Concentrations of PAH and PCB in London

Darren Beriro and **Christopher Vane** explain a study of PAH and PCB concentrations in London

The **British Geological Survey** recently published an open access study on the distribution and abundance of organic pollutants in London soils[1] .

The study reflects an opportunity to characterise soil contamination at different geographical scales to support site specific risk-based land management (RBLM). The policy backdrop for this study is the coalition Government's announcement and implementation of the Environment Theme Red Tape Challenge[2] . Effective changes arising from the initiative may end up being quite far reaching, with the potential archiving of many useful guidance documents[3].

Despite the apparent reduction in regulation, many new and important RBLM tools have also arisen in the past few years. These include the *National Planning Policy Framework*, revised Part 2a statutory guidance, the development of normal background concentrations (NBCs), the production of Category 4 Screening Levels, guidance on understanding and managing asbestos risks in soil by **CIRIA** and the imminent arrival of over 300 new Suitable 4 Use Levels.

Some of these were directly published or funded by Government, others are industry-led initiatives. In each case they suggest that the will to improve decision making and reduce conservatism in human health and environmental risk assessment is still on the agenda. The BGS study explained in this article helps to show how primary scientific research by a world-leading geological survey can contribute by characterising existing organic contaminant concentrations in soils.

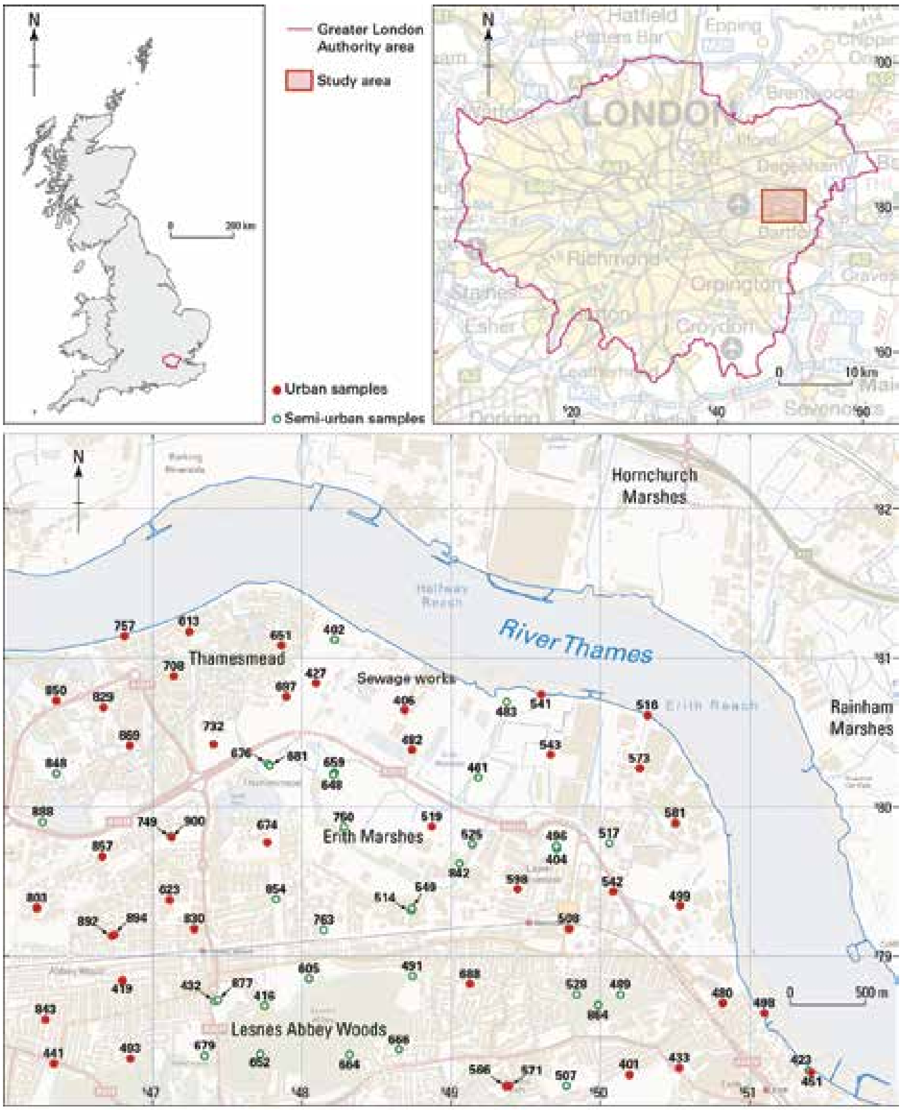

Fig. 1. Map of east London showing the sample locations and reference numbers.

The Organic Geochemistry Laboratory at the BGS Centre for Environmental Geochemistry[4] sampled and analysed 76 soil samples from the **Greater London Authority** area (Fig. 1). This work is the first systematic investigation of organic contaminants in London soils and represents an important contribution to understanding the distribution of concentrations in the study area.

Each soil sample was taken from between five and 20cm below ground level, freeze dried, and milled before being analysed by gas chromatography mass spectroscopy (GC-MS). Analytes included a range of polycyclic aromatic hydrocarbon and polychlorinated biphenyl congeners (33 parent and alkylated PAH, seven PCB congeners, five PCB homologous series and total organic carbon). The PCB homologs were grouped according the degree of chlorination e.g. tri-PCB have three chlorine atoms and hepta-PCB have seven.

These contaminants are important because they have the potential to cause deleterious health effects[5]. The data derived for this study was subject to the following exploratory and statistical analysis:-

- Numerical summaries of the data including maximum, minimum, mean concentrations;
- Boxplots of the data;
- Isomeric double ratio plots to assist with the diagnosis of PAH sources;
- Calculation of representative concentrations of selected compounds using the BGS Normal Background Concentration methodology[6];
- Comparison of the study NBCs with relevant generic assessment criteria[7].

The sample locations were grouped into urban domain, which included developed land, and the semi-urban domain which included undeveloped land, defined as such using 1953-present **Ordnance Survey** maps.

The recorded concentrations of PAH and PCB congers for the two domains are shown to be lower in the semi-urban domain.

