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Reorganisation of the UK Black Carbon Network

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Executive Summary

This note sets out the changes made to the UK Black Carbon Network in 2012. It provides a historical perspective of the Network, the reasons for changes to the Network, the new research objectives of the Network defined in 2011 and the new structure of the Network from 2012.

The UK Black Carbon Network was reviewed in 2011 in order to ensure the research objectives were sound and that the Network was providing optimal data for multiple purposes, was fit for purpose and continued to provide value for money. A revised research network of fourteen aethelometer measurement stations was established in 2012 through a new research contract to reflect the following priorities:

- To maintain coverage of black smoke measurements across the whole UK;
- To maintain continuity of historic datasets;
- To gather data for epidemiological studies of black carbon and health effects
- To gather information about black carbon PM sources in the UK;
- To assess PM reductions from air quality management interventions;
- To quantify the contribution of wood burning to black carbon and ambient PM in the UK; and
- To gather data to address future policy considerations including black carbon and climate change.

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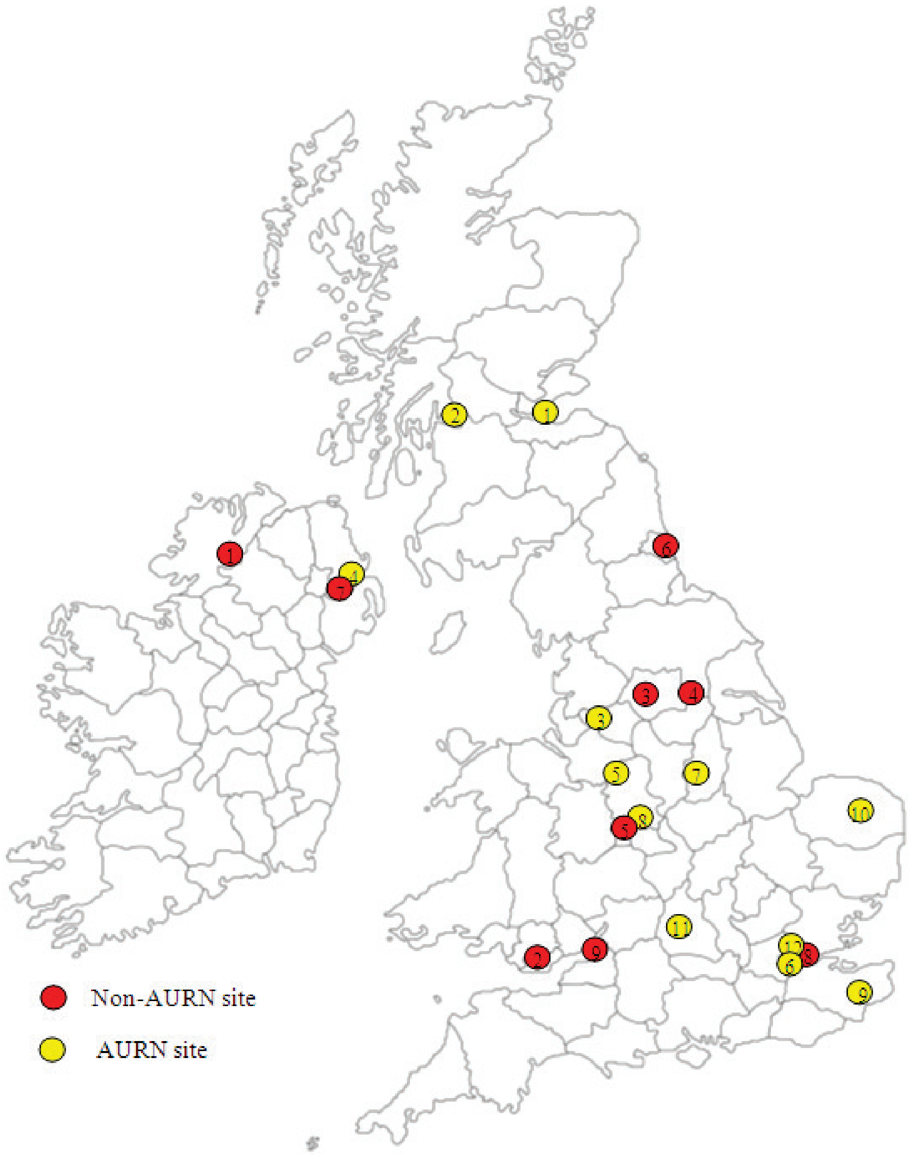
1 History and Development of the UK Black Carbon Network

