Mapping the chemical environment of London, UK:
an important contribution to understanding national levels of normal background contaminant concentrations

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THE LONDON EARTH PROJECT

London Earth is part of the British Geological Survey's (BGS) Geochemical Baseline Survey of the Environment (G-BASE) Project to map the surface geochemical baseline of the UK. The London work represents the world's largest systematic geochemical mapping of an urban area. Sampling and analytical methods are consistent between G-BASE rural and urban areas, only the sampling density is different - 4 sites per km² for urban, 1 site per 2 km² for rural.

Soils have been collected from three depths, surface soil (0-2 cm); topsoil (5-20 cm); and deep soil (35-50 cm), though only the topsoils were routinely analysed by X-ray fluorescence spectrometry (XRFS) for more than 50 elements. Other parameters such as pH and loss on ignition were also determined. At all sites the samplers made detailed site and sample observations including information on soil texture, land use and observed contamination.

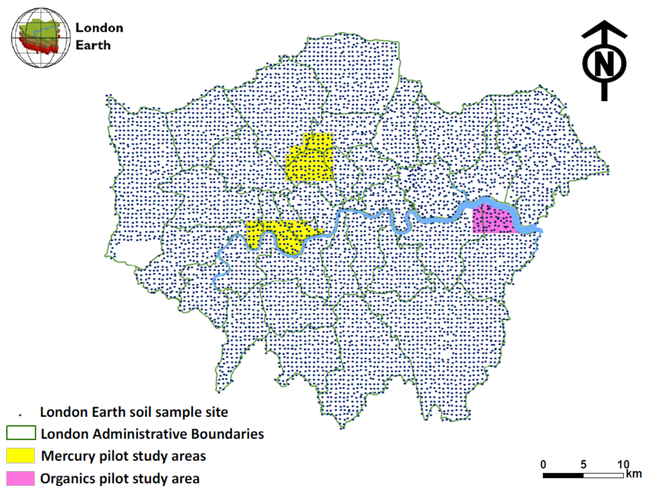
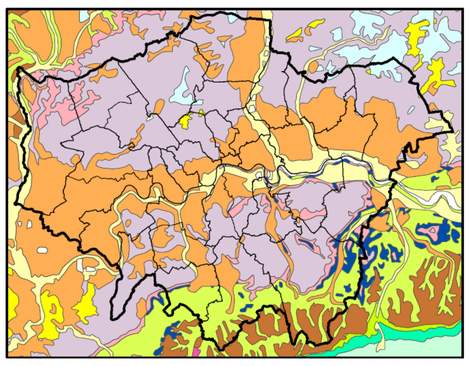


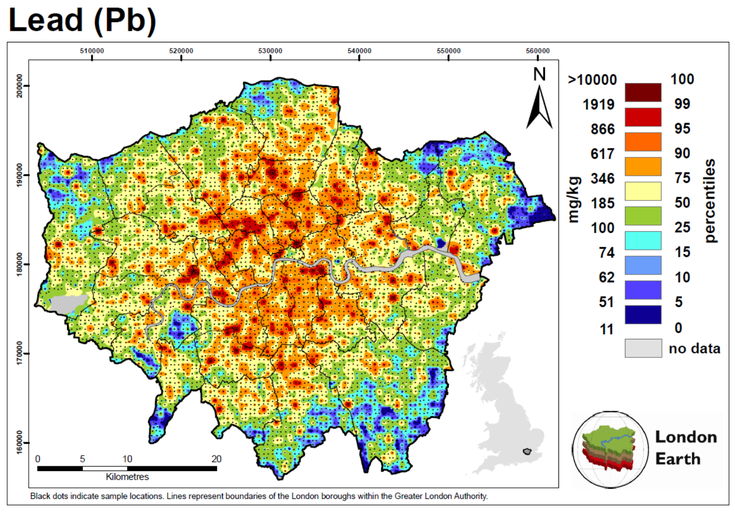
Figure 1: Map showing the c. 7000 soil sampling sites across the Greater London Authority (GLA) region, an area of c. 1800 km². The only area not sampled was Heathrow Airport in the west of the area. The majority of the sampling was done in 2008-9, the Olympic site area (East London) was sampled before redevelopment 2005-6. Several areas have been selected for the investigation of Hg and organic compounds.



