Emissions of black carbon in a road tunnel

C. Blanco-Alegre[1], A.I. Calvo[1], C. Alves[2], P. Fialho[3], T. Nunes[2], J. Gomes[2], A. Castro[1], F. Oduber[1], E. Coz[4], R. Fraile[1], C. Pio[2*]

(1) Department of Physics, IMARENAB University of León, 24071 León, Spain
(2) Centre for Environment and Marine Studies, Department of Physics, University of Aveiro, 3810-193, Aveiro, Portugal
(3) IVAR, University of Azores, 9700-042 Angra do Heroísmo, Portugal
(4) Centre for Energy, Environment and Technology Research (CIEMAT), Department of the Environment, Madrid, Spain
*casimiro@ua.pt

Keywords: absorption coefficient, aethalometer, eBC, exhaust emissions, gaseous correlations, tunnel.

INTRODUCTION

Traffic exhaust emissions of motorized vehicles are one of the main sources of $PM_{2.5}$ in many urban areas (Bycenkiene et al., 2014). Besides, traffic non-exhaust emissions, such as particles from tyre wear, brakes, road surface abrasion and dust resuspension, are one of the principal contributors to airborne particulate matter, mainly in semi-enclosed places like tunnels (Querol et al., 2004). Previous work has focused on the determination of emission factors for particulates and gaseous components in tunnels. However, continuous measurements of black carbon (BC) levels in these road structures are practically non-existent.

This study will contribute to improving BC emission profiles, particularly for the road sector, in the urban areas of southern Europe. In addition, continuous data will make possible to establish relationships between BC and other parameters like gaseous, providing fundamental data for several climate models or to improve ventilation systems.

STUDY AREA

- **BRAGA (PORTUGAL) -** Population: 137,000 inhabitants with 991 inhabitants km^{-2}
- Sampling was carried out in the longest tunnel of the municipality. (1040 m), which serves as the gateway to the city (Figure 1).
- Ventilation system was off during the sampling campaign.
- During sampling, the concentration background were measured in an urban background station.