UK measurements of black smoke using the smoke strain method date back to the 1920s. Along with measurements of acidity/SO_2, black smoke measurements were crucial in the analysis of the infamous 1952 smog (MoH, 1954) and for tracking the improvements in air pollution through the late 1950s and 1960s as a consequence of the Clean Air Acts and the increased availability of natural gas in the mainland UK.

The UK Black Smoke Network and its predecessor national surveys have operated in the UK for over 60 years. In 1997, prior to the EU Air Quality Daughter Directives, a network of 204 black smoke and acidity / SO_2 sampling stations operated in the UK tracking historic trends and assessing compliance with EU Directive 80/80/779/EEC (Loader et al., 1999). Following the repeal of EU Directive 80/80/779/EEC in 2005 (Loader, 2005), a review of non-continuous monitoring networks in the UK was undertaken. It concluded that the acidity/SO_2 measurement method was no longer providing a useful assessment of modern pollution concentrations but that the measurement of black smoke remained valuable, particularly for the assessment of health effects. A new network of around 20 monitoring stations was recommended to provide higher quality measurements, improved temporal resolution, a continuation of measurements in coal burning areas as well as new stations to inform future epidemiological studies (Fowler et al., 2006). Initially this network used the smoke stain method before the installation of automated aethalometers (Magee Scientific) in 2008. The 2011 Network is shown in Figure 1 along with an additional aethalometer at the Harwell rural station as part of the Defra UK Airborne Particulate Concentrations and Numbers research network.

Figure 1 The UK Black Carbon Network 2011 from Butterfield et al 2012.



Tables 1 and 2 below give the station names and classifications for the UK Black Carbon Network in 2011. Table 2 consists of stations which are part of the national compliance monitoring network, the Automatic Urban and Rural Network (AURN).

Table 1 Non-AURN stations in 2011 Network from Butterfield et al 2012.

Key	Station Name	Classification
1	Strabane 2	Suburban Background
2	Cardiff 12	Suburban Background
3	Halifax 17	Suburban Background
4	South Kirkby 1	Suburban Background
5	Dudley Central	Urban Background
6	Sunderland 8	Suburban Background
7	Dunmurry 3	Suburban Background
8	Woolwich 9	Suburban Background
9	Bath 6	Urban Background

Table 2 AURN stations in the 2011 Network from Butterfield et al 2012.

Key	Station Name	Classification	Other Analysers
1	Edinburgh St Leonard's	Urban Background	FDMS TEOM PM_{10} + PM $_{2.5}$
2	Glasgow Centre	Urban Background	FDMS TEOM PM_{10} + PM $_{2.5}$
3	Manchester Piccadilly	Urban Background	FDMS TEOM $PM_{2.5}$
4	Belfast Centre	Urban Background	FDMS TEOM PM_{10} + PM $_{2.5}$
5	Stoke Centre	Urban Background	FDMS TEOM PM_{10} + PM $_{2.5}$
6	North Kensington	Urban Background	FDMS TEOM PM_{10} + PM $_{2.5}$ + anions + EC/OC + number counting + manual $PM_{2.5}$
7	Nottingham Centre	Urban Background	FDMS TEOM PM_{10} + PM $_{2.5}$
8	Birmingham Tyburn	Urban Background	FDMS TEOM PM_{10} + PM $_{2.5}$
9	Folkestone, Kent Network	Rural Background	TEOM PM_{10}
10	Norwich Lakenfields	Urban Background	FDMS TEOM PM_{10} + PM $_{2.5}$
11	Harwell	Rural Background	FDMS TEOM PM_{10} + PM $_{2.5}$ + anions + EC/OC + number counting + manual $PM_{2.5}$
12	Marylebone Road	Urban Traffic	FDMS TEOM PM_{10} + PM $_{2.5}$ + anions + EC/OC + number counting + manual $PM_{2.5}$

2 Monitoring Methodology

Since 2008, black carbon concentrations have been measured using the Magee Aethalometer, model AE22. The Aethalometer measures the light absorption of carbon particles at two wavelengths: 880 nm (IR) and 370 nm (UV).

