A REVOLUTIONARY OUTDOOR MONITORING SOLUTION FOR PMX AND BLACK CARBON

Climate change and public health are quite rightly front and centre within both mainstream and social media front. New approaches and studies are required in order to understand how to deal with the incoming challenge.

Many countries have made a commitment to addressing climate change by reducing greenhouse gas emissions and preventing a global 1.5°C temperature rise by the end of the century.

In an attempt to reach net zero emissions by 2050 we are considering changing personal behaviours such as household heating, diet, personal transportation and improved home waste management - in short every opportunity for reducing carbon emissions is being considered and clearly monitoring Black Carbon will play a part in the pollution evaluation.

Carbon dioxide (CO_2) has an atmospheric lifetime of more than 100 years so in comparison Black Carbon only stays in the atmosphere for a relatively short time (several days to weeks) which makes monitoring Black Carbon a challenge. Laboratory level measurements need to made in real time, providing reliable measurements in varied outdoor conditions.

Once again the solution to this challenge comes from collaboration. In this case Dado Lab Srl, a leading manufacturer of advanced sampling solutions stack emission monitoring and environmental sampling equipment, based their commercial Black Carbon Monitoring solution on cutting-edge technology developed together with PM_TEN, a spin-off from the University of Genova, with long-term expertise in the study and the analysis of cabonaceous aerosol. In the Giano BC_1 they claim to have developed "the world's first PMx sequential sampler equipped with non-destructive optical sensor technology for the real-time determination of Black Carbon concentration directly on to filters."

Dado Lab's Giano BC_1 performs sequential sampling of PMx fractions over 21 days and features advanced solutions for data storage and communication. It is the first sequential sampler system on the market capable of logging the data directly on to the filter cartridge using RFID technology. Where available, it can be connected to a LAN network and facilitate remote control thanks to its integrated web server.

Giano BC_1 also integrates a water-cooled Peltier system for the exposed filter's storage tank, which is kept below 20°C when the ambient temperature exceeds the 23°C.

The sampling operations can be conditioned to allow for the wind speed/direction in order to correctly evaluate the impact of the PM pollution impact between the source and the local, urban areas. In this case the unit will activate the sampling only when the conditions are met and data from the wind speed/direction sensor has been logged in the memory.

This new solution, different from all the other instruments available on the market, offers many advantages such as direct measurements using glass or quartz fibers 47mm filters, readily available on the market, which can then be taken in laboratory for further analysis.

The optical module integrated in the Giano BC_1 uses a single measurement to determine the amount of Black Carbon present in the atmospheric particulate sample, collected on the filter. The sample reflectance (RFN) is correlated with its absorption (ABS) through an empirical equation, derived from the analysis of a large number of reference samples collected in various environments.

The concentration value is calculated starting from the absorption values and the Mass Absorption Cross-section (MAC) characteristic of the sample, is then worked out through the relation:

$$BC = ABS/\sigma_{abs}$$

Figure 1 shows the comparison of the Black Carbon concentration values measured by the Giano BC_1 in an urban background site and the off-line MWAA reference analyses.

The MAC represents the proportionality coefficient existing between the absorption coefficient of particulate matter (ABS) and the concentration of Black Carbon (BC). This parameter depends on the composition and ageing of atmospheric aerosol particles, so it could be site and season dependent. A default MAC value is integrated in the instrument; however, the user can set and/or independently modify this parameter in according to the sampling site characteristics.

The relationship between the reflectance and the absorption of the sample was calculated from the analysis of more than 450 samples, representative of very different concentrations and compositions of atmospheric particulate matter (different urban areas, rural areas, desert areas and also Amazonian rainforest areas), using an optical instrument, the MWAA (Multi-Wavelength Absorbance Analyser) [Massabò et al. 2013, 2015]. The instrument measures the total light transmitted and scattered back from the blank and loaded filter at 5 different wavelengths in the UV-visible spectrum (from infrared @850 nm to UV @375 nm); to obtain the light absorption coefficient a radiative transfer model [Hänel, 1987] is applied. The MWAA partially follows the approach reported by [Petzold e Schönlinner, 2004] and implemented in the MAAP (Multi-Angle Absorption Photometer).

The light absorption coefficient calculated by MWAA using a laser @635 nm (red) was compared to the reflectance measured at an angle of 125° (with respect to the direction of the incident beam on the filter). The same set-up was then implemented in the optical module of the Giano BC_1. An empirical equation was determined as a polynomial curve that interpolates the points corresponding to the reflectance (RFN) and absorption (ABS) values of each sample of reference:

$$ABS=(A\pm\Delta A)\times RFN^2 + (B\pm\Delta B)\times RFN$$

where:

A and B are coefficients whose values depend on the multiple scattering which occurs between the particles and the matrix of the filter, while ΔA and ΔB represent the uncertainties related to the relative coefficients (A and B). In particular, multiple scatterings produce an increase in the optical path of light within the system, causing a non-linearity of the reflection signal as the absorption increases.