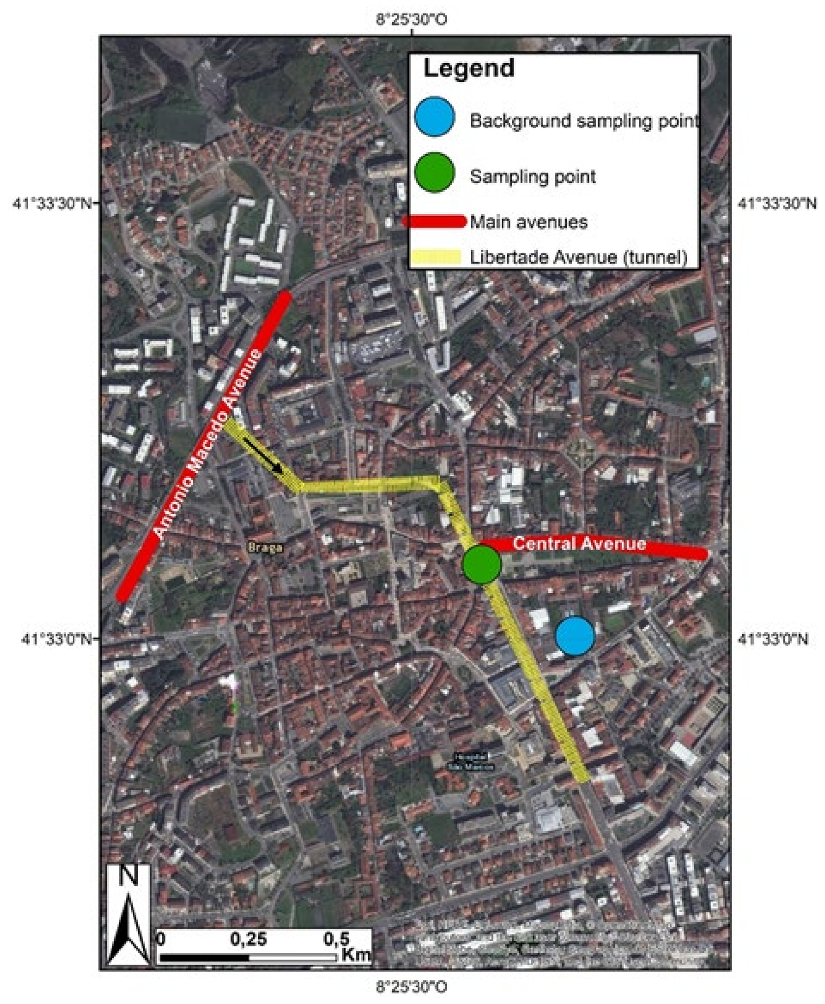


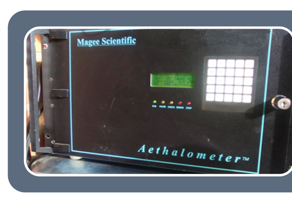
Figure 1. Geographic location of the sampling site in Braga (Portugal). Yellow fractional line indicates the tunnel, the arrow the traffic direction, the blue dot represents the background sampling point and the green dot the sampling point inside the tunnel. The main avenues of Braga were represented with continuous red lines.

Sampling campaign

1 February 2013 → 8 February 2013

MATERIAL

Traffic volume (manual counts, 15-minute intervals)



Quantification of BC (AE-31 spectrometer)

CO and **CO_2 levels** (WolfSense IQ-610 Automatic Infrared)

NO and **NO_2 levels** with analyzers from Environment S.A. (model 31M)

CO & CO_2 concentrations → BC concentration → Absorption Ångström exponent ($AAE_{470-950nm}$) → Corrections based on Weingartner et al. (2003)

RESULTS

Table 1. Daily equivalent Black Carbon (eBC) (µg m^{-3}), $AAE_{470-950nm}$ (mean, minimum and maximum) and number of vehicles registered during the sampling campaign.

Day of the week	eBC mean	eBC max.	eBC min.	AAE mean	AAE max.	AAE min.	Sum of veh.	Veh. h^{-1}
Friday	20 ± 12	45	1	0.95 ± 0.09	1.22	0.84	7319	477
Saturday	23 ± 8	42	13	0.92 ± 0.07	1.09	0.83	6705	339
Sunday	20 ± 4	28	13	1.00 ± 0.06	1.24	0.92	3738	196
Monday	23 ± 12	40	2	1.00 ± 0.13	1.27	0.84	9376	426
Tuesday	24 ± 9	49	10	0.95 ± 0.04	1.03	0.87	8865	454
Wednesday	17 ± 8	30	0	0.98 ± 0.13	1.47	0.81	10119	426
Thursday	19 ± 9	31	2	1.00 ± 0.10	1.26	0.89	9844	447
Mean	21 ± 10	49	0.1	0.97 ± 0.10	1.47	0.81	55966	395

- The daily mean eBC mass concentration was 21±10 µg m^{-3} (Figure 2).
- The eBC concentration reached a maximum value of 49 µg m^{-3} (Tuesday, 05/02/2013 at 1800 UTC).
- The mean of total vehicles during weekdays was around 10,000 vehicles, while in weekend there was a decreased in the traffic density of around 40 % (Table 1).
- Peak concentrations on weekdays occurred between 1400 and 1900 UTC, during the rush hours, when large numbers of people are travelling to or from work or school. However, on weekends, a peak between 1000 and 1200 UTC was observed, probably due to commuting to shopping and leisure activities (Figure 3).
- On Monday, a peak was registered between 0800 and 1200, with a greater circulation of trucks and heavy vehicles.

