LONG-TERM MEASUREMENT OF BLACK CARBON CONCENTRATION AND SOURCE APPORTIONMENT ANALYSIS

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Abstract

Continuous measurement of black carbon (BC) concentrations in ambient air was performed using the optical-based instrument called aethalometer. The attenuation of light by BC was measured at 7 different wavelengths. This gives not only the pure concentration of BC in the ambient air but also dependence of attenuation on the wavelength of light, from which the Angstrom exponent can be derived. Based on the Angstrom exponent, we can estimate the percentage of BC that originates from solid fuel (wood and coal burning) or liquid fuel (diesel). Thus, a simple source apportionment analysis is presented.

Keywords: black carbon; source apportionment; fossil fuels; biomass burning.

1. Introduction

Aerosol black carbon (BC) is a very important component of air pollution. It originates from incomplete combustion of fossil fuels and has deep effects on climate. It is argued that BC is the second largest anthropogenic climate change factor [1], [2] (carbon dioxide being first). The negative health effects of black carbon are well documented [3], [4]. Thus, the research on black carbon is a very significant step towards decarbonization. Previous research articles include Evaluation with a Photoacoustic Instrument [5], method comparisons [6], vertical profiles over Milan [7], diesel exhaust [8], wood combustion particles [9], emissions from fresh biomass burning [10], and source apportionment [11]. The novelty in this article is the long-term campaign of continuous BC measurement with source apportionment analysis.

2. The aethalometer

The instrument for the measurement of BC concentration is called aethalometer (the word comes from the classical Greek verb *aethaloun* which means “to blacken with soot”). The AE33 aethalometer, Magee Scientific, USA (Figure 1) is used in this research. The main specifications of AE33 are:

- 7 measurement wavelengths: 370, 470, 520, 590, 660, 880 and 950 nm,
- Airflow: set-points of 2, 3, 4, and 5 LPM,
- Max power consumption: 90 W. Typical power consumption: 25 W.

Figure 2 shows the flow diagram of AE33. The inlet cyclone, at the beginning of the air sampling line, separates particles greater than 2.5 mm in diameter. BC particles are collected on filter tape and the light absorption method is used to calculate BC concentration at 880 nm of wavelength, as described in our previous work [12]. The black carbon facility is one component of a larger project of our research group, where different aspects of air pollution are observed and compared, including toxic gases [13], [14], and particulate matter [15]-[21].

Fig. 1. The aethalometer.

Fig. 2. AE33 flow diagram (image source: AE33 user manual)

3. Measurements of black carbon in Sarajevo

The test facility is located at the Faculty of Mechanical Engineering in Sarajevo (Figure 3). The average concentration of BC in the period 27.11.2020 - 31.5.2021 was $5,67 \mu\text{g}/\text{m}^3$, or 14,82% of total $\text{PM}_{2.5}$ mass. Figure 4 shows the daily average values of BC concentrations. Since we have measurements from all 7 wavelengths of light, we can calculate the Angstrom exponent [12]. If we assume that value 1 corresponds to liquid fuel (diesel) and value 2 of Angstrom exponent corresponds to biomass burning, we can estimate the biomass burning percentage in total BC mass (Figure 5). From Figure 5 we can see that up to 70% of BC comes from burning solid fuels in the winter (domestic heating season), and only around 20% in May, when the majority of BC comes from diesel engines.

Fig. 3. The location of measurements.

Fig. 4. Daily average values.

Fig. 5. Biomass burning percentage.

Figure 5 also shows significant noise in the results, which should be investigated in more details. But even though this is a rough estimate, this method is a very promising tool for source apportionment of BC.

4. Conclusion

The AE33 aethalometer was successfully used for continuous measurement of BC concentration in Sarajevo from 27.11.2020 - 31.5.2021. The average value of BC concentration was $5,67 \mu\text{g}/\text{m}^3$, or 14,82% of total $\text{PM}_{2.5}$ mass. Angstrom exponent based source apportionment analysis shows that during the domestic heating season most of the BC originates from solid fuels, as expected. However, during May, only 20% of solid fuels and 80% of liquid fuels contributed to the total BC mass. The Angstrom exponent based source apportionment of BC is a very promising tool and it should be investigated more in future work.

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