The Aethalometer is a stand-alone instrument that will run unattended for months at a time, with data being collected remotely via a modem on a daily basis. At 98% the average data capture for 2010 was remarkably high for an automated monitoring network indicative of the reliability of the measurement technique and current operating procedures.

Aethalometers quantify "black carbon" on filter samples based on the transmission of light through a sample. The sample is collected onto a quartz tape, and the absorption coefficient of the sample is measured by a single pass transmission of light through the sample, measured relative to a clean piece of filter.

The aethalometers used on the Network operate at two wavelengths, 880 nm and 370 nm. The 880 nm wavelength is used to measure the black carbon concentration of the aerosol. At wavelengths shorter than about 400 nm, certain classes of organic compounds start to show strong UV absorbance. The UV component can be used as a tracer for specific ambient sources including PM from wood smoke (Sandradewi et al., 2008), mineral iron (Fialho et al., 2006) and PM from coal burning (Yang et al., 2009).

3 Priorities for the revised Black Carbon Research Network

Monitoring networks need to be multi-purpose, providing measurements that meet several policy needs or experimental rationales. In 2011 the aims and objectives of the Black Carbon Network were reviewed with a new focus on research. Advice was sought via peer review from a number of external sources including:

- The Air Quality Expert Group;
- National Physical Laboratory (network manager);
- King's College London (network manager);
- The University of Birmingham;
- The University of Strathclyde; and
- The University of Edinburgh.

The following aims were identified:

1. *To maintain coverage of black carbon measurements across the whole UK*

The Network should aim to represent the areas with existing black carbon sources in the UK, by source type and geographical location. A key priority here is the measurement of black carbon across a range of urban areas of the UK and in parts of Northern Ireland, where coal burning is prevalent.

2. *To maintain continuity of historic datasets*

The Network represents the continuation of a 60 year monitoring programme and continuity with the older data sets was identified as an objective.

Continuity between the aethalometer and previous smoke stain methods have been examined by the National Physical Laboratory and collaborators and conversion methods have been established to allow historic smoke stain measurements to be presented in comparable terms to the new automatic measurements of black carbon (eg Quincey et al., 2011).

Many older monitoring stations in the former Black Smoke Network were established in industrial areas or those with substantial coal burning. Sitting criteria and priorities have changed over time and this left nine stations in the 2011 Network as standalone aethalometers not co-located with AURN measurements of PM_{10}. It was important that the Network should continue measurements in urban background locations (and especially in parts of Northern Ireland where solid fuel use is common place) but it was felt that measurement instruments should be re-located to reflect current rather than past priorities.

3. *To gather data for epidemiological studies of black carbon and health effects*

Many studies have shown associations between black smoke (and other metrics of black and elemental carbon) and health effects. In 2001, the Expert Panel on Air Quality Standards conducted an analysis of daily mortality and hospital admissions as they relate to PM_{10}, $PM_{2.5}$, $PM_{2.5\text{-}10}$, particulate sulphate and black smoke in the West Midlands and concluded that, of all the particle measures, black smoke appeared to be one most consistently associated with health effects (EPAQS, 2001). More recently a comprehensive meta-analysis of time series and cohort epidemiological studies has highlighted the role of black smoke and black carbon as an indicator to evaluate the health risks of air quality dominated by primary combustion particles (Janssen et al., 2011).

Current time series epidemiological studies typically use daily mean background concentrations at a central monitoring station as a surrogate for population exposure. It was felt that a continuation of measurements at background locations in the largest UK urban areas would provide the best opportunity for such studies in the future. Source orientated measurements around London will contribute to the epidemiological studies underway as part of Traffic Pollution and Health in London study which is funded jointly by the Medial Research Council (MRC) and the Natural Sciences Research Council (NERC).

