Black Carbon – the Elephant in the Room!

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Traditionally, ambient particulates have been measured gravimetrically according to their size. However, in this article Jim Mills, Managing Director of Air Monitors, will demonstrate that the time has come to change or at least augment the way ambient particulates are monitored and regulated. Air Monitors has supplied most of the UK's ambient monitoring network, but Jim will explain why the measurement of Black Carbon could change the way we look at particulate pollution, so that focus will be given to strategies that could result in improvements to human health AND make a very significant contribution to the fight against climate change.
Jim will also outline the rationale behind a new €3million EU funded project (Carbotraf) which will use Black Carbon measurements to inform traffic management systems in both Glasgow and Graz.

As a result of the health problems and mortality caused by smoke and soot in the 1950s, legislation was created in a number of countries including the UK and the US, which resulted in a significant decline in the levels of particulates. At that time, most of the particulate was derived from the burning of coal in homes and factories.

The most common measurement standards for particulates specify the mass of particulate that passes through a 10μm inlet (PM10) or a 2.5μm inlet (PM2.5). However, these methods take no account of the chemical or biological content of the particulate nor do they consider the number of particles.

Despite the dramatic reductions in PM10 and PM2.5 that have been achieved, a significant level of human health problems persist, including effects on respiratory and cardio vascular systems, including asthma, heart disease and cancer. People with existing lung or heart conditions may be more susceptible to the effects of air pollution.

Many scientists now believe that finer particles may be the major cause of ill health because they are able to travel deeper into the respiratory system, and because these tiny particles can act as sponges carrying small amounts of toxic species such as PAH's and Dioxins which are adsorbed onto black carbon particles and transported deep into the body. PM10 and PM2.5 measurements provide a total figure for everything with mass in the sample and thereby assume that all particles are of equal significance. In reality this is not the case because some of the particles are benign from a human health perspective or are not anthropogenic so are of less interest from an air quality management perspective.

It is fortunate that the fine particles (from the combustion of fossil fuels) that are of most interest are black carbon and can be measured with an Aethalometer, which employs an optical method to only measure those fine particles which are black.

Importantly, an Aethalometer can provide a real-time readout of the mass concentration of 'Black' or 'Elemental' carbon aerosol particles in the air which means that live data can be used to manage the main contributor of urban black carbon: road traffic.

Global Warming

In addition to the public health issues relating to Black Carbon (BC), there is also a major consideration with regard to climate change, because BC stays in the atmosphere for a relatively short period of time – from days to weeks, before falling to ground as a result of dry deposition or precipitation. This is an important consideration in global strategy to combat climate change because BC emissions are the second largest contribution to current global warming, after carbon dioxide emissions. However, since CO_2 stays in the atmosphere for many decades, emissions reductions will take a long time to have an effect, which means that efforts to reduce BC could have a much faster impact on global warming.

BC reduction is fast becoming recognised as a major opportunity in the fight against climate change. In June 2011, a UN Environment Programme (UNEP) study estimated that 'near-term' global warming could be quickly reduced by 0.5 degrees Celsius by a reduction in BC emissions and that this would have an even greater benefit in the Arctic where it could reduce warming by 0.7 degrees.

BC increases global warming by absorbing sunlight, darkening snow and influencing the formation of clouds. The effects of BC are most noticeable at the poles, on glaciers and in mountainous regions – all of which are exhibiting the greatest effects of climate change.

Why has the elephant been ignored?

In the 1950's it became clear that a dramatic reduction in airborne smoke and soot was required and the PM10 and PM2.5 monitoring standards provided useful tools with which to measure progress. In addition, other measures of air quality such as SO_2, NO_x and Ozone were developed, but the significance of BC has only become clear more recently.

In 1952 over 4,000 Londoners (above the 'normal' mortality rate) are believed to have died as a result of the Great Smog.

However, in 1992, the Department of Health set up a Committee on the Medical Effects of Air Pollutants (COMEAP) which concluded that up to 24,000 deaths were still being 'brought forward' in the UK in 1995/1996 due to the short term effects of air pollution. At that time, no standards or regulations were proposed for BC because it was assumed that effort to reduce PM10 and PM2.5 would also reduce BC.

From a public health perspective, the PM10 approach results in effective legislation to reduce overall particulate emissions, but once this has been achieved it is logical for the focus to move to the finer particulates. These often have the most detrimental effects and it is pleasing to note that BC is becoming one of the most popular subjects for discussion in many recent meetings of air quality and public health professionals.