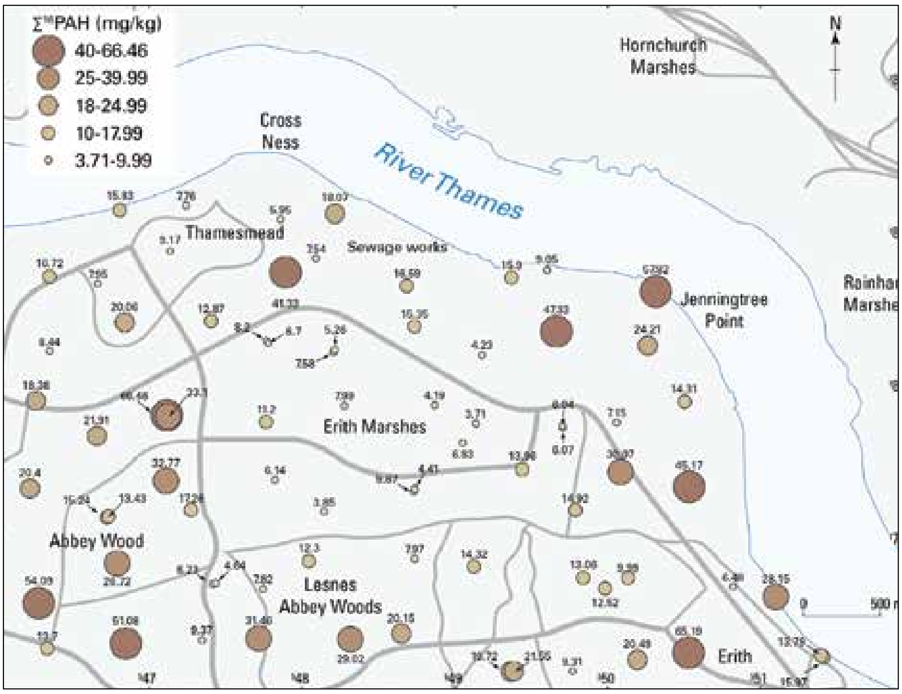

Fig. 2. Map of P16 PAH concentrations across the survey area.

∑16 PAH concentrations ranged from 4-66mg/kg with a mean of 18mg/kg and a median of 14mg/kg (Fig. 1). ∑tri-hepta PCB concentrations ranged from 9 to 2642µg/kg with a mean of 123µg/kg (Fig. 1).

The data presented in the boxplots show that the higher molecular weight congeners for both type of compound are present at greater concentrations than the lower molecular weight congeners. The concentrations and congener distributions are similar to those recorded in other urban areas around the globe, although detailed comparison with specific countries is difficult because of the circumstances of the study, number of samples and the availability of secondary data in the literature.

Characterising the source of PAH can be a useful way of determining whether it is directly attributable to one particular site or a more general feature of the wider area. PAH data for the study area were used to produce diagnostic isomeric double ratio plots to indicate potential dominant sources. In addition, a comparison of organic carbon content of each soil was made for concentrations of PAH. The results of both techniques indicate a mixed source comprising atmospheric pyrogenic PAH as well as additional direct pyrogenic inputs from other sources.

Such sources of contamination were suggested to be typical of diffuse anthropogenic pollution as a result of prolonged emissions from a variety of sources including traffic, chimneys and industrial stacks, site-based industrial, commercial and residential activities.

PCB source characterisation is much more difficult since current knowledge on the relationships between congeners and how they relate to the source is less established than it is for PAH. This study was able to show that the PCB composition is dominated by congeners with a higher degree of chlorination (penta- to hepta-PCB) (Fig. 1). This finding is consistent with similar studies and is thought to reflect the degradation over time of lighter molecules in preference to heavier ones.

NBCs were calculated for **USEPA** 16 PAH, ∑16 and ∑50 PAH as well as the ICES-7 PCB congeners and ∑7-ICES and 6 homologous series. An explanation of NBCs is presented in Box 1.

An illustration of the NBC for benzo(a) pyrene for the urban, semi-urban and combined domain show that the **LQM/ CIEH** GACs to demonstrate that for residential (assuming vegetable growing in gardens) and allotment land-uses, the NBC is higher than the GAC (Fig. 2).

This finding supports an assertion that BaP is widespread across the study area and suggests that the concentrations would require additional investigation and risk assessment if residential land-use changes were to be considered under the *NPPF*. This raises questions about whether the current GACs are overly conservative and do not accurately reflect increased levels risk (assuming that SSAC are often not that much higher than GACs). This is a complex question that would require further research into epidemiological and contaminant bioavailability areas to answer fully.

Other exceedances of the GAC by the NBC were recorded for indeno[*1,2,3-cd*] pyrene (residential only). Comparison of the PCB NBCs with GACs was not possible because the soil guideline value (the only published GAC) for PCB is based on the sum concentration of dioxins, furans and dioxin-like PCBs (residential SGV = 8µg/kg; commercial = 240µg/kg).