Superficial and bedrock geology, 1:625 000 scale (DiGMapGB-625)

Figure 2 (above)*: Simplified geology map of London. The GLA area has a varied geology from Chalk in the south and Cretaceous to Palaeogene clays and sands in the remaining area. Quaternary river terraces and alluvium are also significant soil parent materials. Many of the element maps strongly reflect the underlying geology, despite parts of the area being extensively built-up and inhabited for 2000 years. These can be used to improve the detail of geological mapping at relatively large scales.*

Figure 3 (below)*: Lead in topsoils map. Geochemistry maps have been made using ArcGIS v9.3, extrapolating between sites to give geochemical images such as this Pb map (using IDW, a search radius of 750 m and cell size of 80 m). The images are classified and coloured using percentile classes. Lead is typical of an element showing a strong anthropogenic influence on its distribution with high Pb corresponding to built-up, central areas.*



Soils are a composite of five sub-samples from the corners and centre of 20 m square sampled using a 1 m auger. *Inset*: Soils are collected in Kraft™ sample bags to assist drying.

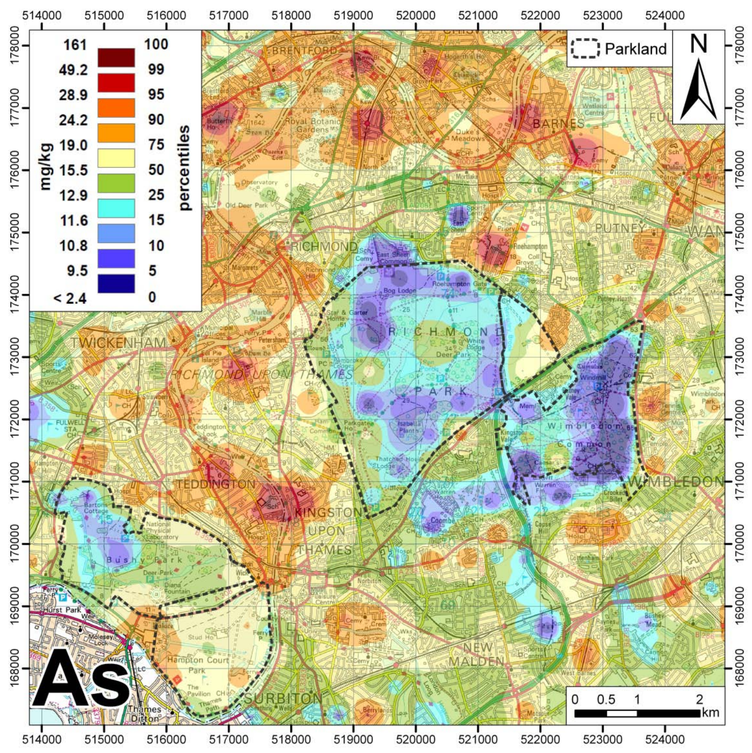
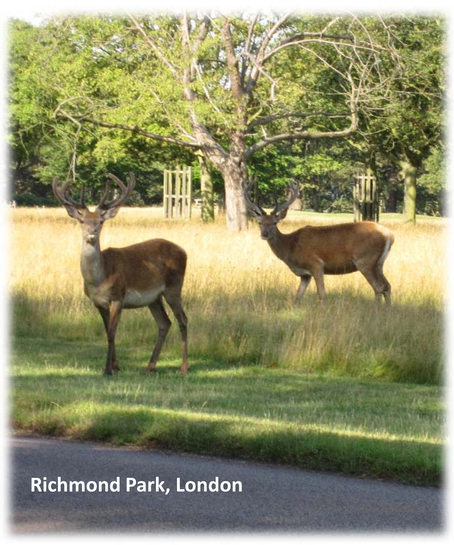


Figure 4 (left)*: Arsenic in the topsoil of SW London. Because of the relatively high density of the sampling in urban areas, the geochemical maps can be interpreted to a reasonably high resolution. A striking feature of the geochemistry maps is how the large parkland areas (for example, Richmond, Wimbledon and Bushy shown here) are oases within the city of land where contaminant levels are more akin to those found in rural environments.*



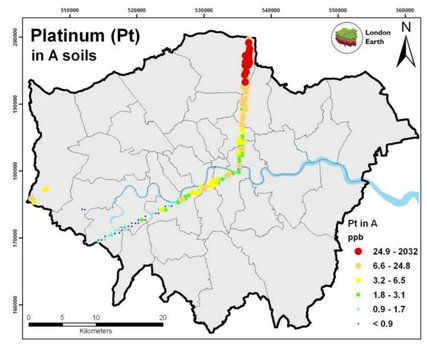


Figure 5 (above)*: Platinum group element (PGE) transect line across London. A transect line of soils was selected from the systematically collected London Earth samples for PGE analyses determined by fire assay – ICP-MS on surface and topsoils. The results provide information on the distribution of some elements not traditionally considered as an anthropogenic pollutant.*

The London Earth soil results and samples are a valuable resource for various sectors and have provided a starting point for many science research projects. In the contaminated land sector alone, the money saved in reducing unnecessary contaminated land remediation justifies the cost of the London Earth project. The chemical results for soil samples from a highly built-up and populated area has provided an urban data set that is extremely useful in the determination of normal levels of contaminants in English soils[a] (see below). BGS is the only UK organisation to be systematically mapping urban soils in this way.

