



**British  
Geological Survey**

NATURAL ENVIRONMENT RESEARCH COUNCIL

# User Guide for the BGS Soil Chemistry Data for Environmental Assessments

Open Report OR/12/050



# User Guide for the BGS Soil Chemistry Data for Environmental Assessments

J D Appleton

*Contributor/editor*

K. Royse, G. Wildman

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*British Geological Survey offices*

### **BGS Central Enquiries Desk**

Tel 0115 936 3143 Fax 0115 936 3276  
email [enquiries@bgs.ac.uk](mailto:enquiries@bgs.ac.uk)

### **Kingsley Dunham Centre, Keyworth, Nottingham NG12 5GG**

Tel 0115 936 3241 Fax 0115 936 3488  
email [sales@bgs.ac.uk](mailto:sales@bgs.ac.uk)

### **Murchison House, West Mains Road, Edinburgh EH9 3LA**

Tel 0131 667 1000 Fax 0131 668 2683  
email [scotsales@bgs.ac.uk](mailto:scotsales@bgs.ac.uk)

### **Natural History Museum, Cromwell Road, London SW7 5BD**

Tel 020 7589 4090 Fax 020 7584 8270  
Tel 020 7942 5344/45 email [bgs london@bgs.ac.uk](mailto:bgs london@bgs.ac.uk)

### **Columbus House, Greenmeadow Springs, Tongwynlais, Cardiff CF15 7NE**

Tel 029 2052 1962 Fax 029 2052 1963

### **Maclea Building, Crowmarsh Gifford, Wallingford OX10 8BB**

Tel 01491 838800 Fax 01491 692345

### **Geological Survey of Northern Ireland, Colby House, Stranmillis Court, Belfast BT9 5BF**

Tel 028 9038 8462 Fax 028 9038 8461

[www.bgs.ac.uk/gsni/](http://www.bgs.ac.uk/gsni/)

### *Parent Body*

### **Natural Environment Research Council, Polaris House, North Star Avenue, Swindon SN2 1EU**

Tel 01793 411500 Fax 01793 411501  
[www.nerc.ac.uk](http://www.nerc.ac.uk)

Website [www.bgs.ac.uk](http://www.bgs.ac.uk)

Shop online at [www.geologyshop.com](http://www.geologyshop.com)

# Foreword

This report presents a description and review of the methodologies developed by the British Geological Survey (BGS) to produce a national scale assessment of the concentrations of five potentially harmful elements (arsenic, cadmium, chromium, nickel and lead) in topsoils.

The BGS Soil Chemistry Data for Environmental Assessments comprises three main components:

1. **Estimated Ambient Background Soil Chemistry** data (Total As, Cd, Cr, Ni, Pb) derived by spatial interpolation of the BGS G-BASE (Geochemical Baseline Survey of the Environment) rural soil data and the BGS and Imperial College (Wolfson Atlas) stream sediment data.
2. **Measured Urban Soil Chemistry** data (Total As, Cd, Cr, Ni, Pb; bioaccessible As and Pb), which is a subset of the BGS G-BASE urban topsoil data.
3. **Estimated Urban Soil Chemistry** data derived by spatial interpolation of the Measured Urban Soil Chemistry data (Total As, Cd, Cr, Ni, Pb; bioaccessible As and Pb). A unique feature of this component is the inclusion for the first time of estimated bioaccessible arsenic and lead data.

The methodologies used to develop the BGS Soil Chemistry Data for Environmental Assessments are briefly described in this report and in four scientific papers. The methods have been critically assessed and their fitness for purpose determined by J D Appleton, B Rawlins and A Scheib who specialise in geochemical hazards at BGS. The purpose of this user guide is to enable those licensing this dataset to have a better appreciation of how the data set has been created and therefore better understand the potential applications and limitations that the dataset may have.

Users should note that the **Estimated Ambient Background Soil Chemistry** data should not be confused with the DEFRA **Normal Background Concentrations** (Johnson et al., 2012; DEFRA 2012 b-o; available at

<http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=17768#Description> ).

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## Summary

This report presents a description and review of the methodologies developed by the British Geological Survey (BGS) to produce a national scale assessment of the concentrations selected potentially harmful elements (arsenic, cadmium, chromium, nickel and lead) in topsoils. The methodologies are described briefly in this report and in four scientific papers.

## Acknowledgements

Chris Johnson, Matt Harrison, Kate Royse and Gerry Wildman (BGS) are thanked for reviewing the dataset and suggesting improvements to this report.



# 1 Introduction

Founded in 1835, the British Geological Survey (BGS) is the world's oldest national geological survey and the United Kingdom's premier centre for earth science information and expertise. The BGS provides expert services and impartial advice in all areas of geoscience. Our client base is drawn from the public and private sectors both in the UK and internationally.

Our innovative digital data products aim to help describe the ground surface and what is beneath the whole of Great Britain (GB). These digital products are based on the outputs of the BGS survey and research programmes and our substantial national data holdings. This data coupled with our in-house geoscientific knowledge are combined to provide products relevant to a wide range of users in central and local government, insurance and housing industry, engineering and environmental business, and the British public.

Public understanding of the effect of land contamination and ground conditions on the health of the occupants, the safety of property, and the implication for the value of property is growing. Local councils are under increasing pressure from central government to provide environmental information. Information about geological and geochemical hazards is needed, in particular, the identification of areas with a potential for land contamination or ground movement.

In response to this, BGS initiated a development programme to produce data sets that identified and assessed potential geohazards threatening the human environment in Great Britain. Since 2000, the programme has generated:

- Six ground stability hazard datasets
- Superficial deposit thickness models
- Scans of onshore borehole logs for Great Britain
- Scans of geology and historic topography maps
- Ground permeability data
- Susceptibility to groundwater flooding data
- Geological indicators of past flooding data
- Radon potential hazard data
- Methane and carbon dioxide from natural sources and mining hazard data
- Non-coal mining hazards data
- A dataset showing suitability of the ground for infiltration sustainable drainage systems

Environmental consultants and other users need to know where potentially harmful elements (including As, Cd, Cr, Ni and Pb) may be a problem. In response to this requirement, the BGS has developed Soil Chemistry Data for Environmental Assessments derived from BGS G-BASE soil and stream sediment chemistry data, and from the Imperial College (Wolfson Atlas) stream sediment data where BGS currently hold no soil or sediment chemistry data.

Further information on all the digital data provided by the BGS can be found on our website at <http://www.bgs.ac.uk/products/home.html> or by contacting:

Central Enquiries  
British Geological Survey  
Keyworth  
Nottingham  
NG12 5GG  
Direct tel. +44(0)115 936 3143  
Fax. +44(0)115 9363150  
email [enquiries@bgs.ac.uk](mailto:enquiries@bgs.ac.uk)

## 2 About the Soil Chemistry Data for Environmental Assessments

### 2.1 BACKGROUND

Potentially harmful chemical elements (PHEs), including arsenic (As), cadmium (Cd), chromium (Cr), nickel (Ni) and lead (Pb), occur in the environment and under certain circumstances can be harmful to plants, animals or people.

PHEs exist in a variety of inorganic forms which have varying toxicity. The toxicity of the common PHEs and the likely adverse affects of chronic ingestion of low doses are described in DEFRA-EA (2002a). Whether or not a particular PHE constitutes a hazard depends on a variety of factors including:

- its chemical form, concentration, behaviour and the extent to which it may be taken up by living organisms,
- the size of the mineral particles in which the element occurs,
- soil or water acidity (pH),
- the type of vegetation cover,
- the extent of exposure to the element,
- the dose received.

The ambient background concentration of a PHE at a location reflects (i) the chemistry of the rocks, metallic mineralisation and weathering processes (geogenic component) and (ii) the impact of human activities (anthropogenic component).

A significant proportion of the landscape in Great Britain has elevated topsoil concentrations of some PHEs which exceed the former Soil Guideline Values (SGV), which are generic assessment criteria used as screening tools in generic quantitative human health risk assessment (DEFRA-EA, 2002b-g; Environment Agency 2008a-b; 2009a-e; DEFRA, 2012a).

The main exposure pathway for PHEs, including As and Pb in soil, is via soil ingestion by people, therefore, from a human health perspective, it is not the total amount of As or Pb in the soil but the fraction that is absorbed into the body during soil ingestion (i.e. the bioavailable fraction), that is important for assessing human health risk.

The measurement of the bioavailability of PHEs in soil requires testing using humans or animal surrogates, which is a time consuming, costly and ethically challenging process. Chemical bioaccessibility testing has been developed and validated specifically to provide a conservative estimate of bioavailability. The bioaccessibility assay estimates the fraction of the PHE released from the soil into solution in the gastro-intestinal (GI) tract in a form that can potentially be absorbed into the blood stream. Guidelines for the use of data produced by bioaccessibility testing methods in human health risk assessment have recently been produced in order to assist the risk assessment and regulatory communities (Nathanail, 2009).

The BGS has used predictive regression modelling between bioaccessible As, Pb and a range of total elemental compositions and soil properties to develop bioaccessible As and Pb datasets (Appleton et al., 2012b-c) derived from the BGS Estimated Urban Soil Chemistry total element concentration data. Bioaccessible As and Pb concentrations estimated by predictive modelling from soil properties mean that a bioaccessibility test does not have to be carried out on every soil from a given soil region. However, the relationship between total and bioaccessible PHE concentrations may vary from site to site dependant on whether high PHE concentrations relate to geogenic or anthropogenic sources, as well as a range of soil factors. Consequently, site specific investigations may be required because the bioaccessible As and Pb data in the BGS Urban Soil Chemistry are estimated values based on national rather than site-specific predictive models.