The only dioxin-like PCB measured in the present study was PCB-118, the data for which was used to calculate a combined urban and semi-urban NBC of 4.4µg/ kg. Interestingly, this value is nearly half the residential SGV, albeit that the NBC includes a few samples with considerably higher concentrations than the remaining population. Notwithstanding, it would be interesting to see what concentration might be recorded for a full suite of dioxins, furans and dioxin-like PCBs given that the PCB-118 NBC contributes nearly 50% of the residential SGV and nearly 2% of the commercial SGV. Experience suggests that

Box 1: Normal Background Concentrations

An NBC is the upper confidence limit of the 95th percentile of the data (Fig 2) – the value provides a conservative estimate of the background concentration over a given area accounting for geogenic and diffuse sources of pollution. NBCs have recently been introduced into the contaminated land regime in England and Wales under Part 2a of the Environmental Protection Act 1990 (EPA) (as amended) by secondary statutory guidance in each country. The regime supports the derivation of normal levels of contaminants as a way of identifying concentrations that represent low rather than unacceptably high levels of risk. NBCs should not be used in support of the National Planning Policy Framework (NPPF), which states that the developer or site owner needs to ensure the land is safe for its intended use. (Paragraph 121: CLG, 2012). The data underpinning the NBCs could contribute to one of many lines of evidence that may be used to assist with RBLM under these and other regimes (Environment Agency, 2004).

