, table 1). More information on the configuration of the devices can be found in Dons et al. (2011). Sixteen people took part in a pilot study in summer 2010; half of them participated again in a more elaborate campaign in winter 2010-2011. The winter campaign was supplemented with 38 new participants. Participants were living in Flanders, Belgium.

In ArcGIS 10 waypoints were joined to the nearest road and the attributes associated with this road. If the distance to the nearest road was larger than 30m, no road characteristics were linked to the BC-observation (figure 2).

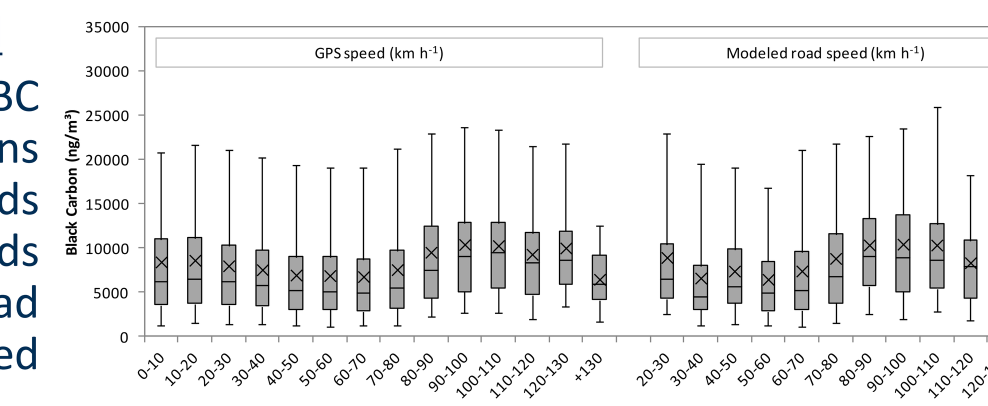
Results

Average in-vehicle concentration is 8036 ng/m³, whereas the average concentration at home is 1246 ng/m³, exposure in transport is thus significantly higher. There are differences between different modes of transport: mean exposure of active travelers is 4290 ng/m³.

During traffic peak hours (morning peak between 7 and 10 a.m., evening peak between 4 and 7 p.m.) exposure of motorists is higher than during off-peak hours.

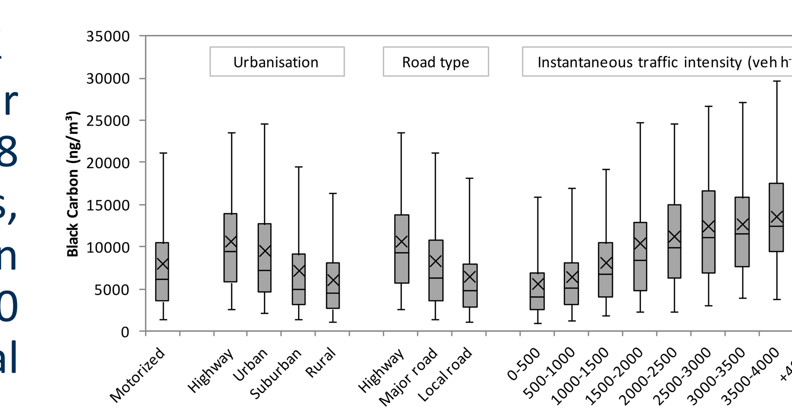
The length of a trip was not of direct influence when considering exposure of car drivers or passengers: there is no build-up of particles inside the car. On the other hand, trip duration is linked to the use of certain road types and this does affect exposure levels: car trips <15min are on highways for only 4% of the time; trips >45min have a larger share of highway use (45%).

Travel speed and traffic speed



Travel speed is related to BC exposure: in-car concentrations are elevated at lower speeds (up to 30 km/h) and at speeds above 80 km/h. Using road speed instead of travel speed does not influence the results.
The speed-exposure function shows a similar pattern than the BC emission function with a trough at speeds around 70 km/h, and with a sharp increase at higher speeds. At lower speeds in urban traffic, or when congestion is present on highways, following distance to other vehicles decreases and emissions can infiltrate in vehicles nearby.

Urbanization, road type, traffic intensity



In urban areas exposure is higher compared to more rural areas (9568 ng/m³ versus 6105 ng/m³). On highways, exposure of motorists is higher than on major and local roads (Highways: 10680 ng/m³ - Major roads: 8359 ng/m³ - Local roads: 6501 ng/m³).
Exposure increases linearly with traffic intensities. Large differences exist between quiet roads and busy roads: the average concentration in cars changes from 5646 ng/m³ to 13623 ng/m³. An exception to this linear trend are highway entries and exits, they have low traffic intensities but have an elevated in-vehicle concentration (due to heavy acceleration and proximity to the highway).

Conclusions

We found a positive association between in-vehicle BC exposure and traffic intensity. In urban areas exposure of motorists is higher compared to exposure in more rural areas; the same holds for highways versus local roads. In-vehicle exposure is highest while driving with speeds around 20 km/h and 100 km/h. There is no build-up of particles inside vehicles, but the duration of a trip is linked to the time spent on each road type. Traveling in traffic peak hours, increases exposure .

References

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