## 2.2 WHAT THE DATASET SHOWS?

The BGS SOIL CHEMISTRY FOR ENVIRONMENTAL ASSESSMENTS data consists of three layers in Geographical Information System (GIS) format that identify the measured and estimated concentrations of five potentially harmful elements in the topsoils of GB :

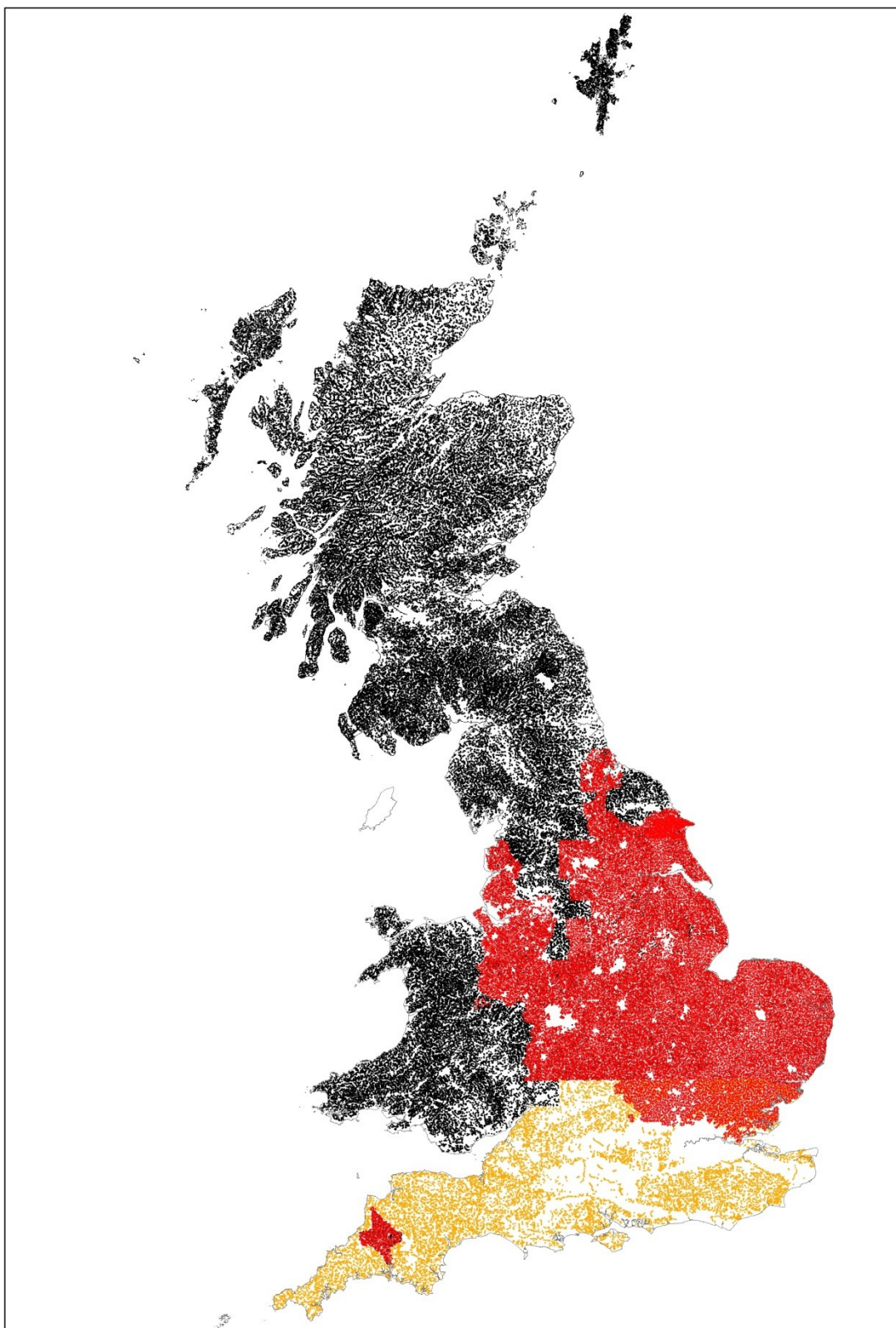
1. The **BGS ESTIMATED AMBIENT BACKGROUND SOIL CHEMISTRY** data indicates the estimated geometric mean concentrations ( $\text{mg kg}^{-1}$ ) of total As, Cd, Cr, Ni and Pb in topsoil derived by spatial interpolation of BGS G-BASE rural soil data and BGS and Imperial College (Wolfson Atlas) stream sediment data (Figure 1). The data indicate the estimated concentrations in topsoil at the site or within a search area. The purpose of this data is to provide an estimate of the average total concentrations in rural soil and the likely geogenic background concentrations in urban areas. For urban areas, this data indicates the likely concentrations of As, Cd, Cr, Ni and Pb prior to the impact of anthropogenic contamination related to human activities.
2. The **BGS MEASURED URBAN SOIL CHEMISTRY** data comprises the locations and concentrations ( $\text{mg kg}^{-1}$ ) of total As, Cd, Cr, Ni and Pb in urban topsoil samples from 23 urban centres across GB (Figure 2). The dataset can be used to identify the concentrations of these elements in urban topsoil samples that are located in and adjacent to a search area, but only in those urban centres where soil samples have been collected by the BGS.
3. The **BGS ESTIMATED URBAN SOIL CHEMISTRY** data indicates the estimated geometric mean concentrations ( $\text{mg kg}^{-1}$ ) of total As, Cd, Cr, Ni and Pb, and bioaccessible As and Pb in topsoil derived by spatial interpolation of the MEASURED URBAN SOIL CHEMISTRY data. The data indicate the estimated concentrations in topsoil at the site or within a search area. This data can be compared with the Estimated Ambient Background Soil Chemistry data to obtain an indication of the level and extent of anthropogenic contamination in these urban areas.

This information is relevant for the first stage of any assessment of risks to human health required by regulatory authorities in relation to land-use and also for assessing ecological risks.

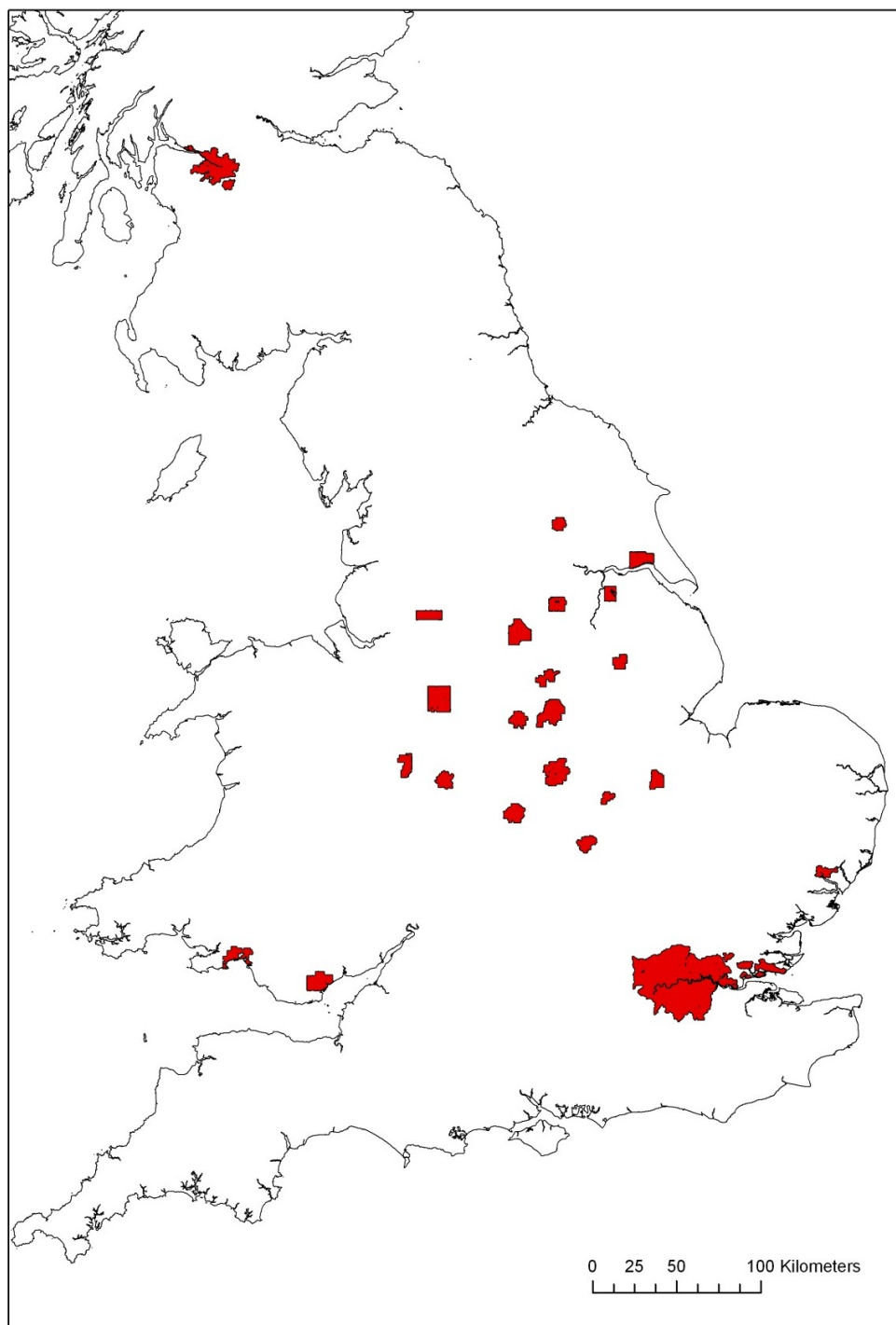
Although measured point source or estimated topsoil PHE concentrations above generic assessment criteria, such as SGVs or the ‘normal’ range, do not necessarily imply a significant health risk, they do highlight the need to consider whether or not there may be a risk.

Comparison of this spatially referenced geochemical data set with (i) information on current or historic land use, (ii) geological information and (iii) technical guidance on “normal” levels of contaminants in soils (DEFRA 2012b-o) may help environmental professionals carry out desk studies for site investigations.

These data have been produced by geochemists and information developers at the BGS and are presented as a number of separate GIS data layers.



**Figure 1 Location of analysed BGS G-BASE rural soil (red dots), G-BASE stream sediment (black dots) and Wolfson stream sediment (orange dots) samples used to produce the Estimated Ambient Background Soil Chemistry data.**



**Figure 2** Extent of urban areas included in the Measured and Estimated Urban Soil Chemistry datasets (see Figure 3 for names of urban centres).

### 2.3 WHO MIGHT REQUIRE THIS DATA?

The BGS Soil Chemistry Data for Environmental Assessments can be used for:

1. Preliminary risk assessments based on the measured and estimated concentration ( $\text{mg kg}^{-1}$ ) of total As, Cd, Cr, Ni and Pb, and the estimated bioaccessible fraction of As and Pb in topsoil.
2. Establishing whether elevated local measurements in urban areas may be the result of significant anthropogenic contamination by comparing the MEASURED AND

ESTIMATED URBAN SOIL CHEMISTRY DATA with information on historic and current land uses (DEFRA-EA, 2002k) and with the ESTIMATED AMBIENT BACKGROUND SOIL CHEMISTRY DATA derived from rural soil and stream sediment data.