4. *To gather information about black carbon PM sources in the UK*

The 2011 Network was optimised to determine urban background concentrations of black carbon but not their sources. An excellent template for source orientated network design was first suggested by Lenschow et al (2001). The so-called Lenschow approach assumes that urban concentrations of air pollutants arise from two sources; the urban area itself and a regional background. By making measurements of primary pollutants simultaneously in urban areas and in the surrounding rural areas it is possible to separately quantify contributions from urban sources and regional factors such as long range transport. Similarly traffic contributions to primary pollutant concentrations can be determined from the concentration differences between roadside and nearby urban background concentrations. This simple source oriented design has been used in several European source apportionment studies (eg AirParif, 2011), it forms the basis of the current design of the Defra's UK Airborne Particulate Concentrations and Numbers research Network and formed the core design of the NERC funded ClearfLo project (http://www.clearflo.ac.uk/) in London.

The 2011 Network was overwhelmingly dominated by urban background monitoring stations, reflecting the original purpose of the Network. It comprised 18 urban stations (urban centre, urban background and suburban), a single kerbside traffic station (Marylebone Road), a single roadside traffic station (Bath) with rural measurements at Harwell. The review of the Network indicated there was a clear need for the Network should be redesigned to provide source information by creating rural, urban and traffic triplicates to enable a Lenschow type source apportionment. Additionally this apportionment should be included in the research activities for the Network.

Nine of the Network's twenty-one monitoring stations were at locations that measured black carbon only. At these stations an opportunity was being missed to use measurements of black carbon to begin to explain the composition and therefore sources of PM_{10} or $PM_{2.5}$. It was important that black carbon measurements should take place alongside AURN PM measurements with priority being given to monitoring locations where the measurement of black carbon would add to current PM speciation programmes namely the UK Airborne Particulate Concentrations and Numbers research network, the European Monitoring and Evaluation Programme (EMEP) supersites and academic research programmes such as ClearfLo and the EU FP7 funded Carbotraf project in Glasgow.

5. *To assess PM reductions from air quality management interventions*

At the sub-national scale, air quality management actions for PM focus on the abatement of primary PM emissions. Decreases in black carbon concentrations and emissions have been demonstrated as a consequence of the introduction of Low Emission Zones in Berlin (Lutz, 2009) and London (Barratt et al., 2009). With further Low Emissions Zones being considered for urban areas of the UK, the Black Carbon Network would therefore have an important role in supporting the assessment of outcomes. The design of a study to determine any such black carbon decreases would, of course depend on the detail of each individual scheme. Black carbon monitoring could usefully be deployed to monitor the impacts of such schemes in the future.

6. *To quantify the contribution of wood burning to black carbon and ambient PM in the UK.*

The 27 member states of the European Union are committed to obtain 20% of their energy requirements from renewable sources, including biomass, by 2020 (EU, 2009) as part of a raft of proposals to reduce CO_2 emissions. The UK Department for Energy and Climate Change (DECC) has announced the world's first Renewable Heat Incentive, which will provide a financial incentive for individuals and businesses to switch from fossil fuel to renewables as part of a strategy to 'de-carbonise' the generation of heat in the UK (DECC, 2010). The Renewable Heat Incentive is one of a number of policy drivers to promote biomass heat in domestic, commercial and industrial settings in the UK. Additionally, the so-called Merton Rule requiring 10% onsite renewable energy in large new developments may drive new biomass installations (Merton, 2009). In Denmark, a doubling of wood stoves and boilers over a ten year period has been partially attributed to increased fossil fuel costs (Glasius et al., 2006) and there is a risk that similar financial pressures may bring about an increase in biomass burning in the UK. It could therefore be considered prudent to assess the PM from wood smoke across the UK to track any impact on ambient PM concentrations.

