Report of the project ATMO-TNA-3-0000000133

Determination of equivalent Black Carbon Concentrations by MABI (Multi-Wavelength Absorption Black Carbon Instrument) and of the respective mass absorption cross section (MAC)

Lucyna Samek[(1)], Evangelia Diapouli[(2)], Anna Ryś[(1)], Stefanos Papagiannis[(2)], Vassiliki Vassilatou[(2)], Rakshit Jakhar[(3)], Konstantinos Eleftheriadis[(2)]

[(1)] AGH University of Krakow, Faculty of Physics and Applied Computer Science, Al. Mickiewicza 30, 30-059 Krakow, Poland

[(2)] National Center of Scientific Research "DEMOKRITOS", Institute of Nuclear and Radiological Science and Technology, Energy and Safety, , Agia Paraskevi, 15310 Athens, Greece

[(3)] AGH University of Krakow, Faculty of Energy and Fuels, Al. Mickiewicza 30, 30-059 Krakow, Poland

Introduction

Equivalent black carbon (eBC) is generated from the partial combustion of fossil fuels and biomass. The scientific interest in eBC is large because its contribution to the $PM_{2.5}$ fraction is high, especially in urban areas. It should be noted that combustion-related aerosols (including eBC) have been linked to adverse health effects and are considered more harmful than other aerosol components. In addition, eBC is considered the second most important component of global warming in terms of direct forcing. Until now, there is a lack of information on eBC concentrations in Poland, mostly due to lack of relevant instrumentation. The position of Poland in the centre of Europe, as well as the presence of multiple combustion sources, make this type of measurements and data very relevant to the scientific community, both for health impact assessment and climate change studies.

In the present study, the MABI (Multi-Wavelength Absorption Black Carbon Instrument), a new instrument measuring light transmission of particles collected on filters, was assessed. MABI was developed by the Australian Nuclear Science and Technology Organization (www.ansto.gov.au). The instrument consists of an optical assembly and electronic case. The instrument optics includes, among others, the multi-wavelength light source (7 LEDs), sampler holder, and photodetector. In the instrument, opaque glass is used to scatter the scattered light back through the filter to the detector. MABI offers the advantage of off-line measurements of aerosol light transmission, at seven fixed wavelengths (from 405 nm to 1050 nm).

The purpose of the project was (i) to calculate the mass absorption cross section (MAC) for the MABI and (ii) to calibrate MABI through parallel measurements with an aethalometer. To this end, PM_{10} and $PM_{2.5}$ samples were collected in two urban background sites, in Krakow, Poland and in Athens, Greece, and during two seasons of the year (heating and non-heating

periods) onto different types of filters (Quartz, Teflon,). The samples were analysed by MABI in order to determine absorption and eBC concentrations.

Methods

In Krakow, samples of $PM_{2.5}$ were collected from 2nd January to 31st January 2024 and from 2nd June to 29th June 2024. Samples of PM_{10} were collected from 2nd January to 31st January 2024 and from 3rd June to 30th June 2024. In Athens, samples of $PM_{2.5}$ were collected from 1st February to 21st February and 20th June to 14th July 2024. Samples of PM_{10} were collected from 13th January to 31st January 2024. All filters were measured by MABI, in the respective city. Additionally, a set of winter samples from Krakow was measured by MABI in Athens, in order to verify the comparability of results of the two instruments, operated by AGH University of Krakow and NCSR "Demokritos", respectively. Similar readings were obtained by both MABI. Mass absorption coefficients provided by the manufacturer were used in order to calculate eBC from light transmission data (Ryś and Samek, Atmosphere, 2022).

Quartz fiber samples were also analysed for the determination of elemental carbon (EC) concentration, by thermo-optical transmittance (TOT), with the use of a Lab OC-EC Aerosol Analyzer (Sunset Laboratory, Inc.), available at the ATMOS-NCSR observational platform, in Athens, Greece (Cunha-Lopes et al., 2023). Quartz filter samples were heated first up to 650 °C in He and then up to 850 °C in a mixture of 2% O_2 in He, using the controlled heating ramps of the EUSAAR_2 thermal protocol. During this analysis, OC evolves in the inert atmosphere, while the thermal refractory fraction EC is oxidized in the He-O_2 atmosphere. Pyrolitic carbon (PC) may be formed during the first stage of analysis and for this reason charring correction is applied by monitoring the sample transmittance throughout the heating process. The limit of detection (LOD) is 0.05 μg C cm^{-2}. The QA/QC procedures of EN 16909:2017 was followed during TOT analysis. EC data were used in order to calculate site-specific mass absorption cross section (MAC) values for the MABI.