3. Assess whether concentrations of these elements fall within the “normal” range for the domain in which the site is located (Johnson et al., 2012; Ander et al., 2011, 2012; Cave et al., 2012) as defined in the Contaminated Land Statutory Guidance (DEFRA, 2012a; Johnson et al., 2012). The concept of “normal levels of contaminants” is an important concept in the recently published Contaminated Land Statutory Guidance for the Environmental Protection Act 1990: Part 2A (DEFRA, 2012). Technical Guidance Sheets on normal levels of contaminants in English soils, along with supplementary information are published for As, Cd, Cu, Ni, Pb and Hg (DEFRA, 2012b-o).

Land contamination is a material planning consideration, which means that a planning authority has to consider the potential implications of contamination when it is developing structure or local plans (or Urban Development Plans) and when it is considering applications for planning permission. When contamination is known or suspected to exist, a planning authority may require appropriate desk studies, and/or site investigations and, if necessary, remediation to be carried out.

The Contaminated Land Statutory Guidance for the Environmental Protection Act 1990: Part 2A (DEFRA, 2012a) explains how local authorities should go about deciding whether land is contaminated land in the legal sense. The concept of “normal levels of contaminants” and the use of “generic assessment criteria” such as the Soil Guideline Values (SGVs) is explained in the statutory guidance (DEFRA, 2012a).

Dealing with land contamination under the planning regime is mentioned in the National Planning Policy Framework (DCLG, 2012). The requirement for site investigation information as part of a planning application includes a risk assessment of any land potentially affected by contamination carried out in accordance with established procedures (such as *BS10175 (2001) Code of Practice for the Investigation of Potentially Contaminated Sites*). The minimum information to be provided by an applicant is a report of a desk study and site reconnaissance.

Consequently, the BGS Soil Chemistry Data for Environmental Assessments can be used to assist Local Planning Authorities to identify those areas where a risk assessment may need to be carried out by developers and to assess whether the levels of contaminants in soils are “normal”. The data is particularly appropriate for use by Value Added Resellers (VARs), for inclusion in their comprehensive environmental reports that cover all types of contamination. These reports will be of particular value to advisers preparing desk study reports for developers and other users.

Land contaminated by potentially harmful elements may lead to financial loss for anyone involved in the ownership or management of property, including developers, householders or local government. These costs could include increased insurance premiums, depressed house prices and, in some cases, engineering works to remediate contaminated land. Armed with knowledge about potential hazards, preventative steps can be put in place to alleviate the impact of the hazard to people and property.

The identification of the concentrations of potentially harmful elements in topsoils can assist regional planners; rapidly identifying areas with potential problems and aid local government offices in making development plans by helping to define land suited to different uses. Other users of these data may include developers, homeowners, solicitors, loss adjusters, the insurance industry, architects and surveyors.

## 3 Technical Information

### 3.1 DEFINITIONS

- PHE = Potentially Harmful Element
- As = arsenic
- Cd = cadmium
- Cr = chromium
- Ni = nickel
- Pb = lead
- B-As = bioaccessible arsenic
- B-Pb = bioaccessible lead
- Topsoil concentrations: As, Cd, Cr, Ni or Pb concentrations in the <2mm fraction of soil taken from a depth interval of 5-20cm
- mg/kg = concentration ( $\text{mg kg}^{-1}$ ; equivalent to parts per million) of PHE in <2mm fraction of topsoil

### 3.2 SCALE

The BGS **Estimated Ambient Background Soil Chemistry** data is produced for use at 1:50,000 scale. The **Measured Urban Soil Chemistry** and **Estimated Urban Soil Chemistry** data is produced for use at 1:10 000 to 1:50 000 scale providing ground resolution that reflects the soil sample density.

### 3.3 FIELD DESCRIPTIONS

**Table 1 Attribute table field descriptions for BGS Estimated Ambient Background Soil Chemistry dataset**

FIELD NAME	FIELD TYPE	DESCRIPTION
SAMPLENO	Numeric-double	BGS sample number
SAMPLETYPE	String	indicates whether the estimated soil PHE value is derived from a statistical assessment of rural soil ( <i>RuralSoil</i> ) or sediment ( <i>Sediment</i> or <i>Sed</i> ) data. “ <i>London</i> ” in this field indicates that no data are available from the London urban area. “ <i>RuSoilLond</i> ” indicates estimates based on rural soil data within the London urban area; “ <i>RuSoilExAs</i> ” indicates that rural soil data were used except from arsenic, when sediment data was used.
ARSENIC	String	Estimated concentration of arsenic ( $\text{mg kg}^{-1}$ ) in topsoil
CADMIUM	String	Estimated concentration of cadmium ( $\text{mg kg}^{-1}$ ) in topsoil
CHROMIUM	String	Estimated concentration of chromium ( $\text{mg kg}^{-1}$ ) in topsoil
NICKEL	String	Estimated concentration of nickel ( $\text{mg kg}^{-1}$ ) in topsoil
LEAD	String	Estimated concentration of lead ( $\text{mg kg}^{-1}$ ) in topsoil
RELEASEDAT	String	Dataset title and release date ( <i>EW_EstimatedAmbientBackgroundSoilChemistry_October2012</i> for England and Wales; <i>SC_EstimatedAmbientBackgroundSoilChemistry_October2012</i> for Scotland)

The estimated soil concentrations are classed as follows:

**Arsenic:** <15, 15-25, 25-35, 35-45, 45-60, 60-120, >120  $\text{mg kg}^{-1}$

**Cadmium:** <1.8, 1.8-2.2, 2.2- 3.0, 3.0-6.0, >6.0  $\text{mg kg}^{-1}$

**Chromium:** <20, 20-40, 40-60, 60-90, 90-120, 120-180, >180  $\text{mg kg}^{-1}$

**Nickel:** <15, 15-30, 30-45, 45-60, 60-80, 80-100, >100  $\text{mg kg}^{-1}$

**Lead:** <150, 150-300, 300-600, 600-900, >900  $\text{mg kg}^{-1}$



**Table 2 Attribute table field descriptions for BGS Measured Urban Soil Chemistry dataset**

<b>FIELD NAME</b>	<b>FIELD TYPE</b>	<b>DESCRIPTION</b>
SAMPLENO	Numeric-double	BGS sample number
SAMPLETYPE	String	Indicates soil type is a topsoil
AREA	String	Urban area code (see Table 5 for explanation)
EASTING	Numeric-double	OS National Grid Easting
NORTHING	Numeric-double	OS National Grid Northing
AS_MGKG	Numeric-double	Concentration of arsenic (mg kg <sup>-1</sup> ) in topsoil
CD_MGKG	Numeric-float	Concentration of cadmium (mg kg <sup>-1</sup> ) in topsoil
CR_MGKG	Numeric-double	Concentration of chromium (mg kg <sup>-1</sup> ) in topsoil
NI_MGKG	Numeric-double	Concentration of nickel (mg kg <sup>-1</sup> ) in topsoil
PB_MGKG	Numeric-double	Concentration of lead (mg kg <sup>-1</sup> ) in topsoil
RELEASEDAT	String	Dataset title and release date: <i>GB_MeasuredUrbanSoilChemistry_October2012</i>

**Table 3 Attribute table field descriptions for BGS Estimated Urban Soil Chemistry data: Cd, Pb and bioaccessible Pb subset**

FIELD NAME	FIELD TYPE	DESCRIPTION
CD_MGKG	Numeric-float	Estimated concentration of cadmium ( $\text{mg kg}^{-1}$ ) in topsoil
PB_MGKG	Numeric-long integer	Estimated concentration of lead ( $\text{mg kg}^{-1}$ ) in topsoil
B_PB_MGKG	Numeric-long integer	Estimated concentration of bioaccessible lead ( $\text{mg kg}^{-1}$ ) in topsoil
SAMPLETYPE	String	Indicates soil type is a topsoil
AREA	String	Urban area code (see Table 5 for explanation)
RELEASEDAT	String	Dataset title and release date: <i>GB_EstimatedUrbanSoilChemistry_CdPb_October2012</i>

Note: Measured soil chemistry data interpolated to 100 m grid.

**Table 4 Attribute table field descriptions for BGS Estimated Urban Soil Chemistry dataset: As, Cr, Ni and bioaccessible As subset**

FIELD NAME	FIELD TYPE	DESCRIPTION
AS_MGKG	Numeric-long integer	Estimated concentration of arsenic ( $\text{mg kg}^{-1}$ ) in topsoil
CR_MGKG	Numeric-long integer	Estimated concentration of chromium ( $\text{mg kg}^{-1}$ ) in topsoil
NI_MGKG	Numeric-long integer	Estimated concentration of nickel ( $\text{mg kg}^{-1}$ ) in topsoil
B_AS_MGKG	Numeric-float	Estimated concentration of bioaccessible arsenic ( $\text{mg kg}^{-1}$ ) in topsoil
SAMPLETYPE	String	Indicates soil type is a topsoil
AREA	String	Urban area code (see Table 5 for explanation)
RELEASEDAT	String	Dataset title and release date: <i>GB_EstimatedUrbanSoilChemistry_AsCrNi_October2012</i>

Note: Corby, Northampton and Scunthorpe measured soil chemistry data interpolated to parent material - 100 m grid; measured data for other urban areas interpolated to 100 m grid

### 3.4 COVERAGE

The Estimated Ambient Background Soil Chemistry data covers the whole of GB apart from London (Figure 1)

The Measured Urban Soil Chemistry data and Estimated Urban Soil Chemistry data is provided to identify the concentrations of each of the 5 potentially harmful elements (As, Cd, Cr, Ni and Pb) and bioaccessible As and Pb in 23 urban areas in Great Britain (Figure 3).

### 3.5 DATA FORMAT

The BGS Soil Chemistry for Environmental Assessments data consists of points and vector polygons and is available in a range of GIS formats, including ArcGIS (.shp), Arc Info Coverages and MapInfo (.tab). More specialised formats may be available but may incur additional processing costs.

