Use of Light Absorption in the Fabrication of a Device for Measuring Ambient Black Carbon Concentration

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Introduction

Soot particles that contain black carbon are generated in combustion processes. Combustion of fossil fuel in automobiles is the major source of high levels of aerosol black carbon in urban areas (Ernesto *et al.*, 2000). Studies have revealed that airborne fine soot particles, that have high catalytic, optical and electrical properties, not only harm human health but also influence global climate change (Gundel *et al.*, 1984; Hansen *et al.*, 1993).

High cost of ambient air sampling devices has limited the span of ambient particulate matter monitoring in Sri Lanka to a few cities only. Our main objective is to design and fabricate an affordable device for measuring the concentration of airborne soot particles. By doing so, our goal is to popularize air quality measuring exercises in the country with the view of raising the awareness on ambient air quality.

Studies have revealed that more than 90% of the absorption of solar light in the visible region is by aerosol black carbon (Horvath, 1993). Therefore, measurement of Light Absorption Coefficient of air is a direct way of determining the concentration of black carbon present in the atmosphere (Hansen *et al.*, 1993). In this research, a compact low cost device has been designed and fabricated to measure the optical absorption coefficient of ambient black carbon particles collected on a filter paper.

Materials and methods

The experimental setup that is used for the measurements is shown in Figure 1. The lamp, convex lens, filter holder, filter and the light dependant resistor are enclosed in a sealed box made out of chip boards. The inner-side of the container is painted black so that light back scattered from the filter does not reach the monitor or by multiple reflections reaches the filter again. When measuring the light absorption, the filter is placed in the filter holder and the lamp is switched on. It takes nearly 15 minutes for the lamp to get stabilized and the container to reach thermal equilibrium. The lamp is at the side of the filter where particles are collected and a light dependant resistor is on the other side of the filter. A convex lens is placed between the light source and the filter to concentrate the light path to a small area of the filter. The light that reaches the filter passes through a layer of particles: part is absorbed by the particles, part is scattered and a part is passed through. The fraction that is passed through reaches the filter and is scattered by its pores. The light path is then again concentrated using a convex lens, and the amount of light that reaches the light dependant resistor is sensed, amplified and measured. At present, the out put signal from the device is a resistance value that is proportional to the light absorption coefficient of the particle sample.

Results and discussion

Table 1 gives the data collected during the experiment. Column 3 of the table shows the concentration of PM_{10} (Particulate matter less that 10 μm in size) obtained at several road side locations (given in column 2) using a high volume air sampler (Envirotech APM 460). "US-EPA federal reference method" (US EPA, 1999) was followed in sampling. Each filter paper is subjected to the light source through the device and the final out put resistance is recorded in ohms, which is shown in the last column of Table 1.

In Figure 2, the recorded value of the resistance is plotted against the concentration of PM_{10}. These two variables correlate with each other with a correlation coefficient (R) of 0.8759, which assures that the method tested in this study could lead to the successful development of the measuring device in its next stages. The results obtained using the above set up are subject to the assumption that all the filter papers have unique and uniform characteristics, and that the amount of light absorbed by the filter material is a constant.

Table 1. Mass concentration of PM_{10} and resistance obtained from the experimental set up for different filter samples

No	Air pollution measurement Site	Concentration of PM_{10} ($\mu g/m^3$)	Resistance from the experimental set up (Ω)
1	Blank Filter paper (Reference)	0	4.5
2	In front of Kandy Girl's High School	171	52.5
3	In front of Art's theater (Peradeniya)	28	9.6
4	Infront of Kandy Post Office	176	14.6
5	Good's shed Bus Stand	167	21.9
6	Gannoruwa	13	5.6
7	Idamegama	17	5.4
8	Inside Peradeniya Botanical Gardens	4	5.9
9	In front of Peradeniya Botanical Gardens	113	12.4
10	Near Katugastota Bridge	346	64.0

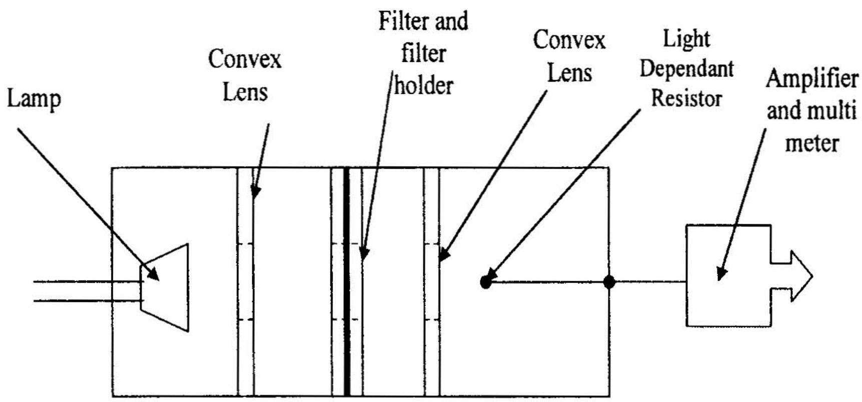

Figure 1. Experimental setup

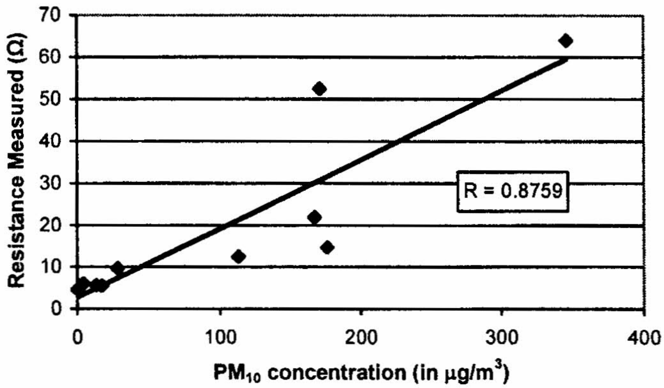

Figure 2. Resistance measured from the device plotted against the PM_{10} concentration

amount of light absorbed by the filter material is a constant.

Conclusions

The results obtained so far using the lab scale device for measuring the light absorption coefficient of ambient particulate matter gives a high correlation coefficient (R) of 0.8759 between the mass concentration of PM_{10} and the resistance reading obtained using the device. Therefore modifications are adopted for further improvement of the device.

At present the light absorption measurements are being repeated with a photo detector in place of the light dependant resistor, since the former has a wider sensitivity range and a longer life than the latter. The sealed box used is also being modified to facilitate online monitoring so that the particles are captured by the filter paper when a mass of air is drawn through the box.

Acknowledgements

University Research Grant No RG/2006/27/E is greatly acknowledged.

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