PM_{10} from wood smoke has different optical absorption characteristics compared to black carbon; particularly due to its content of humic-like substances (HULIS). Relative to black carbon from road transport sources, HULIS have an increased absorption in the UV wavelength compared to IR; in other words PM from wood burning is coloured. The aethalometers in the UK Black Carbon Network make absorption measurements at both IR and UV wavelengths and by determining the absorption wavelength dependence of ambient PM it is possible to apportion black carbon emissions from wood burning and transport sources (Fevez et al., 2011). Additional methods have been devised to quantify the ambient PM from wood burning using aethalometers: the Sandradewi method (Sandradew et al.,2008) which has been used in France and in alpine regions and the delta C method (Wang et al 2011) which was originally devised and applied in the US.

UV signals from the Black Carbon network have undergone initial assessment using an indicative approach. Details can be found in previous network annual reports available from the UK-AIR library. The UV component was found to have greatest magnitude at stations in Strabane and Dunmurry in Northern Ireland (where coal combustion may be an interference) and at Bath and Cardiff in mainland UK. A strong evening source of the UV component was noted in Norwich (Butterfield et al., 2011)

It was clear that the Network could make a valuable contribution to the assessment of PM from wood burning and this should be included in the research activities for the network.

7. Future policy considerations

Recent work by the United Nations Environment Programme has highlighted the importance of black carbon as a short-lived climate forcer. Black carbon emissions control therefore offers benefits to both climate change and human health (UNEP, 2011; Shindel et al 2012). This has led to the inclusion of black carbon in the revised Gothenberg protocol (though an emissions ceiling is not currently proposed). Black carbon is also being considered in the review of the EU Air Quality Directive.

Both processes will require increased investigation of black carbon sources as work is undertaken towards the inclusion of black carbon in emissions inventories. The redesign of the Network to include a source orientated structure and collocated measurements with other PM monitoring programmes is a significant step forward to inform these future evidence requirements.

4 The revised 2012 Network

The revised 2012 Black Carbon Network is shown in Figure 2.

Figure 2 The revised 2012 Black Carbon Network from Butterfield et al 2012. Key in Table 3