## 4 Methodology

### 4.1 ESTIMATED AMBIENT BACKGROUND SOIL CHEMISTRY DATA

The BGS ESTIMATED AMBIENT BACKGROUND SOIL PHE DATA is derived from national, high-resolution geochemical data from the BGS G-BASE (Johnson et al., 2005) and Imperial College Wolfson (Webb et al., 1978) geochemical surveys in combination with maps of soil parent material (PM) derived from the BGS DiGMapGB-50 digital geological data (British Geological Survey, 2006).

Parent material (PM) is the primary control on soil geochemistry in recently glaciated landscapes such as the British Isles (Rawlins et al., 2003). PM classes are based on the concatenation of separate descriptive codes for the underlying bedrock and any superficial deposits present. The high-resolution PM maps for all of Great Britain (1:50 000 scale) provide a firm spatial basis for mapping estimated soil PHE concentrations. The geochemical mapping units are delineations of PM coded polygons within each 1-km square of the British National Grid. By using delineations of PM polygons as soil geochemistry mapping units, it is possible to estimate PHE concentrations based on local averages for such units, without significant errors at PM boundaries.

The BGS ESTIMATED AMBIENT BACKGROUND SOIL DATA is based on G-BASE soil geochemical data where these are available (Figure 1). Elsewhere the stream sediment data are converted to surface soil equivalent PHE concentrations using delineations of PM polygons as the soil geochemistry mapping unit and the statistical relationships between soil and stream sediment data to derive the equivalent soil PHE concentration from the stream sediment data. Where only Wolfson stream sediment data are available in southern England, these data are first transformed to G-BASE equivalent sediment concentrations, and then to soil equivalent concentrations.

Geometric mean ambient background concentrations (ABCs) for PHEs in mineral soils are mapped within delineations of PM polygons to produce a seamless data set covering the whole of Great Britain, with the exception of the London area where an inadequate number of geochemical samples were available when the dataset was produced in 2009.

Further information on the method used to develop the ESTIMATED AMBIENT BACKGROUND SOIL CHEMISTRY DATA is presented in Appleton et al. (2008).

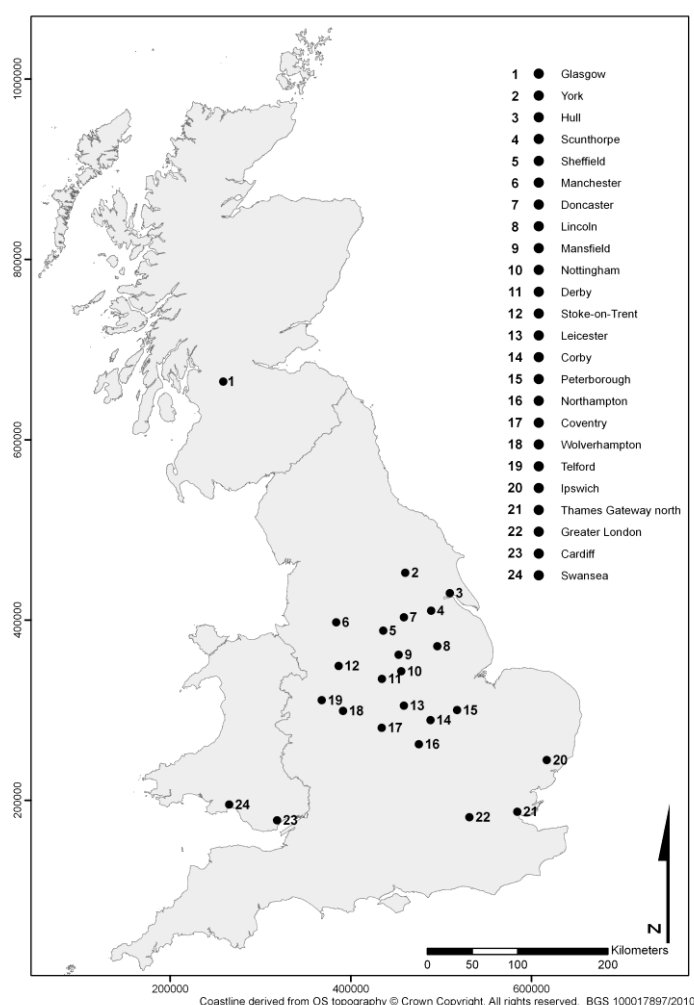
### 4.2 MEASURED URBAN SOIL CHEMISTRY DATA

This dataset comprises the locations and concentrations ( $\text{mg kg}^{-1}$ ) of total As, Cd, Cr, Ni and Pb, and estimated bioaccessible As and Pb in urban topsoil samples. The total element concentration data is a subset of the national, high-resolution urban soil geochemical data from the BGS Geochemical Baseline Survey of the Environment (G-BASE) project <http://www.bgs.ac.uk/discoverymetadata/13480371.html>.

Soil geochemical surveys have been carried out at 23 urban areas in England, Scotland and Wales (Figures 2 and 3). Nineteen of the surveys were undertaken by the BGS as part of the Geochemical Baseline Surveys of the Environment (G-BASE) project (Flight and Scheib, 2011; Fordyce et al., 2005), whereas Wolverhampton, Manchester and Glasgow (Fordyce et al., 2012) were sampled as part of larger multi-disciplinary projects and Greater London as part of the London Earth project (<http://www.bgs.ac.uk/gbase/londonearth.html>). The concentrations of many potentially harmful elements including arsenic (As), cadmium (Cd), chromium (Cr), nickel (Ni), and lead (Pb) are frequently above 'natural' background in urban environments as a result of a range of contaminative processes.

Urban geochemical surveying is based on the collection of samples on a 500 m grid at a density of approximately 4 samples per km<sup>2</sup> across the urban areas. Samples were collected from open ground as close as possible to the centre of each 500 m grid cell. At each sample site, composite samples based on 5 sub-samples taken at the centre and four corners of a 20 m square, were collected from the topsoil (5–20 cm depth). Currently over 50 chemical elements are determined in the <2 mm size fraction of the topsoils.

Summary statistics for PHEs in topsoils for the urban areas are given in Table 5. Further details on the G-BASE project can be obtained from Fordyce et al. (2005), Scheib and Nice (2007) and Flight and Scheib (2011), and in reports quoted in these three publications.



**Figure 3 Urban centres with G-BASE topsoil data**<sup>1</sup>

<sup>1</sup> data for urban centres 21 and 22 are combined under the LOND area code in Table 5

**Table 5 Number (No.) of urban topsoil samples and area summary statistics for As, Cd, Cr, Ni and Pb (concentrations in mg kg<sup>-1</sup>)**

Urban area	Area Code	No.	Avg As	Min As	Max As	Avg Cd	Min Cd	Max Cd	Avg Cr	Min Cr	Max Cr	Avg Ni	Min Ni	Max Ni	Avg Pb	Min Pb	Max Pb
Cardiff	CARD	508	18	6	151	1.3	0.5	82.0	89	5	2456	31	10	437	190	15	7377
Corby	CORB	133	23	11	90	0.3	0.3	4.0	94	56	233	32	17	64	49	18	438
Coventry	COVE	389	10	2	105	0.5	0.3	8.6	66	25	426	25	7	157	108	19	976
Derby	DERB	275	16	6	63	2.4	0.3	12.5	69	30	311	34	12	180	321	21	2053
Doncaster	DONC	279	15	2	75	1.1	0.5	7.0	72	19	504	22	6	150	123	19	1072
Glasgow	GLAS	1381	11	1	285	0.4	0.3	16.0	124	37	4340	52	7	950	177	14	4871
Hull	HULL	408	24	3	207	0.6	0.3	5.0	94	20	1831	34	8	130	227	11	2825
Ipswich	IPSW	200	12	4	47	0.5	0.3	4.8	43	22	119	15	4	51	114	12	909
Leicester	LEIC	652	14	4	85	0.5	0.3	9.3	86	42	770	28	10	87	109	17	2053
Lincoln	LINC	215	15	4	65	0.6	0.5	5.0	48	17	262	15	3	94	109	16	1364
London	LOND <sup>1</sup>	7189	17	1	161	0.9	0.3	165.2	79	13	2094	28	2	506	280	11	10000
Manchester	MANC	300	28	3	1008	1.4	0.3	80.3	92	29	1252	32	6	137	270	21	2687
Mansfield	MANS	257	14	3	72	1.3	0.1	9.0	58	16	251	19	5	95	112	2	1285
Northampton	NORT	275	34	8	107	0.9	0.3	134.1	129	53	4304	30	6	76	82	25	655
Nottingham	NOTT	636	14	5	88	2.2	0.3	17.0	67	27	184	29	6	146	145	14	976
Peterborough	PETE	272	18	7	35	0.3	0.3	3.8	83	41	187	30	14	64	67	15	761
Scunthorpe	SCUN	196	26	3	191	1.2	0.5	28.0	66	5	1121	20	2	186	88	10	3214
Sheffield	SHEF	575	26	4	241	1.2	0.3	8.0	135	42	1265	38	9	434	239	20	4188
Stoke	STOK	745	16	2	137	1.7	0.1	43.0	75	20	445	26	6	115	173	11	4098
Swansea	SWAN	370	77	8	2062	3.1	0.5	61.0	81	18	571	46	9	320	422	21	14328
Telford	TELF	293	12	5	54	2.4	0.1	30.0	71	24	164	31	8	141	147	21	1205
Wolverhampton	WOLV	284	20	4	158	1.9	0.1	70.0	99	38	1312	39	12	243	243	27	2779
York	YORK	191	12	3	94	1.3	0.3	9.0	63	26	645	20	7	78	210	25	2338

