A new aethalometer model for PM source apportionment in mixed solid fuel environments

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The measurement of Black Carbon using a multiple wavelength aethalometer has been proposed as a tool for apportioning particulate matter (PM) contributions from fossil fuel combustion and biomass burning (Sandradewi *et al.*, 2008). The PM emitted by these two sources has different light absorbing properties across the wavelength range 370 - 950 nm, with biomass burning showing stronger absorption at lower wavelengths, due to the presence of "Brown" Carbon (Andrea & Gelencser, 2006). The wavelength dependence of the light absorption is described by a power law fit:

$$b_{abs} \propto \lambda^{-\alpha}$$

where λ is the wavelength and α is the Ångström exponent. By using aethalometer measurements to calculate the values of the absorption coefficient associated with ambient PM, it is possible to estimate the relative contributions of biomass burning and fossil fuel to ambient PM mass. In Europe, this model has been used in several studies to develop source contribution estimates for vehicular and residential heating sources (Favez *et al.*, 2010). This approach to source apportionment is also referred to as the aethalometer model.

However, not all locations have a single solid fuel in use. Ireland is most notable in this respect because bituminous and manufactured "smokeless" coals are used along with indigenous fuels such as wood, turf and peat. Quantification of the separate contribution that these different fuels make to air pollution is required to develop the best policies to reduce PM emissions from solid fuel burning. In particular it is important to ensure that the proposed national ban on the sale and use of bituminous coal in Ireland does not have unintended consequences in terms of switching to more polluting solid fuels.

The standard aethalometer model is based on empirical evidence that the Ångström exponents (α) are ~1 and ~2 for fossil fuel and wood burning, respectively. However, results from field measurements in Ireland suggest that the standard model is not ideal in a mixed solid fuel environment like rural Ireland and Poland and in other locations such as the UK.

In this work, a series of combustion experiments were carried out to gain insights into the different absorption properties of PM produced from a range of fuels. These were carried out using a commercial stove installed in an Irish residence. Multiple types of solid fuel were tested including coal products, wet and dry wood, dried cut turf and peat briquettes. The emissions were sampled continuously from the flue at the roof of the building and analysed in real-time by an AE33 aethalometer from Magee Scientific and a Scanning Mobility Particle Sizer (TSI Inc.). Filter collections were also made and subsequently analysed with a Carbon Aerosol Particulate Analysis Instrument from Sunset Laboratories, Oregon, USA. Vehicular exhaust was also measured.

The results from these burning experiments show a wide variation in absorption coefficients for the fuels (Figure 1). In particular, the wavelength dependence of the absorption from PM generated from coal combustion is significantly different from that produced by wood burning. The values for α, supported by EC/OC analysis from the combustion experiments have been used to develop a modified aethalometer model for apportioning black carbon from vehicle emissions and solid fuel burning. The model has successfully been used to apportion black carbon measured at several locations in Ireland, thus showing that the aethalometer model remains a powerful tool for apportionment of carbonaceous aerosol sources, but in mixed fuel environments, e.g., in Ireland, UK and Poland, the model needs to be adapted.

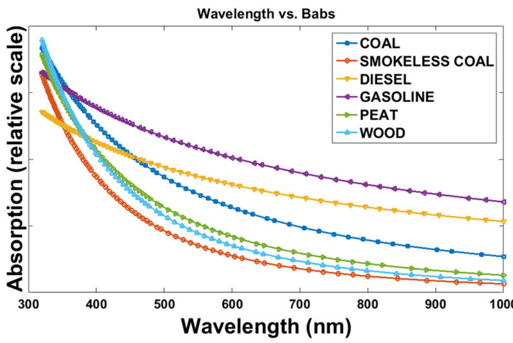

Figure 1. Power law fits of Wavelength versus absorption coefficient (b_{abs}) for a selection of fuel types.

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