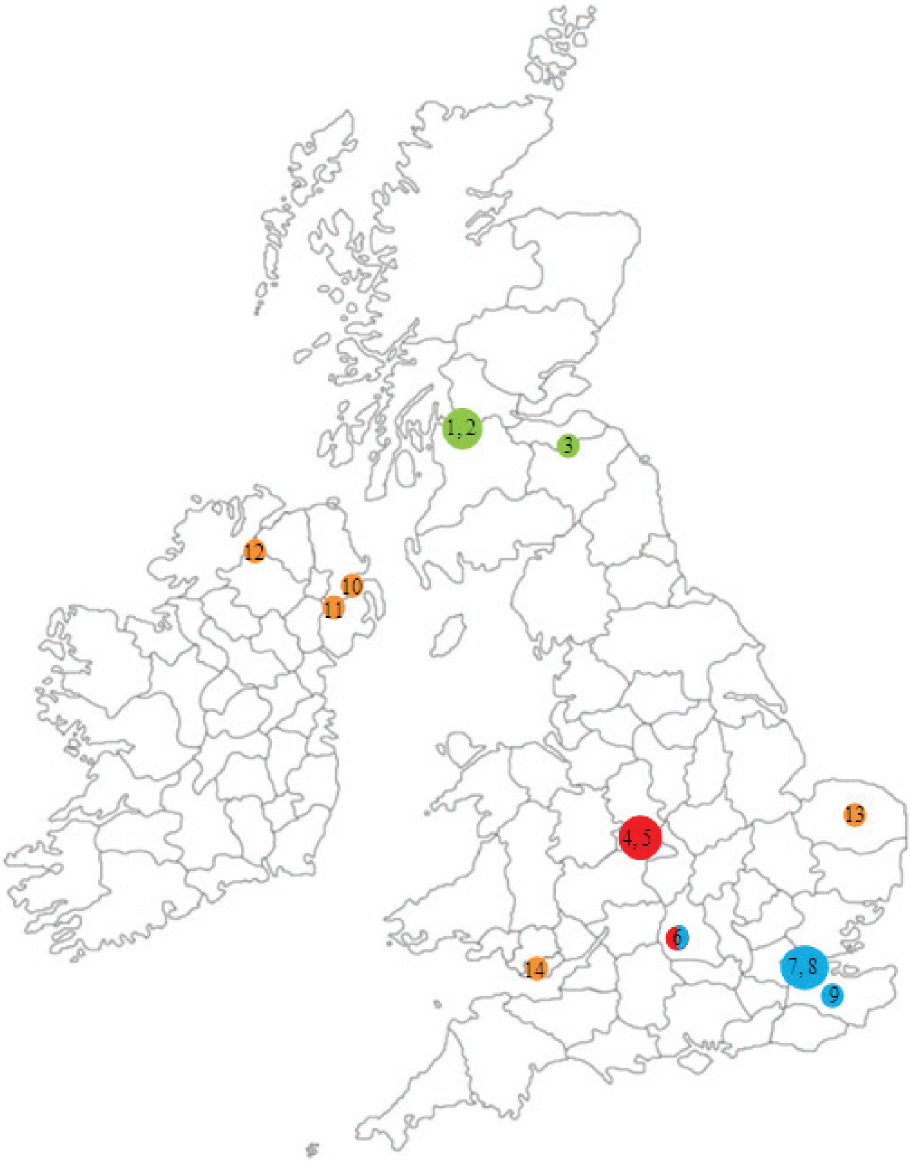


Table 3 provides details of the sites and their purpose.

Table 3 The 2012 Black Carbon Network.

	Station Name	Type of station	Zone / Agglomeration	Comment
1	Glasgow Centre	Urban background	Glasgow urban area	Roadside, urban and rural stations to make a Lenchow triplicate for source apportionment. Glasgow measurements will support the Carbotraf FP7 project. Measurements at Auchencorth Moss adds to PM composition performed at this EMEP supersite.
2	Glasgow Kerbside	Urban traffic	Glasgow urban area	
3	Auchencorth Moss	Rural background	Central Scotland	
4	Birmingham Tyburn	Urban background	West Midlands urban area	Roadside and urban stations, with data from Harwell to make a Lenchow triplicate for source apportionment. Urban background measurements have collocated with particle number concentration.
5	Birmingham Tyburn Roadside	Urban traffic	West Midlands urban area	
6	Harwell	Rural background	South East	A rural station for Lenchow source apportionment for London and Birmingham. Adds to PM composition measurements as part of the EMEP supersite, the particle numbers and concentrations network and NERC funded ClearfLo.
7	Marylebone Road	Urban traffic	Greater London urban area	Roadside, urban, and rural stations, with data from Harwell to provide a transect across London for Lenchow source apportionment. Measurements are collated with the NERC ClearfLo stations. Marylebone Road and North Kensington are part of the particle numbers and concentrations network to contribute to information on the overall composition of PM mass concentration.
8	North Kensington	Urban background	Greater London urban area	
9	Detling	Rural background	South East	
10	Belfast Centre	Urban background	Belfast urban area	Stations to understand the solid fuel contributions to black carbon and ambient PM in Northern Ireland.
11	Dunmurry 3	Suburban background	Northern Ireland	
12	Strabane 2	Suburban background	Northern Ireland	
13	Norwich Lakenfields	Urban background	Eastern	Continuity with long-term datasets. Possible local solid fuel use.
14	Cardiff 12	Suburban background	Cardiff urban area	Continuity with long-term datasets. Possible local solid fuel use.

5 Research priorities for the Network

The core objectives of the research project are to:

- Provide quality assured, quality controlled measurements of black carbon;
- Assess trends in concentrations and spatial distribution of black carbon;
- Evaluate the proportion of black carbon contributing to PM;

These core objectives may be extended through the inclusion of further research options in the future such as:

- Undertaking additional monitoring campaigns and subsequent data analysis;
- Evaluating the contribution of traffic and other emission sources to black carbon concentrations;
- Assessing the effect of diesel engine emissions controls and low emission zones on black carbon trends and concentrations;
- Investigating contributions from biomass burning, and other sources to black carbon as data become available; and
- Investigating associations between black carbon and health effects.

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