The problem with Black Carbon

Generally speaking gaseous pollutants are breathed in and breathed out again in short fashion. In contrast, some of the fine particulate that is breathed deep into the respiratory system tends to stay there. This problem is compounded by the fact that BC effectively acts as a vehicle to transport other harmful materials which can adsorb to its large surface area. These include PAH's and dioxins, which are known to be carcinogenic.

The measurement of particulates to PM10 and PM2.5 is complicated by the fact that a hundred-fold reduction in particle diameter equates to a million-fold reduction in mass, assuming a specific density and spherical particle shape (see table).

Particle Diameter (microns)	Particle Weight (mass units)
10	524.5
2.5	8.195313
1	0.5245
0.1	0.000525

So the most potentially harmful particles are not adequately measured by this method. In addition, carbon concentrations vary from time to time and place to place.

The regulatory focus on PM10 and PM2.5 has resulted in highly efficient combustion processes in industry and in modern engines. However, these new developments are designed to meet the PM mass standards; not necessarily to reduce the fine particulate, for which monitoring is not currently required by legislation. As a result, BC and other fine particulate materials in urban areas have become a major concern.

CARBOTRAF – a project to reduce BC levels through traffic management

CARBOTRAF is a Seventh Framework Programme (FP7) of the European Commission. Lasting for three years, the project will study the relationship between traffic flow, BC emissions and CO_2 in urban environments.

The project aims to create a method, system and tools for adaptively influencing traffic flow in real-time to reduce CO_2 and BC emissions caused by road transport in urban and inter-urban areas.

The inter-relationships between traffic states and CO_2 and BC emissions will be investigated. In particular, a model linking traffic states to emission levels will be established on the basis of existing and new simulation methods and tools.

Rack-mounted Aethalometer


Aethalometers employ an optical method to only measure those fine particles which are black

A decision support system for online prediction of emission levels will use real-time and simulated traffic and air-quality data. Based on the prediction, a low emission traffic scenario will be achieved by imposing ITS (Intelligent Transport Systems) measures such as re-routing and adjustment of traffic light sequences.

The two host cities are Glasgow, Scotland and Graz, Austria which were chosen due to their ability to manage traffic flows using ITS which will be enhanced by real-time air quality monitoring systems and a decision support system provided by IBM Inc.

The project will involve international partners from both the academic and industrial sectors. For example, Air Monitors will provide BC monitors, meteorology, mobile air quality and traffic monitoring equipment, and Envirologger (an associate company of Air Monitors) will provide real-time data collection, storage and display technology. Other partners include Imperial College London, the Austrian Institute of Technology, VITO (Belgium), ETS (Belgium), EBE Solutions (Austria) and IBM.


Handheld Aethalometer

Recent developments

Encouragingly, the elephant in the room is starting to be noticed. On 14th November 2011, BBC UK Environment correspondent Richard Black published an article entitled: 'air pollution 'puts lives at risk'' in which he outlined the Environmental Audit Committee's recent report which claimed the government's failure to meet EU standards on air pollution is 'putting the health of UK residents at risk. Bad air quality costs the nation £8.5 - £20bn per year via poor health,' the report says, 'and can cut life expectancy by years.'

Following a similar theme, the Sunday Times published an article entitled 'How a Breath of Air is Toxic' on 13th November 2012 which reported that people living or travelling in Britain's cities 'could be sucking in more than 100 million tiny toxic pollutant particles with each breath, according to the government's National Physical Laboratory (NPL).'

The article went on to explain: 'The tiny particles of soot and poisonous carbon compounds come from car exhausts, brakes and tyres and are thought to contribute to about 30,000 premature deaths a year from heart and lung problems.'

Clearly, the importance of BC is starting to become accepted and it is encouraging to note that a new PhD project will commence at King's College London in 2012 to study ambient levels of Black Carbon.

Summary

Historically, air quality legislation has been largely driven by human health issues and major advances have been achieved in developed countries. However, it is clear that whilst the focus on PM10/2.5 has resulted in major reductions in total airborne particulate; to date, fine particles have been largely ignored.

Additional new monitoring standards based on BC would substantially help to address this issue and drive improvements that would both enhance human health and help in the fight against climate change. If we are to make progress on both fronts, we must recognise the elephant in the room and Black Carbon should become the new PM10.

Further information is available at www.airmonitors.co.uk