Finally, an aethalometer (AE33, Aerosol Magee Scientific) was used in parallel to PM sampling in Athens, in order to provide a reference eBC value, against which the performance of MABI was assessed. The instrument is operating on a continuous basis at the ATMOS-NCSR observational platform.

Results

The linear regression of absorption (babs) at 880 nm measured by AE33 and EC concentrations measured on PM_{10} quartz fibre filters is shown in Figure 1. An average MAC value of 5 was obtained, in agreement with previous studies (Diapouli et al., 2017). A time-series of winter data on EC and eBC estimated by AE33 is provide in Figure 2, demonstrating the very good agreement between eBC and EC concentrations. The absorption data obtained by MABI (at 870 nm) were compared with the corresponding average values measured continuously by AE33 (at 880 nm) in Athens (Figure 3). A very good correlation was observed, but with a significant overestimation of absorption my MABI.

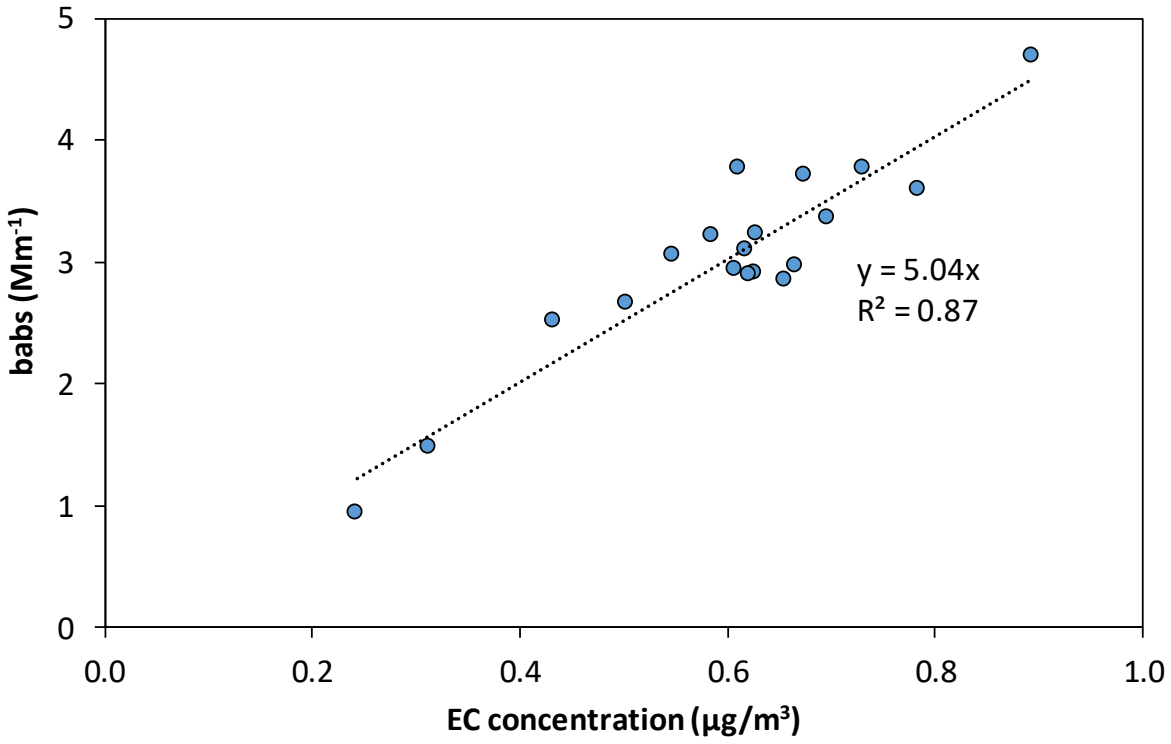

Figure 1. Linear regression of absorption measured by AE33 at 880 nm versus EC concentrations measured in PM_{10} by TOT, in Athens.