The result of this comparison shows the full compatibility of the measurements by the optical module of the Giano BC_1; in

addition to that, the real-time measurements during sampling enable the operator to follow the temporal trend of Black Carbon concentration without altering the filter, which can then be taken in laboratory for further analysis. This aspect could be very helpful to identify the sources that produced Black Carbon in the atmosphere: for example a peak of BC concentration in the early morning in an urban area or a peak in the late afternoon in winter could be easily associated to traffic or home heating, respectively. The frequency of the on-line measurements is user-selectable and should be tuned according to the average levels of Black Carbon concentration in the PM.

Therefore, the Giano BC_1 aims to represent an innovative PMx sequential sampler that can provide real-time determination of Black Carbon concentration directly on the filter without altering it, thanks to the non-destructive single optical measurement in reflection. This important result combined with the data coming from the PMx sampler and wind speed/direction sensor, allows operators to generated exhaustive reports related to pollution impact.

This innovative solution is currently patent pending

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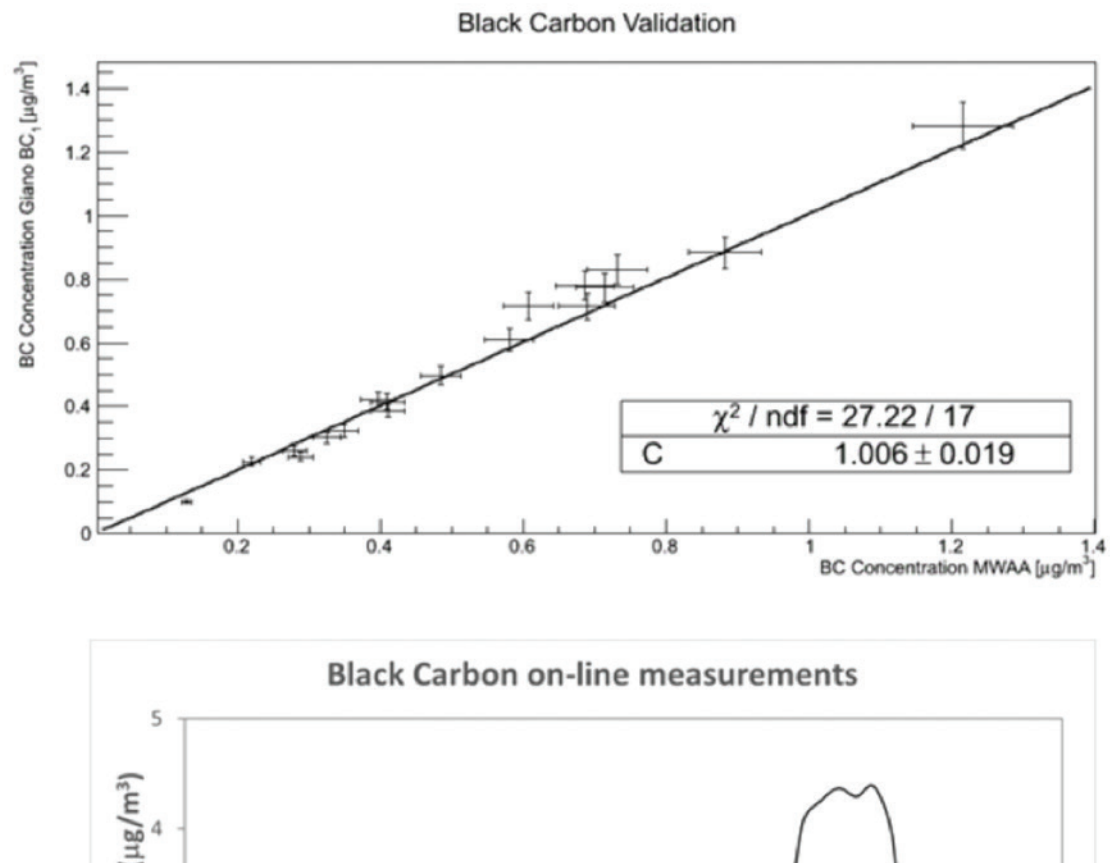

Figure 2 shows an example of the on-line measurements of the Black Carbon concentration values measured by the Giano BC1 in an industrial site.

Author Contact Details

Gianluca Cazzuli, Dado lab Srl • Via P. da Volpedo 101a - 20094 Cinisello B. (MI) - Italy

• Tel: +39 02 36569420 • Email: info@dadolab.com • Web: www.dadolab.com