Climate Change Control: Going Above and Beyond CO_2

Up until now, global and domestic efforts to curb climate change have largely focused on reducing the amount of carbon dioxide (CO_2) in the atmosphere. While this is still a vital aspect of managing climate change, there is increasing acceptance that more can be achieved in the shorter-term by targeting black carbon.

> *"Enviro Technology is now supplying the PAX system, the world's most advanced black carbon monitoring equipment."*

Author Details:
Duncan Mounsor,
Sales and Marketing Director,
Enviro Technology
Email: duncan.mounsor@et.co.uk
Tel: 01453 733 200 Web: www.et.co.uk

Black carbon affects the climate by intercepting and absorbing sunlight, darkening snow and ice when deposited and helping to form clouds. When the dark particles of black carbon absorb sunlight, either in the air or when they accumulate on snow and ice, they increase radiative forcing, which is the effect it has on the balance of incoming and outgoing energy in the atmosphere and the main concept behind global warming. It is most noticeable at the poles, on glaciers and in mountain regions – all environments which are, unfortunately, showing the greatest impact of climate change.

Emitted during incomplete combustion of fossil fuels and biomass, some of the main culprits for the creation of black carbon are: brick kilns, wood-burning stoves and diesel engines.

While the full impact of black carbon is still being assessed, it is linked to the melting of the glaciers in the Himalayas, disruption of traditional rainfall patterns in India and Africa and low yields of cereal crops such as: maize, rice, wheat and soya bean crops in Asia and elsewhere. It also has a significant effect on human health as it can be inhaled deeply into the lungs, where it causes cardiovascular disease and lung cancer.

According to a United Nations Environment Programme (UNEP) report published last year, ground-level ozone and black carbon together could be reducing crop yields by as much as 50m tonnes per year and leading to 2.5m premature deaths per year.

Climate change 'quick win'

The fact that black carbon has a relatively short atmospheric life-span of up to just a few weeks is a critical factor in the worldwide fight to combat climate change. CO_2 can stay in the atmosphere for centuries and means that efforts to reduce emissions will take a very long time to be effective. Measures to reduce black carbon levels are therefore a much 'quicker win' and have a faster impact on global warming levels.

Monitoring black carbon levels

In recognition of the importance of black carbon as a major climate change 'quick win' UNEP has embarked on a global collaborative initiative to mitigate global warming by monitoring and targeting black carbon levels. It is now more important than ever that black carbon particles are measured accurately and effectively.

There are two technologies available for the measurement of black carbon using optical absorption – namely filter methods and photoacoustic technology.

Filters have been used to measure black carbon concentrations for several decades and they have provided the foundation for the science world's basic understanding of the distribution of black carbon in time and space. The basic principle behind the measurement is that the amount of light attenuated by the combination of the filter and the deposited sample can be related to the mass of black carbon sampled. It is a relatively simple measurement to make, which is one of its biggest

advantages and because a high volume of air can be sampled through the filter, the technique can be quite sensitive.

However, according to Gavin McMeeking, a Scientist at US-based Droplet Measurement Technologies, the filter method has its disadvantages. He explains: "One of the major downsides to sampling onto a filter is that you have to measure light attenuation - light is absorbed by particles (the signal), but also scattered by particles and the filter fibres - and you have to assume a relationship to convert the light attenuation to light absorption or black carbon mass.

"There is also the potential for the properties of the light-absorbing particles to change once they are embedded in the filter. They can absorb additional light that is scattered by the filter itself, or other particles embedded in the filter, or can change due to the addition or removal of material by air as it passes through the filter. There are several correction routines that can be applied when post-processing the data, but each requires assumptions or additional measurements of other particulate matter properties and introduce uncertainties. Worse, there is evidence that for some conditions, such as when there are high organic aerosol loadings or there are changes in relative humidity, the accepted corrections still do not provide an accurate result."

Newer techniques avoid most of these problems by eliminating the filter. The photoacoustic approach used by the photoacoustic extinctiometer (PAX) instrument measures absorption of the particulate sample directly in air. It does this by measuring the pressure wave caused by the heating of the air surrounding a light absorbing particle when it is illuminated by a laser of the wavelength absorbed by the particle. The amplitude of the pressure wave is proportional to the light absorbed by the particles.

Since the particles are not embedded in a filter and absorption is measured directly, the photoacoustic technique avoids the artefacts affecting the filter-based measurement methods. For this reason, photoacoustic instruments have been used to validate filter-based measurements in a number of field and laboratory studies. Photoacoustic instruments also have the advantage of being able to be calibrated using absorbing particles or gases, depending on the wavelength of the measurement, which gives the method a physical grounding.

Bruce Gandrud, another Scientist from Droplet Measurement Technologies, adds: "Until recently, photoacoustic instruments had to be custom built and have generally been available only for intensive field and laboratory campaigns. However, we are now able to make this technology accessible to a wider group of users, including monitoring, where accurate measurements of black carbon will be crucial to any efforts to regulate the particles from a climate change perspective.

"In addition, the photoacoustic measurement of light absorption is the fundamental property relevant to black carbon climate forcing. The PAX instrument also measures light scattering by particles, which provides an additional check on particulate mass measurements and together with absorption provides information required to determine aerosol optical properties relevant for climate forcing."

PAX – technical specifications

Enviro Technology is now supplying the PAX system, the world's most advanced black carbon monitoring equipment. The fact that it is sensitive and provides a highly accurate, speedy, high-resolution measurement means that it is ideal for use in a range of measurement applications including air quality and visibility, atmosphere & climate, health effects, combustion source emissions and biomass burning.

It is suitable for fixed site, mobile or airborne sampling and the technical specification includes:

- Direct in-situ measurement of light absorption and scattering in a single instrument
- Absorption measurement correlates to black carbon mass concentration
- Reciprocal nephelometry provides excellent scattering coefficient sensitivity
- Choice of wavelengths: 870 nm (standard); optional 405 nm, 532 nm or 781 nm
- Fast response, one-second resolution, real-time data display
- Wide dynamic range suitable for pristine regions to source sampling
- Continuous and autonomous operation
- High-resolution touch screen display for real-time data and instrument status
- No filter collection required - no filter data artefacts

A tale of two cities

The deployment of PAX black carbon monitors has led to a better understanding of pollution in Los Angeles and Mexico City.

The equipment has been used to deliver a more accurate picture of daily Black Carbon trends in these two similarly densely-populated cities.

Monitors in the two cities demonstrated quite different weekend and weekday trends. Los Angeles had higher concentrations on weekends, whereas Mexico City had much higher concentrations during the week. Overall, Mexico City's daily peak values were double those of Los Angeles, but hourly maximum values were similar, reaching almost 10μg m^{-3}.

The differences can be clearly attributed to contrasts in meteorology and traffic patterns, particularly wind patterns and the percentage of diesel-burning vehicles on the road.

This tale of two cities has important implications for the understanding of the monitoring of black carbon levels and highlights the effectiveness of photoacoustic technology for accurate measurements.