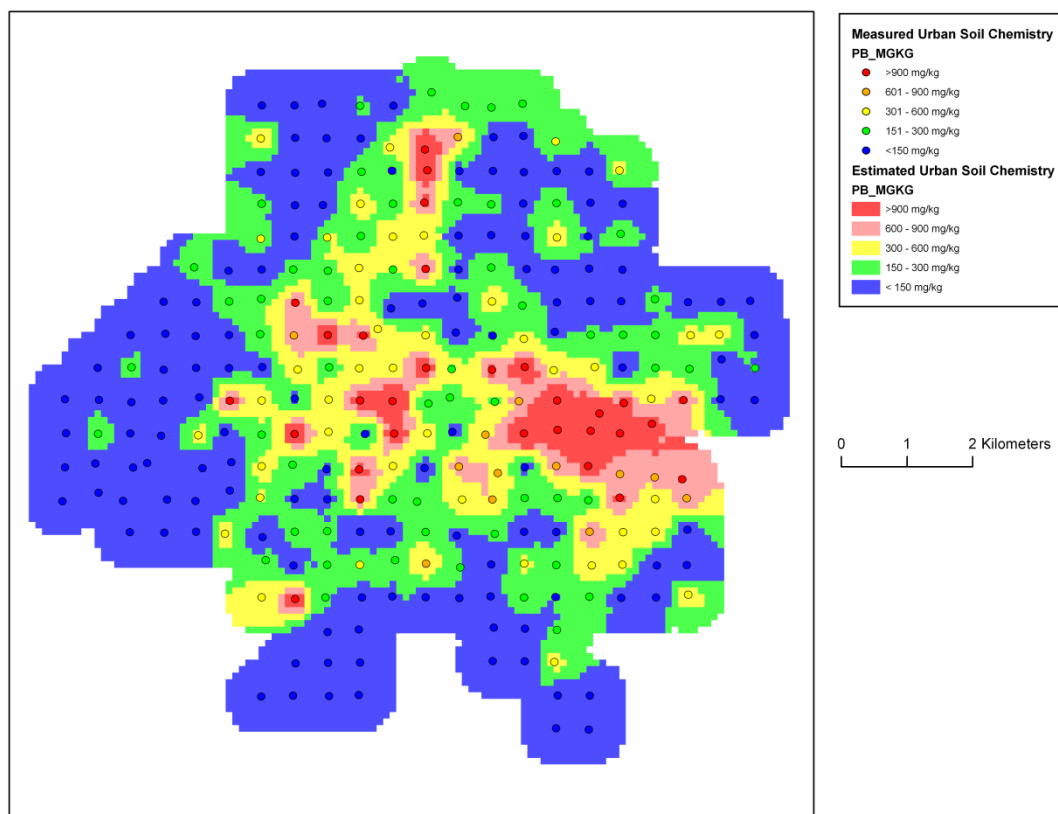
<sup>1</sup> Greater London includes satellite towns Brentwood, Basildon, Canvey Island, Southend, Tilbury and Grays

### 4.3 ESTIMATED URBAN SOIL CHEMISTRY DATA

This dataset indicates the estimated topsoil total As, Cd, Cr, Ni and Pb, and bioaccessible As and Pb concentrations ( $\text{mg kg}^{-1}$ ) derived by spatial interpolation of the MEASURED URBAN SOIL CHEMISTRY data.

Urban soil geochemical data generally have large positive skewness coefficients so were transformed by taking natural logarithms (Ln). To overcome the bias associated with traditional measures of location (mean) and scale (standard deviation) for log-normal data, the inverse distance weighted (IDW) mean of log transformed element concentrations were used for mapping the spatial variation in Cd and Pb concentrations, whose distribution in urban areas is not usually strongly controlled by the underlying geology (soil parent material).

Figure 4 illustrates the relationship between the Measured Urban Soil Chemistry data and Estimated Urban Soil Chemistry data for lead (Pb) in the Derby urban area.



**Figure 4 Distribution of measured and estimated total lead ( $\text{mg kg}^{-1}$ ) in the <2 mm fraction of topsoils in the Derby urban area<sup>2</sup>**

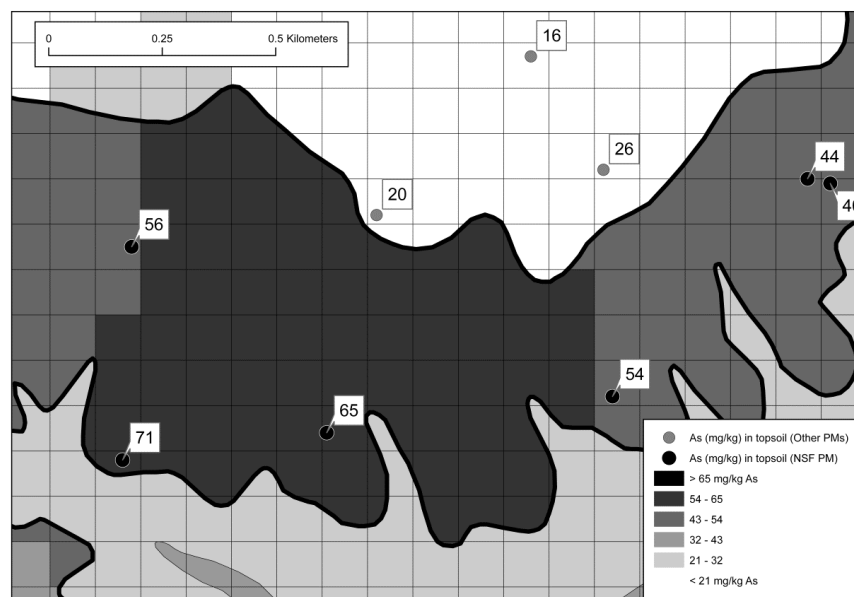
Analysis of variance (ANOVA) of soil data both regionally and for some urban areas suggests that spatial interpolation of soil concentrations using parent material (PM) classified soil data is justified for those elements with strong geogenic control (As, Cr and Ni) in urban areas underlain by ironstones (Corby, Northampton, and Scunthorpe; Appleton and Adlam, 2012a).

<sup>2</sup> 100 m grid values calculated from LnPb in the nearest 4 soil samples by IDW. Measured (point source) data indicated by filled circles.

Using PM polygons as soil chemistry mapping units, it is possible to estimate element concentrations based on local averages, without significant errors at PM boundaries (Appleton et al., 2008). This methodology is appropriate in situations and for elements where PM explains a relatively high proportion of the variance. The method is less appropriate for elements where the proportion of variance explained by PM is low, for example where point source or diffuse anthropogenic contamination is a major factor in urban areas, such as Cd and Pb in all urban areas, and As, Cr and Ni in urban areas apart from those where ironstones are important. Where anthropogenic inputs are dominant, conventional IDW grid square mapping is the appropriate technique for estimating average topsoil concentrations.

Parent material classes in the Corby, Northampton and Scunthorpe urban areas are based on surface geology. Parent material (surface geology) polygons derived by unioning BGS DiGMapGB-10 (1:10,000 scale) bedrock and superficial geology data are subdivided into separate 100 m square polygons of the British National Grid using ESRI® ArcGIS geoprocessing tools to produce the shape files. These store non-topological geometry and attribute information for the spatial features that form the basis for the production of the geochemical maps. Parent material (surface geology) codes and codes for the relevant 100 m grid square are attached to the locations of all soil samples. Parent material geochemical mapping was executed using an ArcGIS tool written in Vb.Net. On a map extract from the Northampton urban area (Figure 5), the Northampton Sand Formation (NSF, ironstone) is outlined by a thick black line and individual soil samples derived from the NSF identified by black filled circles labelled with As concentrations (mg kg<sup>-1</sup>). The estimated geometric mean (GM) As concentration for each individual 100 m square polygon within the boundary of the NSF is the average (i.e. GM) of LnAs in the nearest 4 topsoil samples. Topsoil samples on other PMs are indicated by grey filled circles (Figure 5).

Independent validation of mapping methods (Appleton and Adlam, 2012a) indicated that for As and Cr, which both exhibit relatively strong geogenic control in the Northampton urban area, the PM soil chemistry mapping method is more accurate and effective than the conventional IDW grid mapping.



**Figure 5 Geochemical mapping using PM-grouped data (see text for explanation)**

### *Estimated bioaccessible arsenic (B-As) concentrations*

Predictive linear regression (LR) modelling between bioaccessible arsenic (B-As) and a range of total elemental compositions and soil properties was used to assess the potential for developing a national B-As dataset for the UK (Appleton et al., 2012b). LR indicates that total arsenic (As) is the only highly significant independent variable for estimating B-As in urban areas where it explains 75-92% of the variance. The broad compatibility of the LR models derived from topsoil data from the London, Glasgow and Swansea urban areas indicates that application of these models to estimate bioaccessible As in UK soils impacted by diffuse anthropogenic urban contamination and non-ferrous metal processing should be relatively accurate. In areas dominated by Jurassic ironstones and associated clays and limestones, total As, P and pH are significant, accounting for 53, 14 and 5%, respectively, of the B-As variance. Models based on total As as the sole predictor in the combined Jurassic and Cretaceous sedimentary ironstones datasets explain about 40% of the B-As variance. The median As bioaccessible fraction (%As-BAF) is 19 to 28% in the anthropogenic contamination impacted urban domains, but much lower (5-9%) in geogenic terrains dominated by ironstones. For the **Estimated Urban Soil Chemistry** dataset, B-As was estimated from total As concentrations in urban areas underlain by ironstones (Corby, Northampton and Scunthorpe) using the following formula:  $B-As = 0.0513 \text{ total As}$ . In the other urban areas impacted by diffuse anthropogenic contamination, B-As was estimated using the following formula:  $B-As = 0.175 \text{ total As}$  (Appleton et al., 2012b).

### *Estimated bioaccessible lead (B-Pb) concentrations*

Predictive linear regression (LR) modelling between bioaccessible Pb (B-Pb) and a range of total elemental compositions and soil properties was executed for the Glasgow, London, Northampton and Swansea urban areas in order to assess the potential for developing a national urban bioaccessible Pb dataset for the UK (Appleton et al., 2012c). LR indicates that total Pb is the only highly significant independent variable for estimating the bioaccessibility of Pb. Statistical tests demonstrated that the relationship between total Pb and bioaccessible Pb is broadly the same in the four urban areas. The median bioaccessible fraction ranges from 38% in Northampton to 68% in London and Swansea. For the **Estimated Urban Soil Chemistry** dataset, B-Pb was estimated from total Pb concentrations using the following formula:  $B-Pb = 0.687 \text{ total Pb}$  (Appleton et al., 2012c).

## 5 Dataset History

### 5.1 ESTIMATED AMBIENT BACKGROUND SOIL CHEMISTRY

The **ESTIMATED AMBIENT BACKGROUND SOIL CHEMISTRY** (previously called the **Estimated Soil Chemistry Data for Great Britain Version 3; release date 2009**) is based on an interpolation of soil and stream sediment data within the framework of the **DiGMapGB-50 Version 3 (2006)** bedrock, superficial and artificial data sets intersected with a 1-km grid. Each data layer is rectified to align with British National Grid origin. There are some areas where 1:250 000 scale DiGMapGB data is used, for example, in upland areas of Scotland and Wales, because 1:50 000 scale data were not available in 2006. BGS is continually surveying and resurveying areas of Britain, improving and updating the geological maps.

