Summary of Techniques for the Monitoring of Black Carbon Aerosol in Ambient Air

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For routine, continuous measurement of atmospheric black carbon (BC), the analytical techniques have focused on BC's optical absorption property. The absorption coefficient for BC is significantly higher proportionally than for soil dust or any other common aerosol, giving high specificity for the measurement of BC by light absorption.

There are two technologies generally available for the measurement of BC using optical absorption. First are instruments that rely on collecting the atmospheric aerosols on a sheet of filter medium and measuring the change in light intensity while the particles are deposited. The reduction in light is then correlated with the concentration of BC in the air. This analytical method is often called the aethelometer. The second method, photoacoustic technology, relies on the absorption of light by BC while still in the air. This light absorption and resultant heating produces a sound wave that is directly measured. The intensity of the sound is directly related to the absorption and can be correlated with the amount of BC.

The aethelometer and photoacoustic methods are discussed in more detail below.

I. Filter Techniques

Figure 1 shows the typical system for the filter based BC analytical principle.

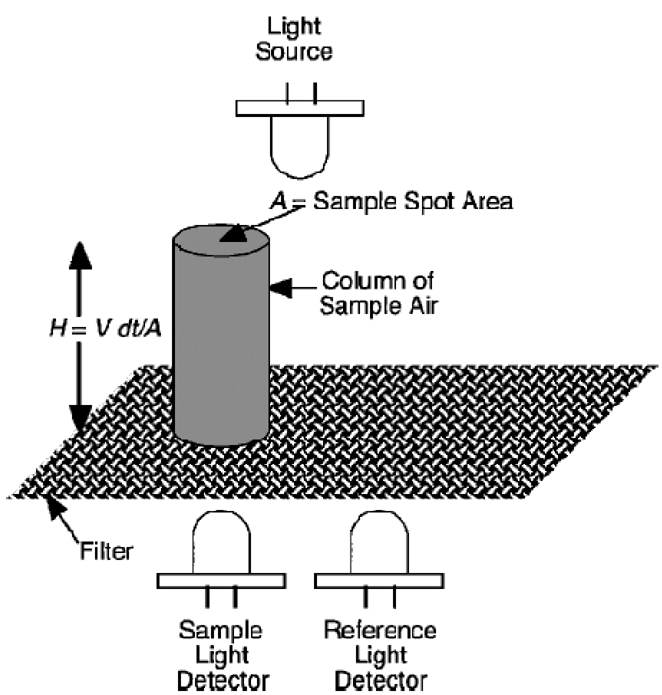

Figure 1. Schematic diagram of filter based BC measurement system.

Atmospheric aerosols are collected on the filter media, typically a glass fiber or cellulose type of filter. The light source is split into two paths, one passing through the spot created by the collected aerosols and then a reference with no air passing through the paper. The reference compensates for changes in the filter media or light intensity of the source. These instruments are often automated with a roll of filter tape and an advancing mechanism, so that after a preset amount of reduction in light transmission intensity, the tape will advance to a clean spot. A time series of BC concentration is produced by measuring the reduction in light intensity with time.

Filter Method Drawbacks

The difficulty with this analytical technique is that the measurement is actually light attenuation. In most cases, attenuation is not equivalent to absorption, which is necessary for accurate BC measurements. Some of the major factors complicating this measurement can be summarized as follows:

- ♦ light scattering from non-absorbing aerosol particles
- ♦ scattering and lens effects from the fibers in the filter causes multiple absorption of the light
- ♦ accumulation of BC material on the filter reduces the absorption, as the freshly deposited material will shadow the BC already deposited on the filter.
- ♦ the presence of other organic material "yellow beads" changes the absorption properties of the BC deposited on the filter and of the filter itself

There have been numerous studies and approaches to correct the filter BC data for these effects. There is some improvement in the data with these corrections, but ultimately all of this work concludes that it is impossible to make accurate BC measurements using a filter based BC measurement technique.

Another difficulty with the light transmission, filter-based BC analytical techniques is that it is impossible to calibrate them. There are no know standard sources of BC aerosol, and the measurements rely on several assumptions on the performance of the electronics and optics.

II. Photoacoustic Technique

Implementing the light absorption approach while the particles are still suspended in the air removes most of the uncertainties associated with the filter techniques. This is implemented via the photoacoustic measurement technology.

A schematic diagram of the photoacoustic analytical technique is given in Figure 2. Since many of the components that are necessary for the photoacoustic measurement can also be utilized in a light-scattering measurement, the latter is incorporated as part of the photoacoustic measurement. The light-scattering measurement provides additional information and also allows easy calibration of the entire system. The prime measurement is the photoacoustic absorption, however, and even though dual measurements of scattering and absorption are provided, the technology will be referred to as photoacoustic.