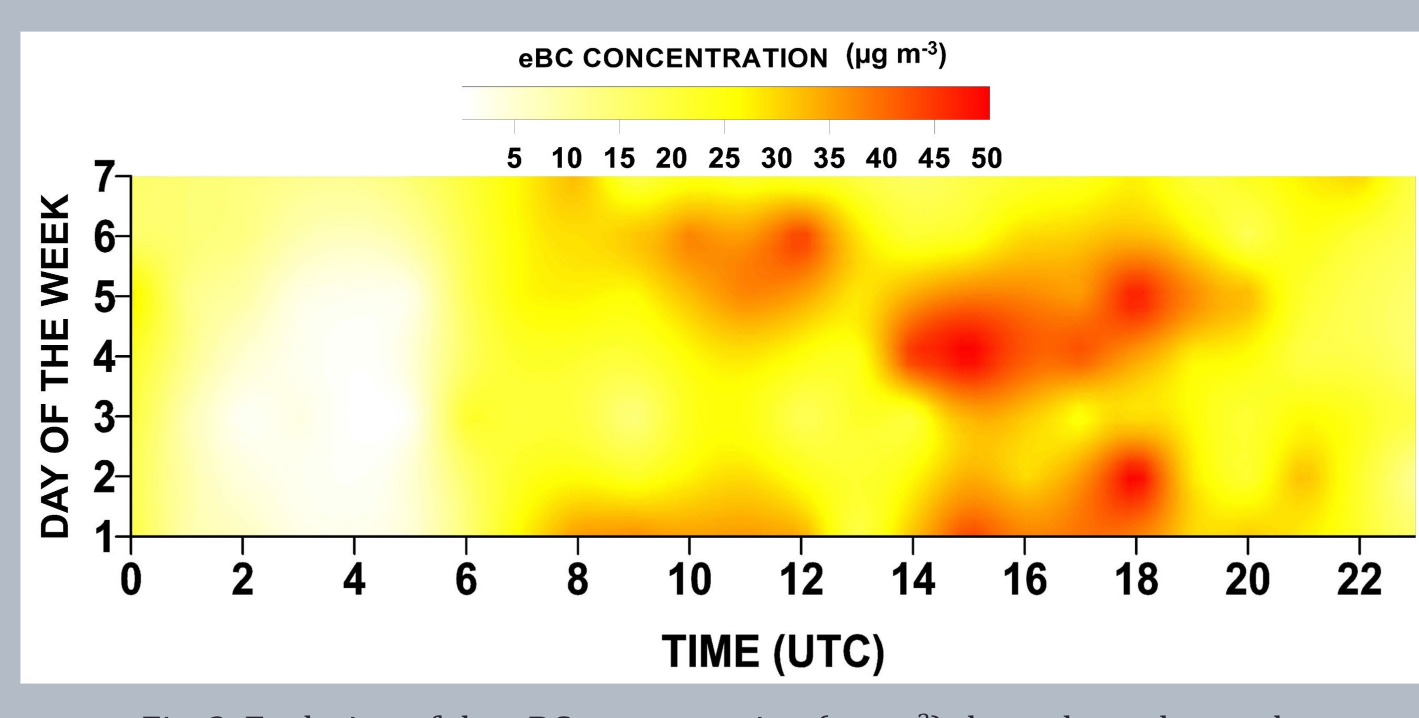


Fig. 2. Evolution of the eBC concentration (µg m^{-3}) throughout the week. The first day of the week is Monday.