2000 polygons outside the margins of the BGS Estimated Urban Soil Chemistry data for the London area that were classified as SAMPLETYPE “London” (no data available) in the 2009 dataset, are given estimated soil chemistry values in the October 2012 version using recently released G-BASE rural soil chemistry data.



Metadata for the G-BASE soil and stream sediment data can be found at <http://www.bgs.ac.uk/discoverymetadata/13480412.html>. The specifications for the Wolfson stream sediment data are detailed in Webb et al. (1978).

## 5.2 MEASURED URBAN SOIL CHEMISTRY AND ESTIMATED URBAN SOIL CHEMISTRY

**Version 1 (released 2009):** Data for 20 urban centres.

**Version 2 (released 2011):** Data for Greater London, Doncaster, Ipswich added to the 20 urban centres of version 1 (v1). Greater London includes data for the satellite towns of Brentwood, Basildon, Canvey Island, Southend, Tilbury and Grays (Thames Gateway north, Figure 3).

As a result of new quality control procedures, 25 duplicate samples were removed from the Point Source (now called *Measured*) Urban Soil Chemistry dataset and three incorrect location coordinates were corrected. The new analytical data for the London area was quality controlled using international Certified Reference Materials (CRM) whereas the data for the other urban centres had been quality controlled using BGS Secondary Reference Materials (SRM). In order to ensure compatibility between the two datasets, correction factors were applied to the version 1 (v1) Point Source Urban Soil Chemistry data (and the DONC and IPSW data). As a consequence, the version 2 (v2) Point Source (now called *Measured*) data, and the Estimated Soil Chemistry data derived from the Point Source data, were slightly different to the version 1 data. The magnitude of these differences is illustrated in Table 6.

**Table 6 Magnitude of differences between version 1 and version 2 Measured (Point Source) element concentrations as a result of data conditioning**

Element	v1 (mg kg <sup>-1</sup> )	v2 (mg kg <sup>-1</sup> )	v1 (mg kg <sup>-1</sup> )	v2 (mg kg <sup>-1</sup> )
As	100	100.75	1000	1007
Cr	100	99.5	1000	1011
Ni	100	92.8	1000	916
Pb	100	98.5	1000	975

Note: data conditioning not applied to Cd concentrations

The term ‘surface soil’ used in v1 was replaced by the term ‘topsoil’ in v2.

**Version 3 (released 2012):** PM geochemical mapping was used to produce estimated soil As, Cr and Ni data for the Corby, Northampton and Scunthorpe urban areas which are underlain by ironstones and where the distribution of these elements is strongly controlled by soil parent material (surface geology). Thin horizons of ironstone occur in the Lincoln urban area, but only one soil sample is located on the ironstone so PM mapping using the urban soil data was not a practical option in this area. Estimated total As, Cr and Ni concentrations for the other urban areas are the same as in Version 2, as is all the estimated total Cd and Pb topsoil data. Estimated bioaccessible As (B-As) and Pb (B-Pb) concentrations were determined by using the regression models in Appleton et al. (2012b, 2012c).

BGS continues to collect soil and stream sediment samples from rural and urban areas in Great Britain, improving and updating the geochemical database. BGS is committed to improving the **BGS Soil Chemistry for Environmental Assessments** dataset as more information becomes available.

## 6 Limitations

**6.1** The BGS SOIL CHEMISTRY DATA FOR ENVIRONMENTAL ASSESSMENTS has been developed at 1:50 000 scale (Estimated Ambient Background Soil Chemistry data) or 1:10 000 scale (Estimated Urban Soil Chemistry data) and must not be used at larger scales. Spatial searches against the data must be made with a 50m buffer (Estimated Ambient Background Soil Chemistry data) or 10 m buffer (Estimated Urban Soil Chemistry data) in order to allow for the spatial uncertainty of the data (this should be in addition to any buffer applied to define the extent of a site)

**6.2** The BGS ESTIMATED AMBIENT BACKGROUND SOIL CHEMISTRY data is derived by the interpolation of the low density rural soil and/or stream sediment data to vector polygons made by unioning 1:50,000 scale geological data with a 1-km grid. The ESTIMATED URBAN SOIL CHEMISTRY data is derived by the interpolation of the high density urban soil data to either (i) a vector polygon 100 m grid (for Cd and Pb in all urban areas and As, Cr and Ni in all areas except Corby, Northampton, and Scunthorpe) or (ii) to vector polygons made by unioning 1:10,000 scale geological data with a 100-m grid for As, Cr and Ni in the Corby, Northampton and Scunthorpe urban areas. Estimated concentrations in (i) the Estimated Ambient Background Soil Chemistry and (ii) the Estimated Urban Soil Chemistry datasets are likely to be different (a) because of the different interpolation methods and (b) because in many cases urban soil samples are likely to be more strongly impacted by anthropogenic contamination than rural soil or sediment samples.

**6.3** The BGS ESTIMATED AMBIENT BACKGROUND SOIL CHEMISTRY and ESTIMATED URBAN SOIL CHEMISTRY data consists of vector polygons and is available in a range of GIS formats, including ArcGIS (.shp), Arc Info Coverages and MapInfo (.tab). More specialised formats may be available but may incur additional processing costs. Due to the differences in precision of different formats and to small changes in precision during translation between formats, the absolute position of features in different GIS systems may vary by a few millimetres on the ground.

**6.4** All address searches against the data should be made using Ordnance Survey ADDRESS-POINT® coordinates, under the Terms & Conditions described by the Ordnance Survey.

**6.5** The ESTIMATED AMBIENT BACKGROUND SOIL CHEMISTRY data based on DigMapGB-50 does not quite extend to the coastline in some areas; either because reclamation of land has moved the coastline or because the coastline used on the paper map from which the digital geology was captured does not quite reach the actual coastline due to the scale of the mapping.

**6.6** The BGS ESTIMATED AMBIENT BACKGROUND SOIL CHEMISTRY is concerned with As, Cd, Cr, Ni and Pb concentrations in mineral soils related mainly to natural geological sources although the influence of some anthropogenic effects, such as mining and mineral processing, will also be represented in the map data.

**6.7** As, Cd, Cr and Ni concentrations in organic soils (i.e. with more than 15-20% organic carbon) are likely to be significantly lower than those indicated by the ESTIMATED AMBIENT BACKGROUND SOIL CHEMISTRY data which are estimated concentrations in mineral soils. In some circumstances, such as adjacent to areas where smelting of Pb has occurred in the past or adjacent to major urban centres or roads, the Pb concentrations in organic soils may be significantly higher than estimated due to adsorption of Pb onto organic material.

**6.8** The MEASURED and ESTIMATED URBAN SOIL CHEMISTRY data are concerned with As, Cd, Cr, Ni and Pb related to both natural geological sources and the influence of anthropogenic sources.

**6.9** The ESTIMATED AMBIENT BACKGROUND SOIL CHEMISTRY is based on, and limited to, an interpretation of the records in the possession of the British Geological Survey at the time the data set was created (2008). The MEASURED and ESTIMATED URBAN SOIL CHEMISTRY data is based on, and limited to, an interpretation of the records in the possession of the British Geological Survey at the time the data set was created (2011).

**6.10** Bioaccessible arsenic (B-As) and lead (B-Pb) data can be used as part of a lines of evidence approach to localised risk assessment but should not be used to replace bioaccessibility testing at individual sites where local conditions may vary considerably. A lines of evidence approach means that no single piece of evidence should be solely relied on to make a decision about health risks. This data can, however, be used alongside other investigations and considerations to inform a site-specific risk evaluation.

**6.11** An indication of high ESTIMATED AMBIENT BACKGROUND SOIL or ESTIMATED URBAN SOIL concentrations does not necessarily mean that an individual site will have a high PHE concentration. Topsoil concentrations, especially in urban areas are frequently characterised by strong spatial variation over short distances so the MEASURED and ESTIMATED URBAN SOIL CHEMISTRY DATA should be interpreted and used with caution. The only way to find out whether a site does in fact have high soil PHE concentrations is to carry out a site investigation that includes the sampling and analysis of soil samples. Guidance on soil sampling and PHE analysis can be obtained from the BGS (BGS Central Enquiries Tel: 0115 9363143).

## 7 Model Questions, Answers and Maps for Environmental Reports

### 7.1 INTRODUCTION

Six examples are given:

1. **Sheffield:** Estimated Urban Soil Chemistry for all elements interpolated to 100 m grid
2. **Northampton:** Estimated Urban Soil Chemistry for As, Cr and Ni interpolated to PM (Parent Material) – 100 m grid
3. **Derby:** Estimated Urban Soil Chemistry for all elements interpolated to 100 m grid
4. **Swansea:** Estimated Urban Soil Chemistry for all elements interpolated to 100 m grid
5. **Kettering :** No urban soil chemistry data available
6. **London:** No Estimated Ambient Background Soil Chemistry data currently available