Investigation and interpretation of the results has only just begun (see the examples in Figures 1, 5, 6 and 7) and London Earth will continue to be the seed for collaborative multi-disciplinary research for many years to come.

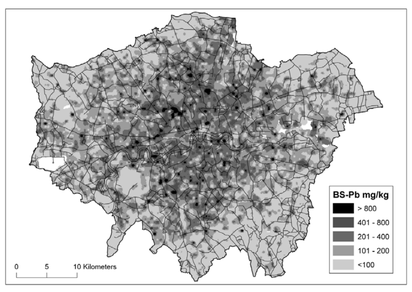


Figure 6 (left)*: A subset of 49 topsoils has been studied for bioaccessible Pb (BS-Pb using the universal BARGE method). A linear regression model of the bioaccessible Pb v total Pb has enabled a bioaccessibility map for London to be prepared[b]. The median bioaccessible fraction of the total Pb is 68%*

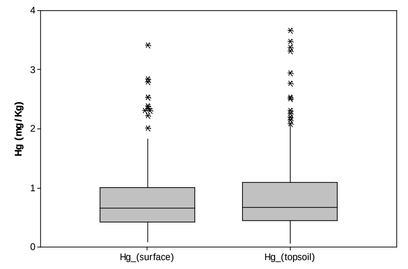


Figure 7 (above)*: A boxplot of Hg in surface and topsoils. This shows no major difference between soils at the surface (0-2 cm) and those collected from a depth 5-20 cm. Generally, Hg levels in the targeted areas (Figure 1) are high (median 0.67 mg/kg, 216 samples) compared with topsoils from outside urban areas in England (median 0.12 mg/kg, 1132 samples)[c].*

NORMAL BACKGROUND CONCENTRATIONS (NBCs) OF CONTAMINANTS IN ENGLISH SOILS

The Secretary of State from the United Kingdom Department for Environment, Food and Rural Affairs (Defra) issues Statutory Guidance (SG) in accordance with section 78Y of the Environmental Protection Act 1990 establishing a legal framework for dealing with contaminated land. The revised SG was issued in April 2012[d]. The intent of the SG is to explain how the contaminated land regime should be implemented and makes reference to "normal" levels of contaminants in soils. The BGS has been commissioned by Defra to determine what are the normal levels of contaminants in English soils.

The London Earth soil results form an important part of the systematically sampled and analysed soil database for England (Figure 8). Urban soils are especially important in this process as they come from where the majority of the population lives alongside the legacy of contaminating industries. The SG specifies that normal levels are typical and widespread and can be the result of contributions both from natural geogenic processes and diffuse anthropogenic pollution.

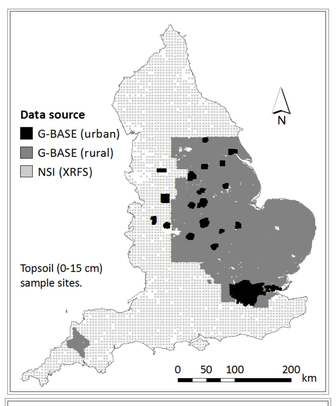


Figure 8: Map showing the distribution of samples used in the NBC determinations for As, Cd, Cu, Ni and Pb[a]. G-BASE sampling densities for rural and urban are 1:2 km² and 4:1 km², respectively. The National Soil Inventory (NSI) samples cover the whole of England at a sampling density of 1:25 km² . All samples are topsoils (sieved < 2 mm) and analysed at the BGS XRFS laboratory.

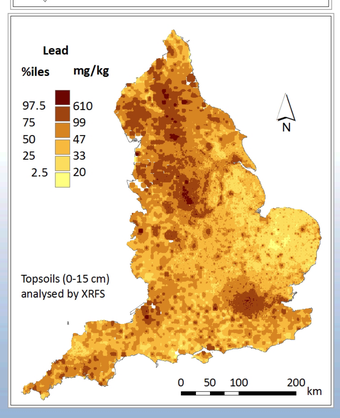


Figure 9: Map of Pb in English topsoils. Exploration of the contaminant data shows a spatial variability across England with high levels attributed to the underlying parent material, metalliferous mineralisation and mining, and urbanisation. Regions of elevated contaminant levels are identified as "Domains". Each contaminant domain is attributed with a NBC value rather than defining a single national value.

