Evaluating the performance of the low-cost black carbon sensor bcMeter at an urban background site

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Black carbon (BC) is emitted in the atmosphere by incomplete combustion processes and its impact on both human health and climate are well-documented in the scientific literature. Atmospheric BC is usually monitored through filter-based optical techniques, measuring the light attenuation at a defined wavelength (880 nm). While these instruments are widely employed in the scientific community and can offer high accuracy data, their deployment in the field is often limited by the high costs to a restricted number of reference monitoring sites, resulting in lower spatial and temporal coverage of BC data. Given the recent WHO air quality guidelines (WHO, 2021), advocating systematic measurements in urban areas to mitigate the uncertainty surrounding spatial and temporal variability of black carbon (BC), the integration of low-cost sensors with conventional monitoring systems holds considerable potential. In this perspective fits the bcMeter, a recently developed low-cost (<300€ for total cost of materials) BC device, operating with the same principle as traditional aethalometers. This sensor aims, through a lower cost compared to scientific grade BC-measuring devices and ease of assembly and use, to facilitate the spatial coverage of BC measurements while fostering the community through citizen science.

In this work, the performance of two bcMeter sensors was evaluated at an urban background site in Mülheim-Styrum (Germany) against reference data from an AE33 aethalometer (Aerosol Magee Scientific) from a co-located official LANUV (State Office for Nature, Environment and Consumer Protection North Rhine Westphalia) monitoring station. Hourly averages of BC concentrations were highly scattered for both bcMeters due to the high instrumental noise, while linear fits against the reference AE33 aethalometer from the LANUV station showed almost no correlation between the devices (R^2 = 0.22-0.28). Reducing time resolution to 24-hour averages highlighted how the bcMeter followed the overall trend in BC concentration over time as the reference AE33, while data correlation increased for both sensors (R^2 = 0.77 - 0.79, after outlier removal). The campaign also highlighted how both bcMeters consistently underestimated BC concentrations, mostly due to a too low airflow. An airflow-based correction factor was calculated for each sensor, retrospectively correcting the underestimation (resulting slope = 0.94 - 1.02) for both devices.

Overall, the bcMeter provided results comparable with a reference aethalometer (AE33, Aerosol Magee Scientific) in daily averages (Figure 1), proving to be a promising option for future application in monitoring networks for orientation measurements, where daily data resolution is sufficient. However, the sensor showed several technical limitations that impacted the entire campaign, like software and firmware issues, air leakages and airflow issues.

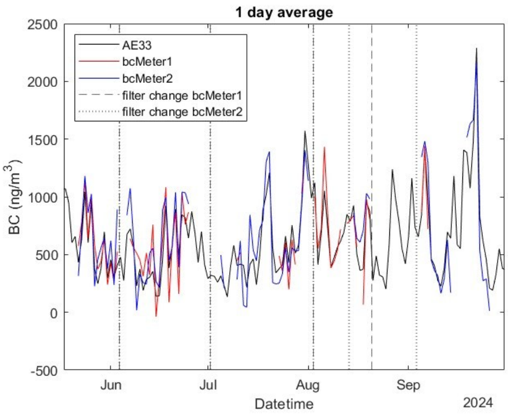

Figure 1. BC concentration corrected for the airflow as 24-hour averages for bcMeter1 (red) and bcMeter2 (blue), and BC concentration for the AE33 (black) obtained from the LANUV station in Mülheim-Styrum.

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WHO (2021). *WHO global air quality guidelines. Particulate matter ($PM_{2.5}$ and PM_{10}), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide.*