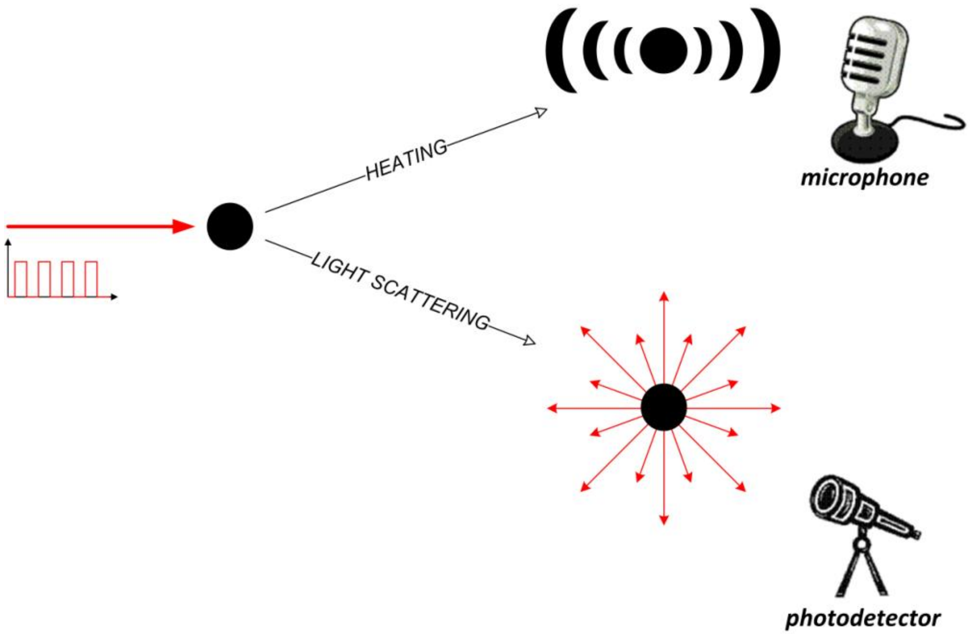

Figure 2. Schematic diagram of the photoacoustic technique showing both the absorption and scattering measurements.

The PhotoAcoustic eXtinctiometer (PAX).

Droplet Measurement Technologies' PAX offers the advantages of photoacoustic and light-scattering technology in a single instrument (Figure 3). The PAX is affordable and easy-to-use.

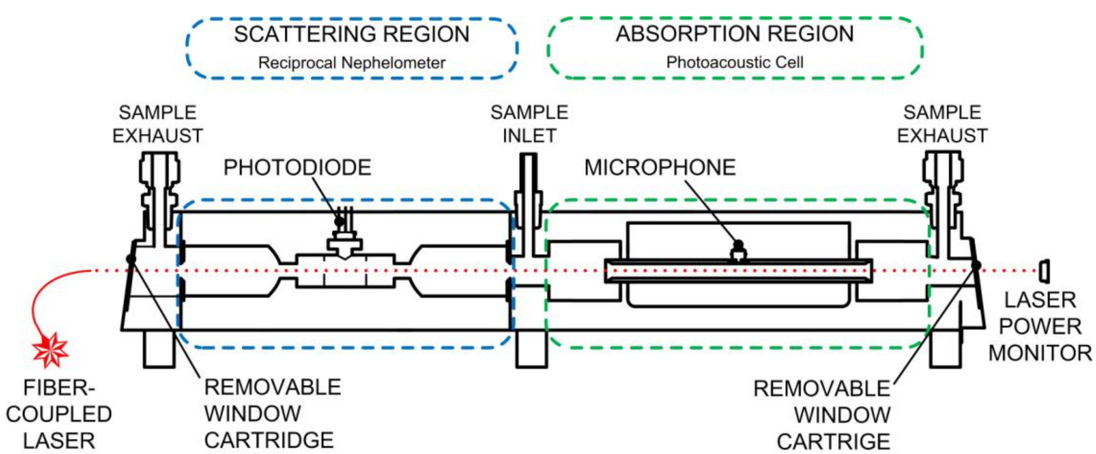

Figure 3. Diagram of the PAX cell incorporating light scattering and absorption measurements.

The PAX cell is divided into two sections, one set aside for scattering measurements and the other for absorption. There is no collection of the aerosol on any substrate, so the measurement is continuous, without the artifacts caused by the filters.

There are a number of advantages to the photoacoustic technique as follows:

- measurement accuracy
- no consumable materials such as filters
- measurement is independent of flow rate
- easy and direct calibration

PAX Calibration

Calibration is accomplished by first putting a high concentration of white particles into the PAX. Nebulized polystyrene latex (PSL) particles are especially good, being uniform and having negligible absorption. In this case the primary measurement is extinction from the laser power meter, and this is equivalent to scattering. Following this scattering calibration, a high concentration of black aerosol is provided to the PAX, and extinction is measured again. The scattering component is subtracted and the resulting absorption provides calibration of the absorption section. This entire procedure can be accomplished in 30 minutes or less.

References and more details on the photoacoustic technology can be found at the link given below:

http://www.dropletmeasurement.com/resources/88#PASS Advantages