### 7.2 SITE IN SHEFFIELD

#### 7.2.1 Estimated Ambient Background Soil Chemistry

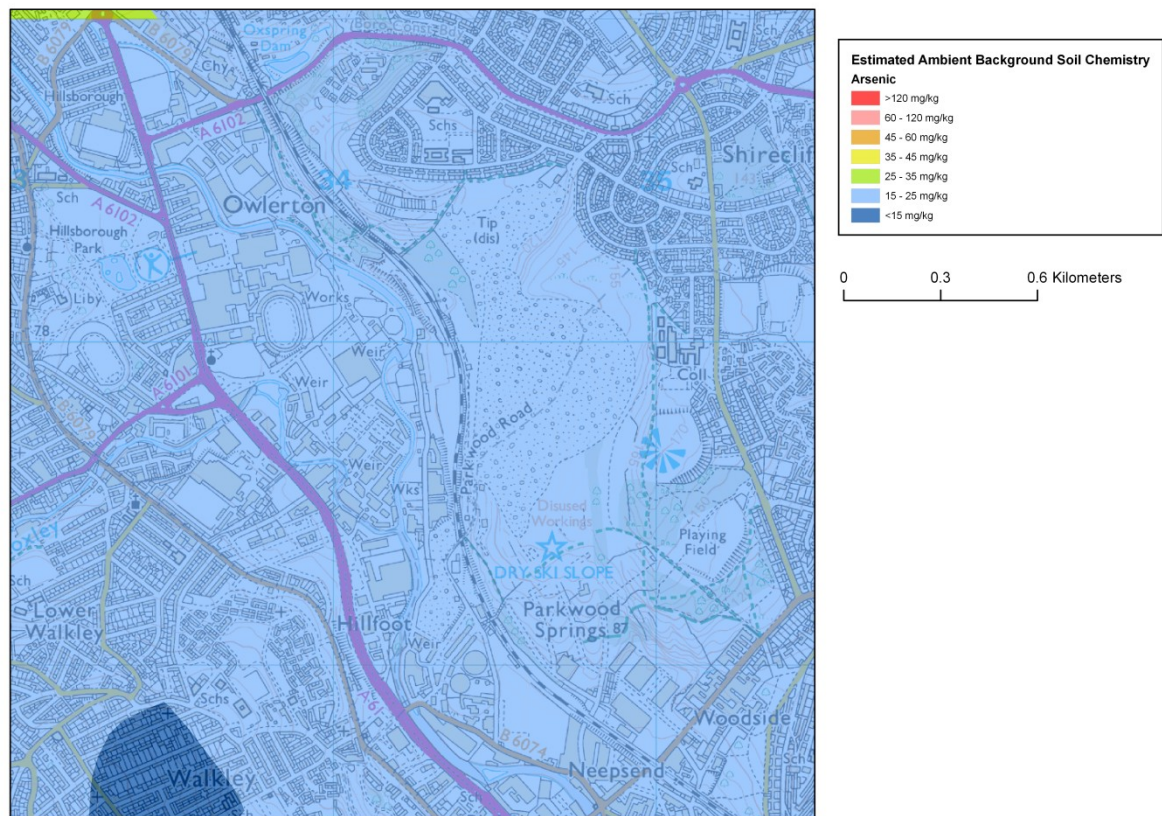
##### Question

What is the estimated ambient background concentration of As, Cd, Cr, Ni and Pb in the search area?

##### Answer

The map (Figure 6) shows the estimated ambient background concentration of As ( $\text{mg kg}^{-1}$ ), interpolated from BGS rural soil data, in the search area. Additional maps would be included for the Cd, Cr, Ni and Pb. *If the search area is in an urban area, then As, Cd, Cr, Ni and Pb*

concentrations are likely to be significantly higher than indicated by the estimated ambient background concentrations.



**Figure 6 Map of Estimated Ambient Background Soil Chemistry data for arsenic (As) in a sector of Sheffield**

### 7.2.2 Measured Urban Soil Chemistry

**Question:** What are the measured concentrations of total As, Cd, Cr, Ni and Pb in BGS urban topsoil samples located in or close to the search area?

**Answer:** The concentrations ( $\text{mg kg}^{-1}$ ) of As, Cd, Cr, Ni, and Pb in the topsoil samples located in or closest to the search area are given in the Table below and illustrated in Figure 7. Additional maps would be included for Cd, Cr, Ni and Pb.

#### Measured Urban Soil Chemistry data

NGR		Measured Concentrations in Urban Soil Samples				
EASTING	NORTHING	AS_MGKG	CD_MGKG	CR_MGKG	NI_MGKG	PB_MGKG
434280	389240	12	1.0	106	33	124
433400	389750	24	2.0	108	32	185
433750	389240	20	1.0	132	38	157
433740	389750	49	2.0	144	58	152
434760	390740	14	1.0	155	39	115
433240	389220	47	2.0	108	35	540

NGR		Measured Concentrations in Urban Soil Samples				
EASTING	NORTHING	AS_MGKG	CD_MGKG	CR_MGKG	NI_MGKG	PB_MGKG
434840	389660	11	0.3	123	42	61
433960	390210	24	2.0	87	22	141
433250	390760	30	1.0	97	33	245
434780	388700	13	2.0	707	71	294
434750	389240	29	1.0	106	45	1162
433250	390260	29	2.0	102	23	185
434250	390250	22	2.0	194	57	169
434250	390750	24	1.0	130	40	113
434250	389790	78	7.0	649	287	1267
433750	390750	58	1.0	159	51	432
434760	390270	53	1.0	156	51	291
435230	390750	30	2.0	132	42	271
435240	388750	30	1.0	135	43	145
435250	389250	16	1.0	98	33	82
435250	389730	33	1.0	123	45	302
435250	390260	12	0.3	108	42	89
434240	388750	11	2.0	68	18	161
433770	388780	13	1.0	59	16	81
433250	388740	14	0.3	106	17	88

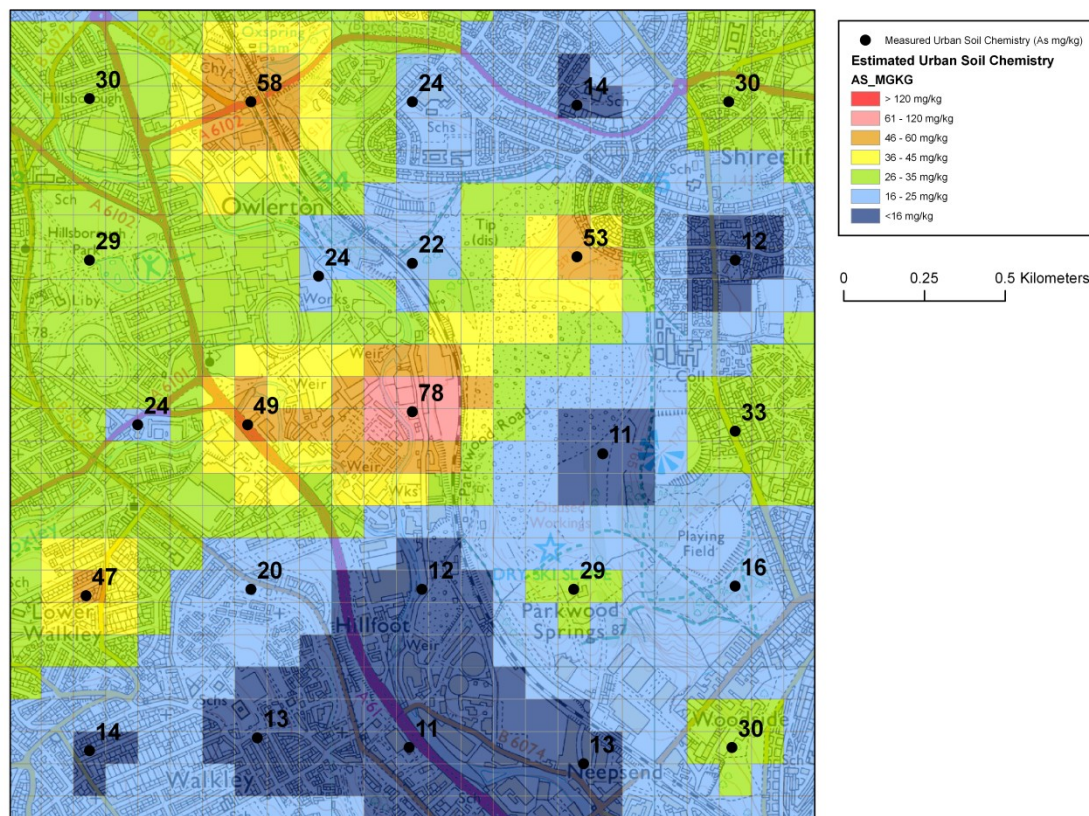
### 7.2.3 Estimated Urban Soil Chemistry

**Question:** What are the estimated topsoil concentrations of total As, Cd, Cr, Ni and Pb, and bioaccessible arsenic (B-As) and bioaccessible Pb (B-Pb) in the search area?

**Answer**

The BGS estimates for As concentrations in topsoils are shown in the map (Figure 7). Additional maps would be included for Cd, Cr, Ni, Pb, bioaccessible As and bioaccessible Pb.





**Figure 7 Map of BGS Measured Urban Soil Chemistry and Estimated Urban Soil Chemistry data for arsenic (As) in a sector of Sheffield**

### 7.3 SITE IN NORTHAMPTON

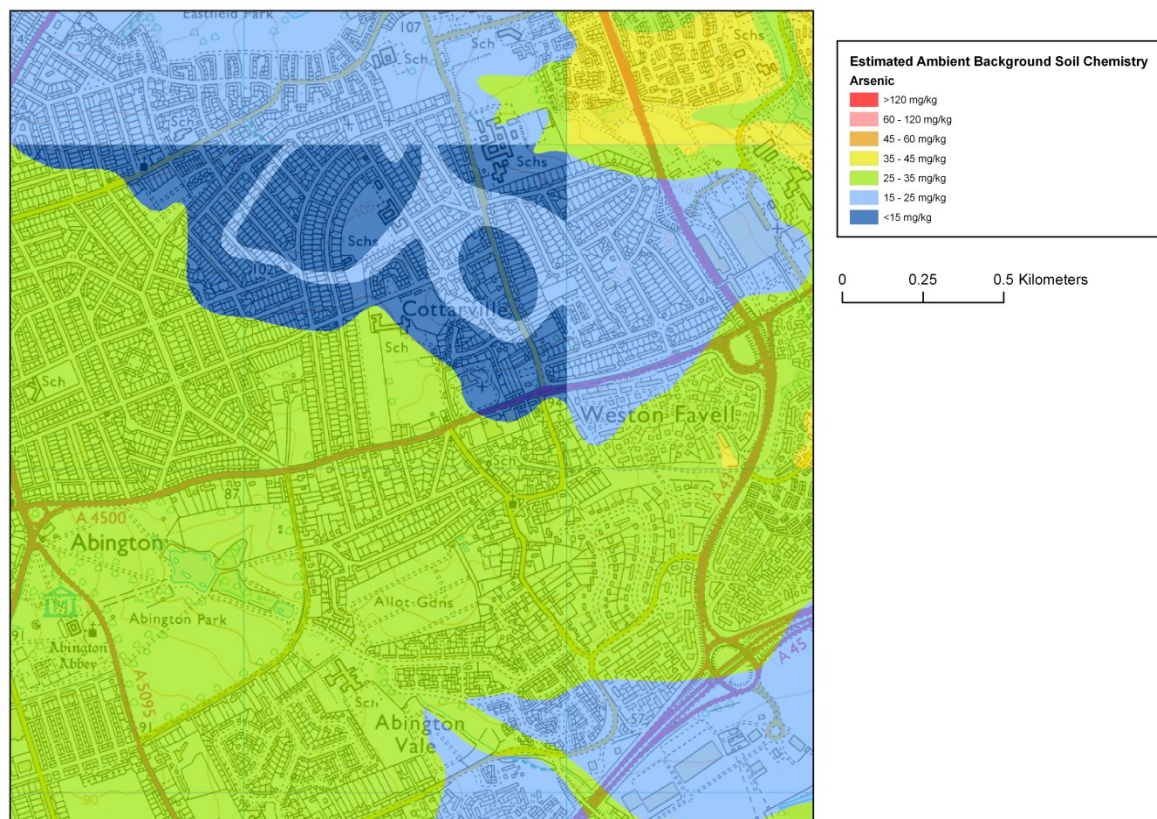
#### 7.3.1 Estimated Ambient Background Soil Chemistry

##### Question

What is the estimated ambient background concentration of As, Cd, Cr, Ni and Pb in the search area?