Annotated plot TBI

London air

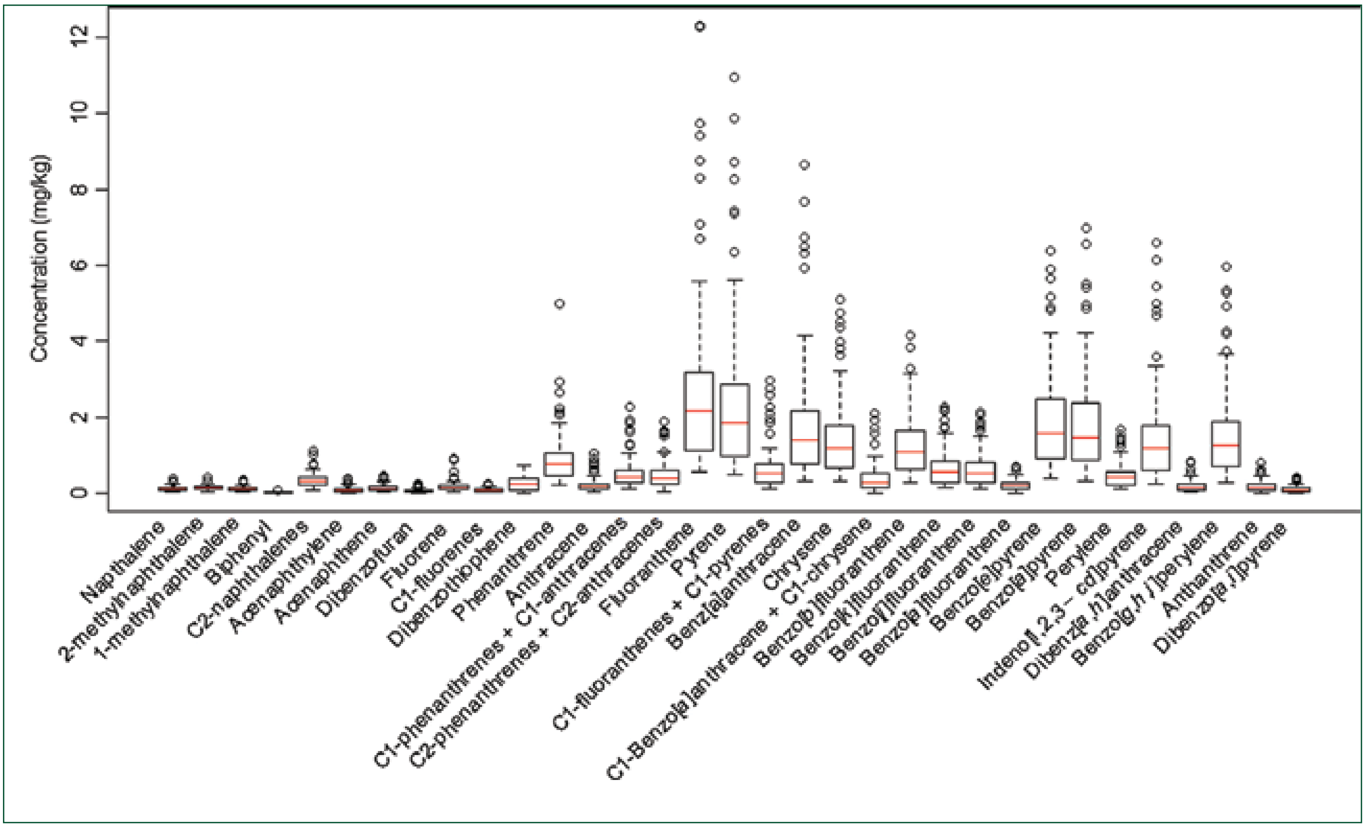

Fig. 3. PAH concentrations for all samples displaying outliers (circle markers), highest and lowest non-outliers (upper and lower whisker limits), upper and lower quartiles (upper and lower box limits) and median values (horizontal red line)

such analyses are rarely completed as part of routine site investigation, usually only being included if there is a known history of PCB contamination.

One aspect of the BGS vision is to work with new data to understand geological processes that matter to peoples' lives and livelihoods[8]. The current research contributes to this by providing important information about the distribution and abundance of PAH and PCB in London soils.

The research has also raised questions about how this data and information may be used by the RBLM industry by finding that the benzo[*a*]pyrene NBC exceeds the residential and allotment GAC. It also highlights the potential importance and paucity of PCB measurements in UK soils, given that here, a single dioxin-like PCB was high relative to the published SGV. BGS continues to provide the additional context to site-specific investigations of organic contaminants in soils.