Part 2 A contaminated land Statutory Guidance , April 2012 – Section 3.23 [d]

"For the purpose of this Guidance, "normal" levels of contaminants in soil may result from:
(a) The natural presence of contaminants (e.g. caused by soil formation processes and underlying geology) at levels that might reasonably be considered typical in a given area and have not been shown to pose an unacceptable risk to health or the environment.
(b) The presence of contaminants caused by low level diffuse pollution, and common human activity other than specific industrial processes. For example, this would include diffuse pollution caused by historic use of leaded petrol and the presence of benzo[a]pyrene from vehicle exhausts, and the spreading of domestic ash in gardens at levels that might reasonably be considered typical."

In its work for Defra, BGS has represented "normal" levels of contaminants in soils by defining Normal Background Concentrations (NBCs). A NBC is the upper confidence limit of the 95th percentile of a soil data set[e]. What is considered typical and normal for a domain is therefore a range of values up to and including the domain NBC.

NBCs have been calculated by dividing the soil results into the important domains for each contaminant. Using distribution density plots and skewness testing, appropriate data transformation are made to reduce the influence of any point source contamination on the calculations. The method of percentile calculation depends on the nature of the data population distribution.

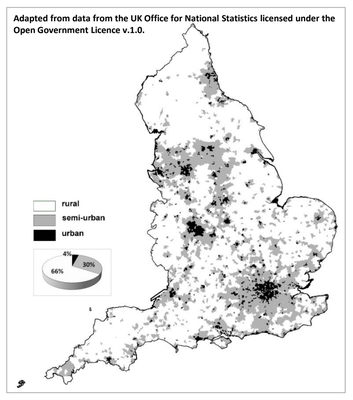


Figure 11: Map of urban areas of England[a]. The Urban Domain is identified as being associated with higher levels in soil of many contaminants such as benzo[a]pyrene (BaP), Cd, Cu, Hg and Pb. Soil results are attributed to domains in a GIS and NBCs calculated for each domain. From this map (defined by an urbanisation index using land use data) it can be seen how significant the area of urbanisation is in SE England.

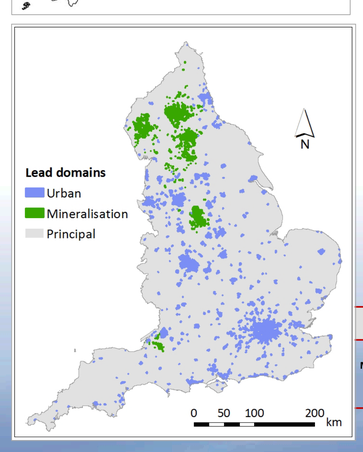


Figure 12: Map showing the Pb domains of England[a]. Exploration of soil Pb results identified areas of metalliferous mining and the urban environment as the two most significant regions of elevated Pb concentrations. What are typical and widespead for these areas is higher than the rest of the country. Lead NBCs have been assigned to these domains (see below).

Domain	Area (km²)	Area (%)	NBC (mg/kg)	n
Urban	5,400	4	820	7,529
Mineralisation	2,900	2	2,400	347
Principal	124,600	94	180	34,257

Table of Pb domain NBCs (n=number of samples)

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(a) Johnson, CC, Ander, EL, Cave, MR and Palumbo-Roe, B. 2012. Normal background concentrations (NBCs) of contaminants in English soils: Final project report. *British Geological Survey Commissioned Report*, CR/12/035. 40pp.

(b) Appleton, JD, Cave M R, Scheib, A and Wragg J. Modelling lead bioaccessibility in urban topsoils based on data from Glasgow, London, Northampton and Swansea, UK. Accepted for publication in Environmental Pollution, 29 June 2012.

(c) Ander, EL, Cave, MR, Johnson, CC and Palumbo-Roe, B. 2012. Normal background concentrations of contaminants in the soils of England. Results of the data exploration for Cu, Ni, Cd and Hg. British Geological Survey Commissioned Report, CR/12/041. 88pp.

(d) Defra, 2012. Environmental Protection Act 1990: Part 2A Contaminated Land Statutory Guidance. April 2012. Department for Environment, Food and Rural Affairs (Defra). HM Government. http://www.defra.gov.uk/environment/quality/land/ .

(e) Cave, MR, Johnson, CC, Ander, EL and Palumbo-Roe, B. 2012. Methodology for the determination of normal background contaminant concentrations in English soils. British Geological Survey Commissioned Report, CR/12/003. 41pp.

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Further geochemical maps and information about London Earth, including a "geochemical viewer", are available from the project website at: **www.bgs.ac.uk/gbase/londonearth.html**

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