Can lung-deposited surface area measurements serve as surrogate for black carbon?

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Mass-based limit values for particulate matter, based on size cut-offs at a few micron such as PM2.5 and PM10, are used all over the world for legal purposes, but the awareness is growing that these measurements may not adequately reflect the negative health impact of ultrafine particles. In particular, the world health organization (WHO) declared diesel soot particles to be carcinogenic in 2012, and these soot particles with typical diameters of around 70nm only contribute very little to PM2.5 and PM10 mass. Therefore, the search is on for alternative particle metrics that might be more health relevant with respect to ultrafine particles, and which could complement today's PMx standards. Due to the toxic properties of soot, the most obvious candidate is elemental carbon or black carbon (EC or BC), the latter can be continuously measured e.g. with an Aethalometer.

Another recent trend in urban air pollution monitoring is the move to multiple small and possibly mobile monitoring stations to complement today's fixed monitoring sites. These two trends are actually connected: The characteristic length scale over which PM mass based metrics vary is much larger than the length scale over which ultrafine particles vary, and therefore, if ultrafine particles are to be measured properly in an urban environment, a single fixed central measurement station – which was fine for PM10 - is no longer sufficient.

Since common instruments for BC measurements are bulky and expensive, they cannot be used in such sensor networks, and here we explore the use of another alternative metric, the lung-deposited surface area (LDSA), as a surrogate for BC in urban environments. LDSA is also interesting in its own, since the interaction of inhaled particles with the human body takes place on the particle surface; and a number of toxicology studies have found a better link between health effects and particle surface area than either particle mass or number (e.g. Waters, 2009). The lung-deposited surface area can be measured approximately with diffusion charging sensors (Wilson, 2007), which can be miniaturized easily. Such miniature diffusion charging sensors are interesting, because they can be incorporated in large numbers in sensor networks due to their low power consumption, comparatively low price, and long maintenance intervals. Moreover, they provide a much higher time resolution than common instruments for BC (on the order of seconds), which is necessary for mobile sensing platforms.

Our hypothesis is that LDSA and BC correlate well in urban environments, since both are dominated by combustion related aerosol. We verified the hypothesis by computing LDSA from SMPS data of the Swiss air pollution monitoring network (NABEL) and comparing it to BC. Figure 1 shows the two pollutants for the urban background site Zürich-Kaserne.

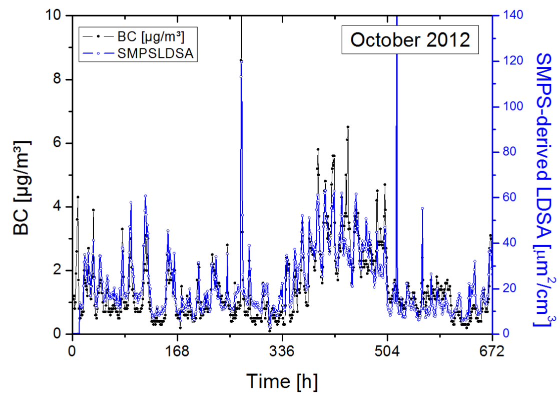

Figure 1. Time series of BC and SMPS-derived LDSA at the urban background site Zürich-Kaserne during 4 weeks in October 2012.

We have now deployed four miniature LDSA sensors (naneos partector) at four selected NABEL sites with BC monitoring (Basel, Bern, Lugano and Zürich). These four sites represent different environments: Lugano and Zürich are urban background sites; Bern is an urban street canyon site while Basel is a suburban site.

The LDSA sensors will run for the first half of 2013, providing us with a lot of useful information. We will learn more about the reliability and the applicability of these sensors for deployment in unattended sensor networks; and at the same time we will be able to answer the question whether or not BC can be approximated by LDSA as surrogate measurement in urban environments.

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