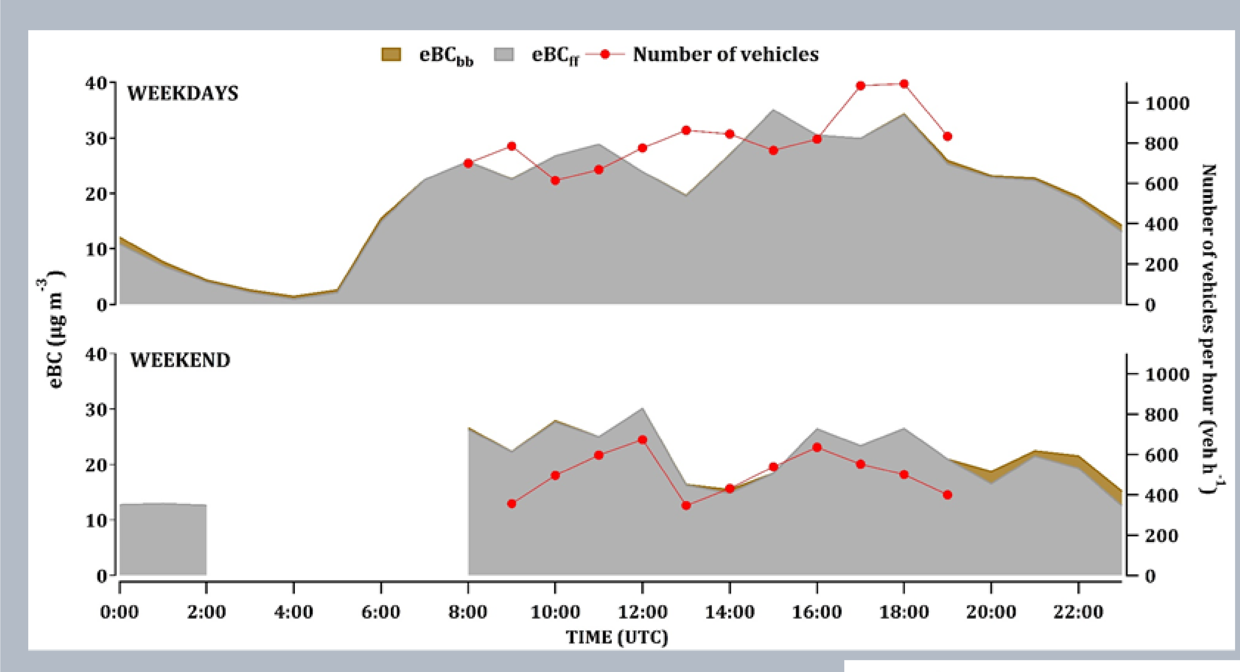


Figure 3. Evolution of eBC_{ff}, eBC_{bb} concentration (µg m^{-3}) and number of vehicles per hour throughout the day along weekdays and weekend.

- The contribution from fossil fuel (eBC_{ff}) and biomass burning (eBC_{bb}) was estimated through the Aethalometer Model (Sandradewi et al., 2008).
- eBC_{ff} was 21±10 µg m^{-3} (about 98 % of total eBC), while eBC_{bb} was 0.4±0.8 µg m^{-3}.
- The mean black carbon emission factors (EF_{BC}) were estimated to be 0.31±0.08 g (kg fuel)$^{-1}$ and 0.11±0.08 mg veh^{-1} km^{-1}, which are higher than those derived in other studies for gasoline and diesel vehicles in road tunnels.

- A mean Absorption Ångström Exponent ($AAE_{470-950nm}$) value of 0.97±0.10 was obtained.
- Positive significant correlations were observed between eBC and the gaseous emissions: CO, CO_2, NO and NO_2 (Figure 4).