Phase 2 of this research is already underway and includes widening the study area to 12 central London boroughs. This new study will calculate NBCs and interrogate the data using a range of multivariate methods to help understand the distribution and sources of organic contaminants in urban areas in the context of RBLM.

Darren Beriro and Christopher Vane work at the British Geological Survey, Keyworth. In the interest of transparency and collaboration, if any reader has any questions, thoughts or would like to see the data produced for this work please do contact Dr Vane (head of organic geochemistry) at chv@bgs.ac.uk

1. http://dx.doi.org/10.1016/j.apgeochem.2014.09.013
2. https://www.gov.uk/government/publications/red-tape-challenge-environment-theme-proposals
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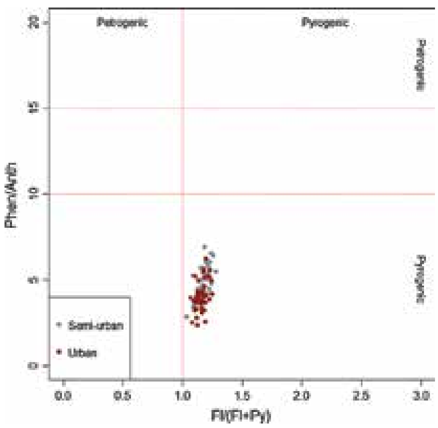

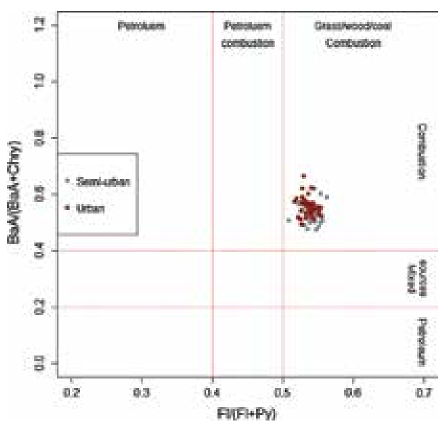

(Left) Fig. 4. Isomeric ratio plot of Phen/Anth and Fanth/Pyr.
(Right) Fig 5. Bi-plot of BaA/BaA+Chrys and Fanth/Fanth+Pyr for London soils.