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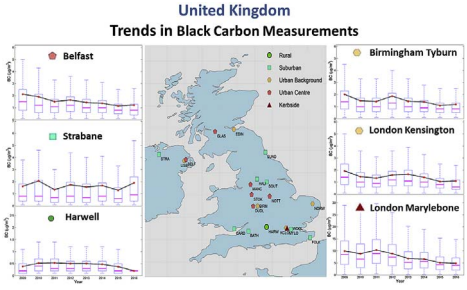
Trends of atmospheric black carbon concentration over United Kingdom

Vikas Singh[a,1], Khaiwal Ravindra[b,*], Lokesh Sahu[c], Ranjeet Sokhi[d]

[a] National Atmospheric Research Laboratory, Tirupati - 517 502, India
[b] School of Public Health, Post Graduate Institute of Medical Education and Research (PGIMER), Chandigarh, 160012, India
[c] Physical Research Laboratory, Ahmedabad - 380009, India
[d] Centre for Atmospheric and Instrumentation Research (CAIR), University of Hertfordshire, Hatfield, Hertfordshire, AL10 9AB, United Kingdom

GRAPHICAL ABSTRACT



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ABSTRACT

The continuous observations over a period of 7 years (2009–2016) available at 7 locations show declining trend of atmospheric BC in the UK. Among all the locations, the highest decrease of 8 ± 3 percent per year was observed at the Marylebone road in London. The detailed analysis performed at 21 locations during 2009–2011 shows that average annual mean atmospheric BC concentration were 0.45, 1.47 ± 0.58, 1.34 ± 0.31, 1.83 ± 0.46 and 9.72 $\mu g m^{-3}$ at rural, suburban, urban background, urban centre and kerbside sites respectively. Around 1 $\mu g m^{-3}$ of atmospheric BC could be attributed to urban emission, whereas traffic contributed up to 8 $\mu g m^{-3}$ of atmospheric BC near busy roads. Seasonal pattern was also observed at all locations except rural and kerbside location, with maximum concentrations (1.2–4 $\mu g m^{-3}$) in winter. Further, minimum concentrations (0.3–1.2 $\mu g m^{-3}$) were observed in summer and similar concentrations in spring and fall. At suburban and urban background locations, similar diurnal pattern were observed with atmospheric BC concentration peaks ($\approx$1.8 $\mu g m^{-3}$) in the morning (around 9 a.m.) and evening (7–9 p.m.) rush hours, whereas minimum concentrations were during late night hours (peak at 5 a.m.) and the afternoon hours (peak at 2 p.m.). The urban centre values show a similar morning pattern (peak at 9 a.m.; concentration - 2.5 $\mu g m^{-3}$) in relation to background locations but only a slight decrease in concentration in the afternoon which remained above 2 $\mu g m^{-3}$ till midnight. It is concluded that the higher flow of traffic at urban centre locations results in higher atmospheric BC concentrations throughout the day. Comparison of weekday and weekend daily averaged atmospheric BC showed maximum concentrations on Friday having minimum levels on Sunday. This study will help to refine the atmospheric BC emission over Europe and also provide inputs for climate change models, which in turn will help policy makers to reduce atmospheric BC emissions, globally.

* Corresponding author. Tel.: +911722755262; fax: +911722744401.
E-mail addresses: Khaiwal@yahoo.com, khaiwal.ravindra@pgimer.edu.in (K. Ravindra), vikas@narl.gov.in (V. Singh).
[1] Previously at University of Hertfordshire, Hatfield, UK.

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1. Introduction

Aerosols are being increasingly recognized as the crucial factor in affecting air quality, climate change and human health. Atmospheric Black Carbon (BC) is a major component of carbonaceous aerosol and is emitted from incomplete combustion of carbonaceous material (Karanasiou et al., 2014). According to World Health Organization report (WHO, 2015), atmospheric BC and other short lived pollutants contribute not only to global warming but also to over 7 million premature deaths related to air pollution (WHO, 2015). Atmospheric BC absorbs solar radiation and thus contributes to warming of the atmosphere as highlighted by Unites States Environmental Protection Agency (USEPA 2012) and (Ramanathan and Carmichael, 2008).

In addition to the global effect, it also responsible for severe health effects related to cardiopulmonary and respiratory diseases (Stoeger et al., 2006), and lack of visibility (Jiang et al., 2005). Khan et al. (2006) found that due to its sub-micron size range, atmospheric BC particles has a life time ranging from several days to weeks and can be transported to thousands of kilometers contributing to regional climate change. The long range transport of fine particles can lead to further enhancement of BC concentrations in urban areas which are already influenced by local urban emissions. In a modelling analysis done by Singh et al. (2014), it was estimated that the urban increment (including the contributions from urban traffic and other urban sources) was evaluated to be on the average 18%, 33%, 39%, and 43% of the total $PM_{2.5}$ in suburban environments, in the urban background, near roads, and near busy roads, respectively.

The anthropogenic sources of atmospheric BC include vehicular emissions especially from diesel engines, domestic heating, biomass burning and industrial emissions, whereas naturally it is emitted from volcanic emissions and forest fires. The contribution of atmospheric BC emission from fossil fuel, bio fuel and open biomass burning which includes forest fires and agricultural waste burning, has been estimated to be ≈ 38%, 20% and 42%, respectively (Bond et al., 2004). It is present in the atmosphere as primary particles and thus can be used as a tracer for combustion sources (Kendall et al., 2001).