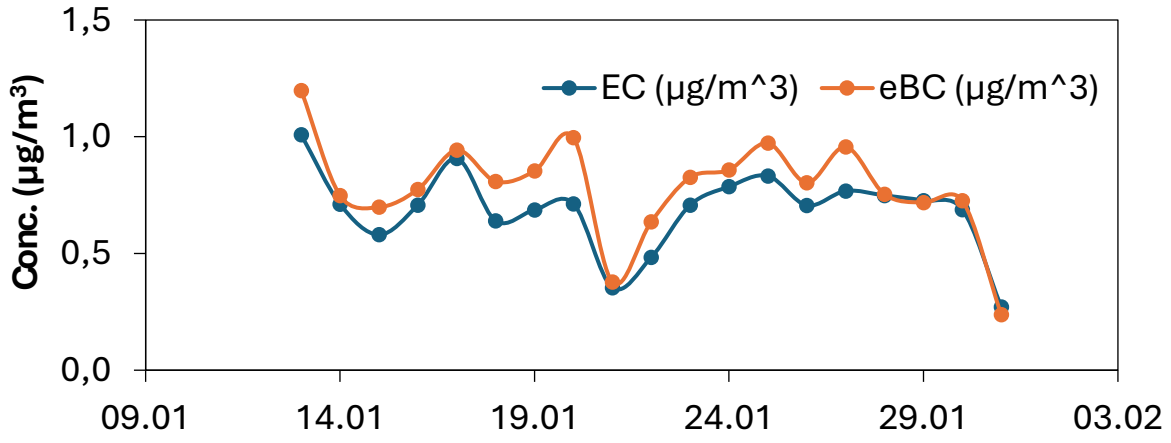

Figure 2. PM_{10} EC and eBC concentrations during winter period in Athens.

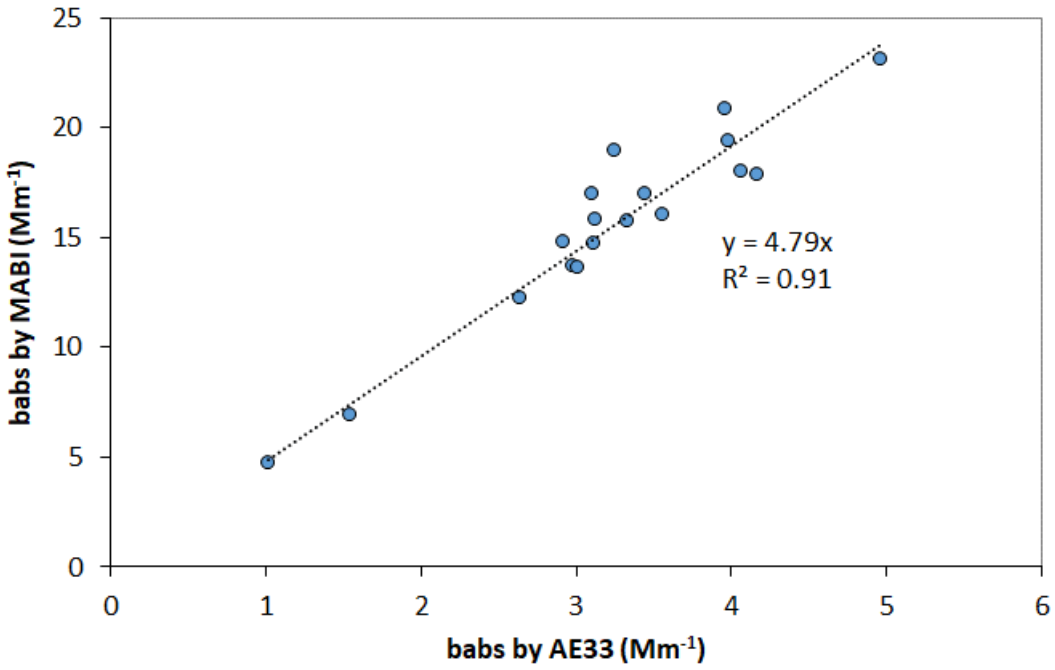

Figure 3. Comparison of absorption measured by AE33 (at 880 nm) and MABI (at 870 nm), in Athens.

The linear regression of absorption measured by MABI in Krakow versus the respective EC concentration, for the two PM size fractions, is shown in Figure 4. A very good correlation was observed between these values, with PM_{10} and $PM_{2.5}$ following the same pattern.