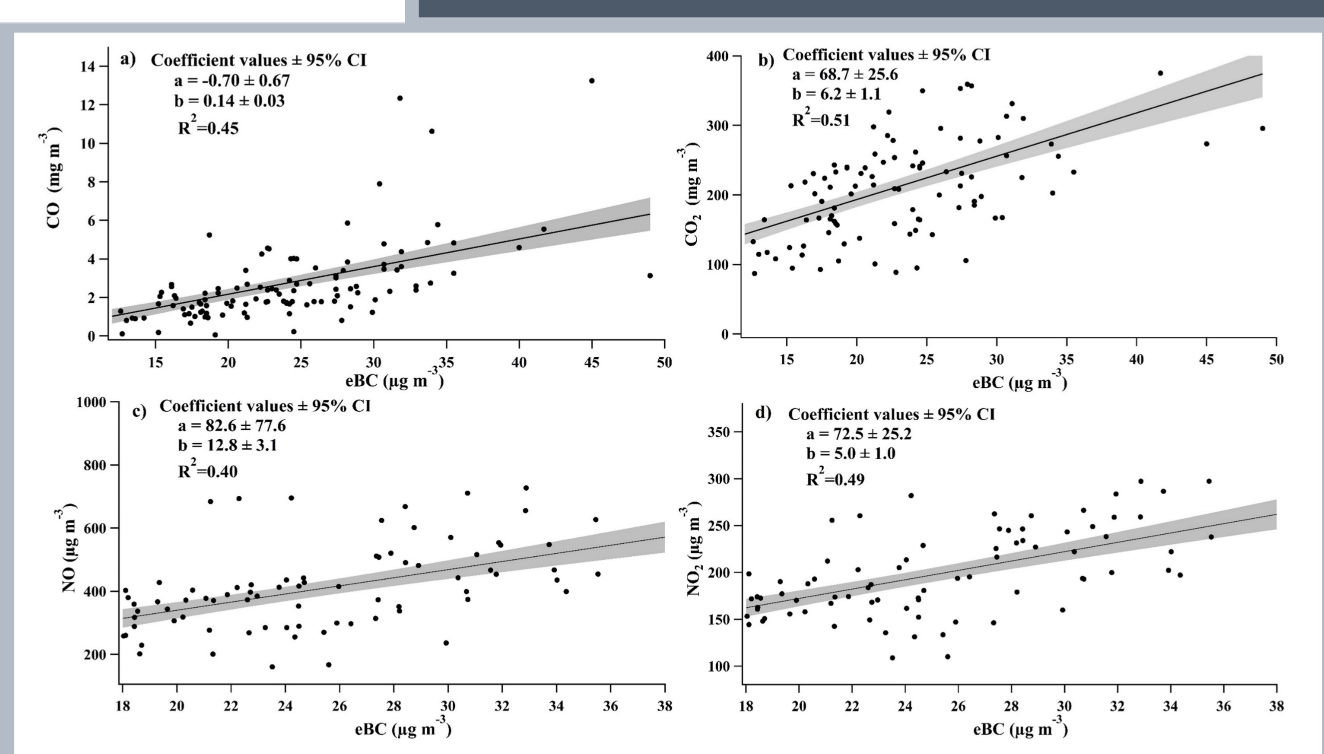


Figure 4. Linear regression and confidence bands (shaded) with 95% significance level between eBC concentrations and levels of: a) CO b) CO_2 c) NO and d) NO_2.

CONCLUSION

The study of black carbon in a road tunnel contributes to better characterize emissions of this pollutant from traffic in real circulation conditions and without influence from other sources providing valuable information on BC emission factors, which are useful as input data to climate and air quality models, as well as to updated emission inventories. Furthermore, the quantification of BC is essential to assess air quality in road tunnels and, thus, improve ventilation systems.

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ACKNOWLEDGEMENTS

The sampling campaign described in is work was funded by the Portuguese Science Foundation through the project “Source apportionment of URBan Emissions of primary particulate matter”, PTDC/AAC-AMB/ 117956/2010 (URBE). Special thanks are given to the Braga City Council, Municipal Police and University of Minho for all the logistic support. F. Oduber and C. del Blanco Alegre acknowledge the grants BES-2015-074473 and FPU16/05764 from the Spanish Ministry of Economy and Competitiveness and the Spanish Ministry of Education, Culture and Sports, respectively. This study was partially supported by the University of León (Programa Propio 2018/00203/001) and the AERORAIN project (Ministry of Economy and Competitiveness, Grant CGL2014-52556-R, co-financed with FEDER funds). Data treatment was carried out within the project “SOPRO - Chemical and toxicological SOurce PROfiling of particulate matter in urban air”, POCI-01-0145-FEDER-029574, funded by FEDER, through COMPETE2020 - Programa Operacional Competitividade e Internacionalização (POCI), and by Portuguese funds (OE), through FCT/MCTES.