Long term measurement of atmospheric BC can be used to estimate its role in regional and global climate change, and also to analyze the temporal variation. Source measurements can be utilized for assessing anthropogenic role in varying atmospheric BC concentration. Several short and long term measurements have been done in the past to investigate the seasonal and diurnal pattern of atmospheric BC, in Europe and worldwide (Sahu et al., 2011; Backman et al., 2012; Feng et al., 2014; Tiwari et al., 2013). However, limited number of studies using long term atmospheric BC data has been done in this area, in United Kingdom (UK). Järvi et al. (2008) reported temporal variation of atmospheric BC in Helsinki, Finland in three campaigns with different time scales during 1996–2005 and reported that median atmospheric BC concentration decreased from 1.11 to 1.00 μgm^{-3} during 1996–2005. Saha and Despiau (2009) in its study over Mediterranean coast, Southeast of France during 2005–2006, found that the diurnal variations were more amplified in winter season.

Similarly, Bencs et al. (2010) monitored various pollutants including BC at six sampling sites across Belgium during 2001–2002 for different seasons. Petroleumkaai, one of the site of this study is a famous harbor of Antwerp which is surrounded by petroleum industries. The BC concentration during autumn and winter varies between 0.014–7.4 and 0.025–1.7 μgm^{-3}, respectively. Atmospheric BC were also monitored at the Bight Bank and British Channel shipping route between 2010 and 11 to compare exhaust atmospheric BC concentration with a coastal background site i.e. DeHaan, Belgium. Average BC concentrations at shipping route was 0.366 μgm^{-3} as compared to the DeHaan background site, where BC levels were 0.2 μgm^{-3} (Bencs et al., 2017). Study also report that presence of several oil refining and petroleum industries led to higher values of elemental carbon (EC) at Petroleumkaai than at southern Bight of the North Sea.

Hence, to better estimate the overall atmospheric BC emission load over UK, current study critically assesses the data of real time atmospheric BC observations made during 2009–2016 using UK Black Carbon Network across UK. This analysis includes 21 stations having various locations i.e. rural, suburban, urban background, urban centre and kerbside. This study specifically focus on seasonal and diurnal variations in atmospheric BC concentrations at all 21 stations during 2009–2011 for better geographical representation and try to understand the atmospheric BC trends over 7 locations during 2009–2016. Variations in atmospheric BC concentrations at different locations were also compared using site specific characteristics and emissions. Further, difference in atmospheric BC concentration during weekday and weekend concentrations were also analyzed. A comparison of the atmospheric BC annual average concentration was also made with other studies including other large scale atmospheric BC measurement networks in Europe, United States, China, etc.

Thus the study would be useful to plan various mitigation actions and policy making to curb the atmospheric BC levels. Further, the study also provides input for various global and regional climate models to estimate regional aerosol radiative forcing.

2. Methodology

Atmospheric BC concentrations were measured at 21 locations (Fig. 1) using AE22 Aethalometers make of Magee Scientific (Please see detail in Annexure T1). The network provided ratified AE-22 data based on Virkkula et al. (2007) correction scheme. The BC monitoring sites are part of the UK Black Carbon Network, which is managed and operated for Department for Environment, Food and Rural Affairs (DEFRA, 2018) (https://uk-air.defra.gov.uk/networks/network-info?

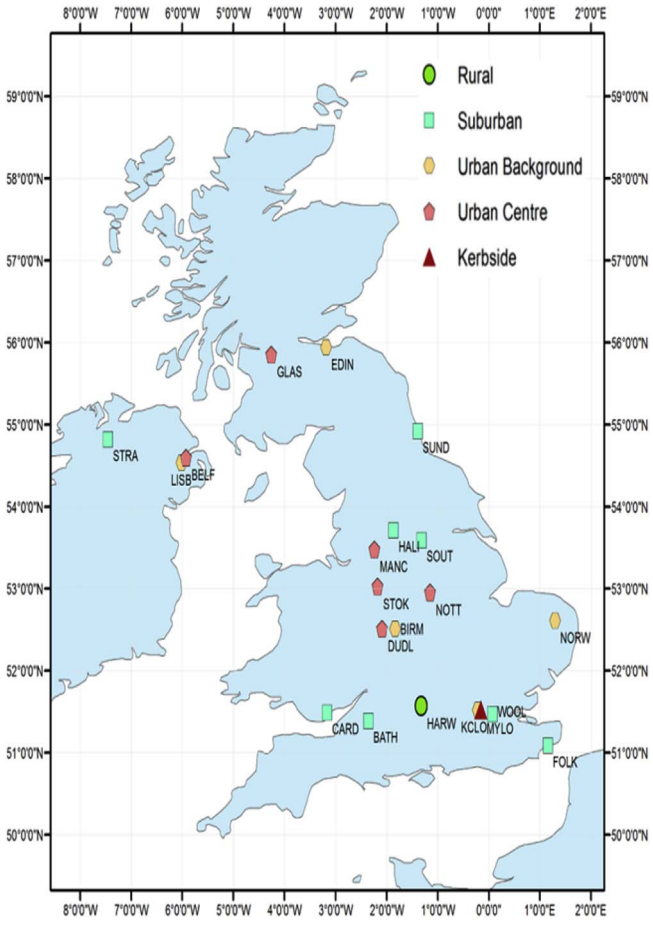

Fig. 1. Map showing atmospheric BC monitoring sites in UK.