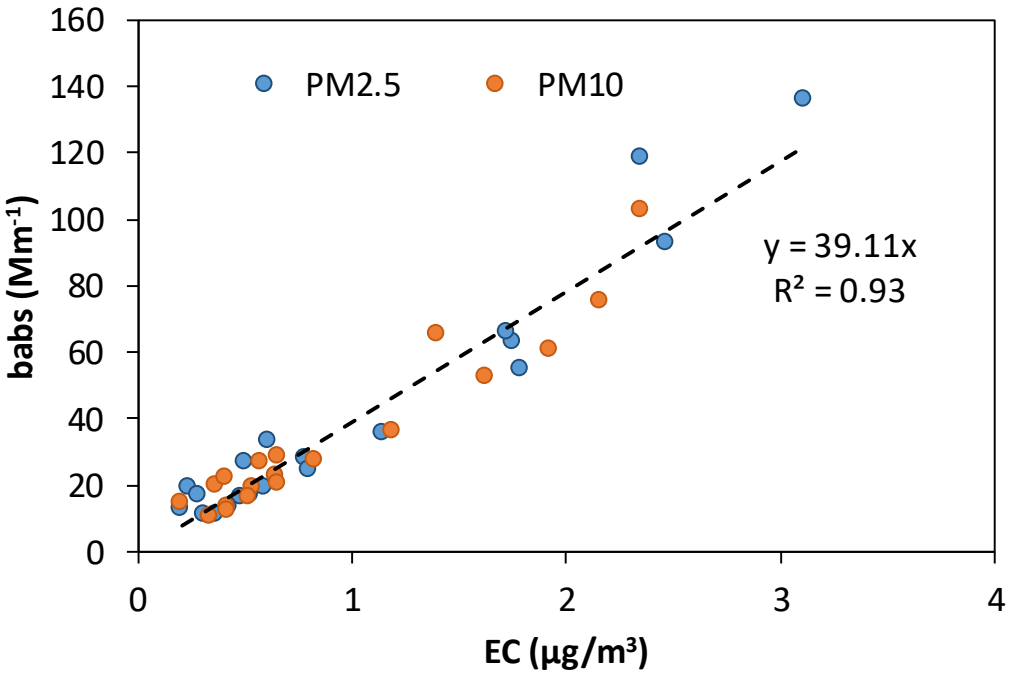

Figure 4. Linear regression of absorption measured by MABI (at 870 nm) versus EC concentrations.

In Figure 5, the comparison between the absorption values obtained in Teflon and Quartz fibre filters is presented. A similar trend was observed for both studied size fractions, demonstrating the impact of filter material on MABI analysis.

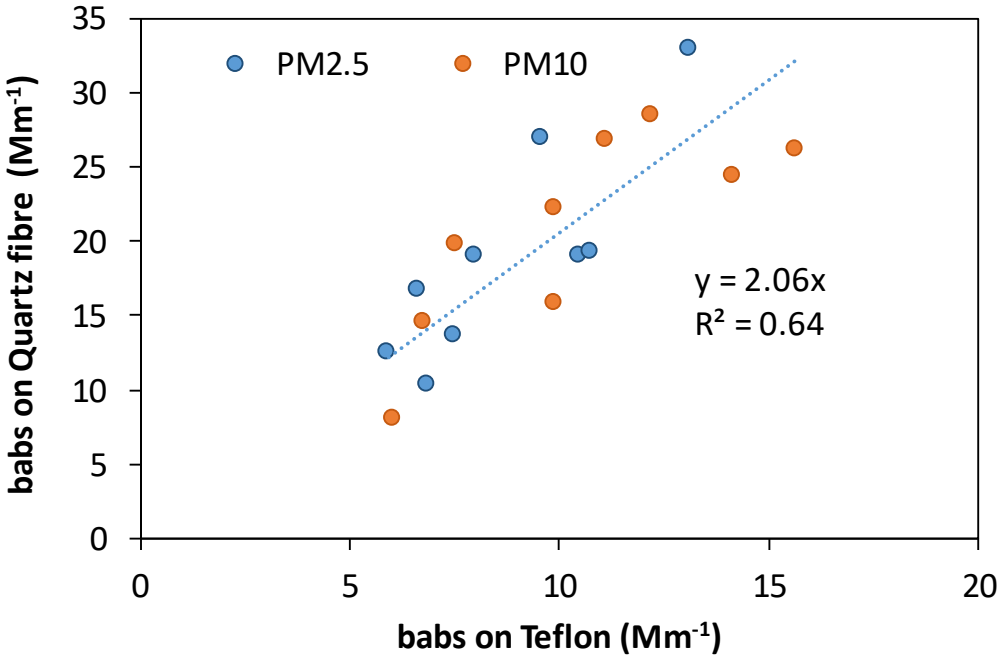

Figure 5. Comparison of absorption measured by MABI on Teflon and Quartz fibre filters, collected in parallel, in Krakow.

The results provide a promising assessment with respect to the use of MABI for the off-line measurements of aerosol light transmission. Nevertheless, it should be taken into account that MABI may significantly overestimate absorption, when compared to high-end instruments as the aethalometer, while the type of filter material should be also considered.

References

Cunha-Lopes I., Alves C.A., Rienda I.C., Lucarelli F., Diapouli E., Almeida S.M., "Characterisation of vehicle emissions in a road tunnel in Lisbon", 2023, Atmospheric Research, 295, 106995.

Diapouli E., Kalogridis A.-C., Markantonaki C., Vratolis S., Fetfatzis P., Colombi C., Eleftheriadis K., "Annual variability of black carbon concentrations originating from biomass and fossil fuel combustion for the suburban aerosol in Athens, Greece", 2017, Atmosphere, 8(12), 234.

Ryś A. and Samek S., "Yearly Variations of Equivalent Black Carbon Concentrations Observed in Krakow, Poland", 2022, Atmosphere, 13, 539. https://doi.org/10.3390/atmos13040539.