##### Answer

The map (Figure 8) shows the estimated ambient background concentration of As ( $\text{mg kg}^{-1}$ ), interpolated from BGS rural soil data, in the search area. Additional maps would be included for Cd, Cr, Ni and Pb. *If the search area is in an urban area, then As, Cd, Cr, Ni and Pb concentrations are likely to be significantly higher than indicated by the estimated ambient background concentrations.*



**Figure 8 Map of BGS Estimated Ambient Background Soil Chemistry data for arsenic (As) in a sector of Northampton**

### 7.3.2 Measured Urban Soil Chemistry

**Question:** What are the concentrations of total As, Cd, Cr, Ni and Pb in BGS urban topsoil samples located in or close to the search area?

**Answer:** The concentrations ( $\text{mg kg}^{-1}$ ) of As, Cd, Cr, Ni, and Pb in the topsoil samples located in or closest to the search area are given in the Table below and illustrated in Figure 9. Additional maps would be included for Cd, Cr, Ni and Pb.

**Measured Urban Soil Chemistry data for area centred on site 478520, 262160**

NGR		Measured Concentrations in Urban Soil Samples				
EASTING	NORTHING	AS_MGKG	CD_MGKG	CR_MGKG	NI_MGKG	PB_MGKG
478610	261740	65	0.3	193	60	124
479240	261820	54	0.3	191	52	52
478180	262150	56	0.3	120	35	48
479130	261200	24	0.3	76	22	42
478720	262850	18	0.3	77	21	94
479220	262320	26	0.3	86	26	76
479670	262300	44	0.3	129	31	37
479060	262570	16	0.3	87	27	47
479340	263100	35	0.3	97	22	35
478720	262220	20	0.3	71	13	48
478680	263290	24	0.3	80	17	46
478400	261220	27	0.3	115	35	71
478160	261680	72	0.3	146	38	49
478740	261260	19	0.3	108	34	36
477740	261700	42	0.3	125	38	73
477710	261250	29	0.3	94	29	73
477360	261690	42	0.3	93	31	129
477350	261330	35	0.3	75	21	98
477680	262340	39	0.3	80	19	71
477400	262270	47	0.3	92	30	111
478260	262960	33	0.3	87	24	125
477330	262700	61	0.3	123	36	286
478250	263330	14	0.3	99	25	37
477770	262910	19	0.3	113	24	86
477770	263270	14	0.3	77	19	39

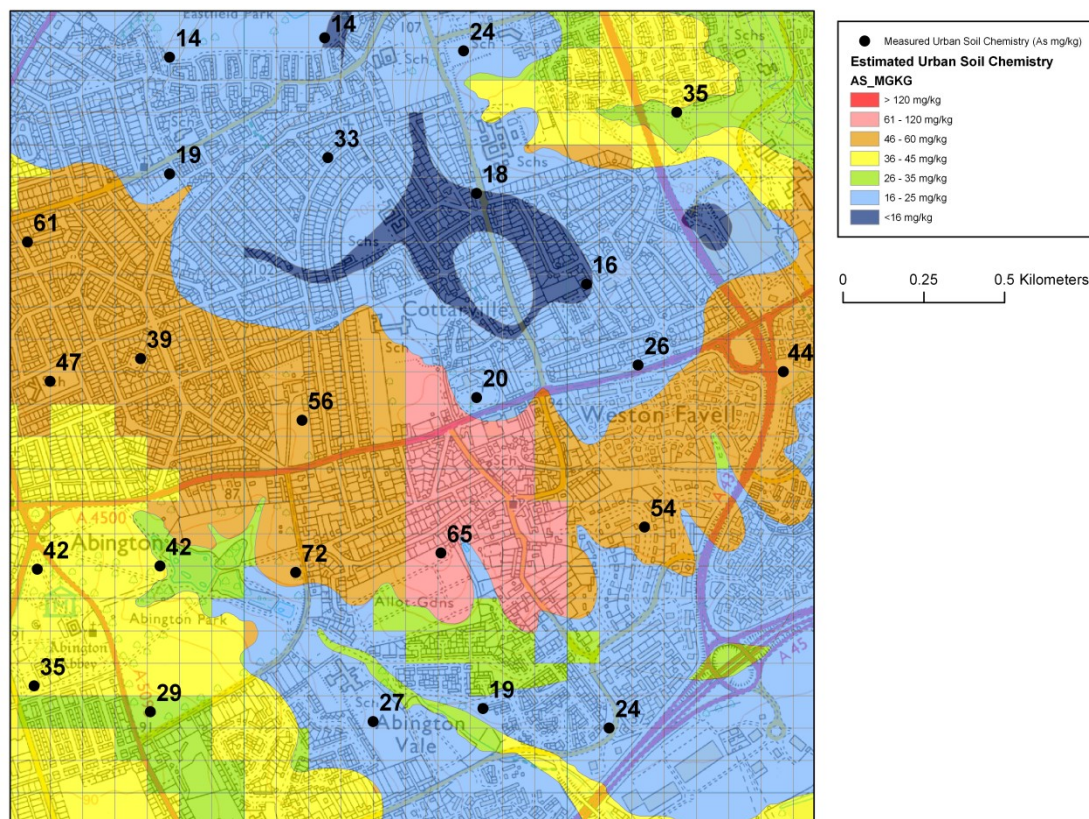
**7.3.3 Estimated Urban Soil Chemistry**

**Question:** What are the estimated topsoil concentrations of total As, Cd, Cr, Ni and Pb, and bioaccessible arsenic (B-As) and bioaccessible Pb (B-Pb) in the search area?

**Answer**

The BGS estimates for As concentrations in topsoils are shown in the map (Figure 9). Additional maps would be included for Cd, Cr, Ni, Pb, bioaccessible As and bioaccessible Pb.





**Figure 9 Map of BGS Measured Urban Soil Chemistry and Estimated Urban Soil Chemistry data for arsenic (As) for a sector of Northampton**

## 7.4 SITE IN DERBY

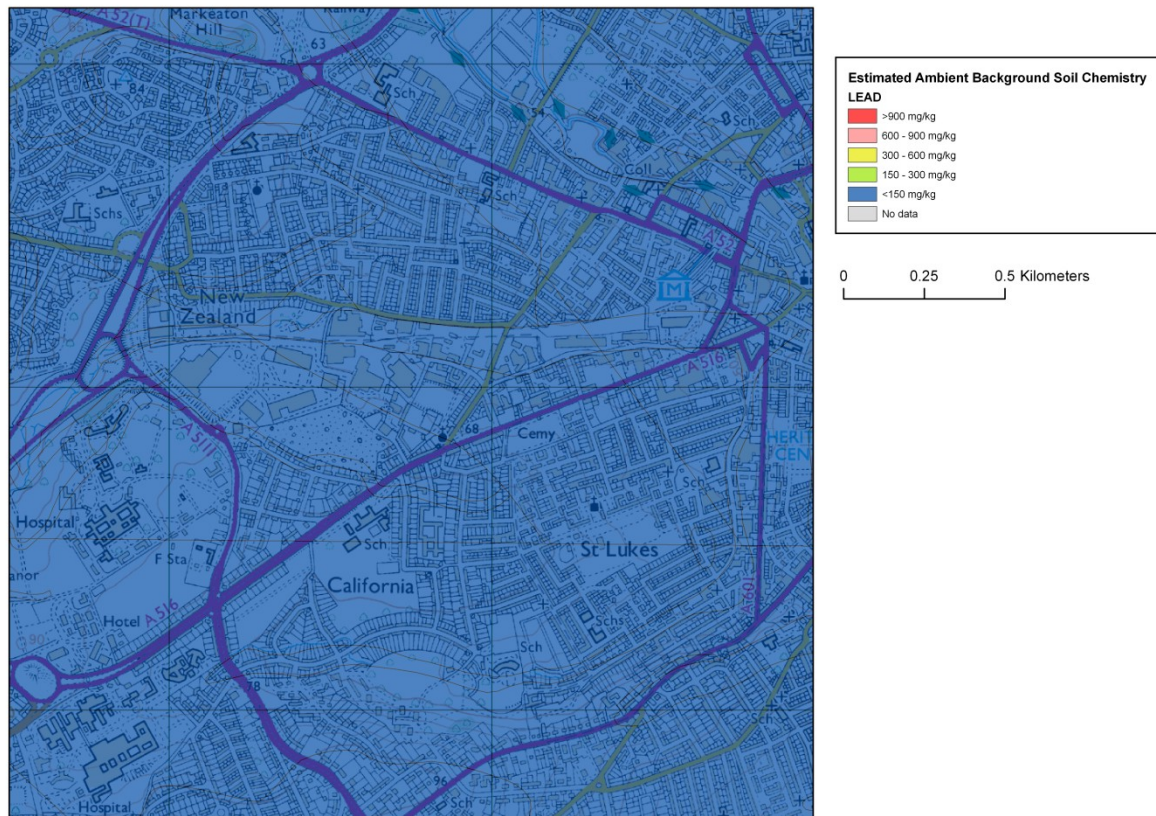
### 7.4.1 Estimated Ambient Background Soil Chemistry

#### Question

What is the estimated ambient background concentration of As, Cd, Cr, Ni and Pb in the search area ?

#### Answer

The map (Figure 10) shows the estimated ambient background concentration of Pb ( $\text{mg kg}^{-1}$ ), interpolated from BGS rural soil sample data, in the search area. Additional maps would be included for As, Cd, Cr and Ni. *If the search area is in an urban area, then As, Cd, Cr, Ni and Pb concentrations are likely to be significantly higher than indicated by the estimated ambient background concentrations.*



**Figure 10 Map of Estimated Ambient Background Soil Chemistry data for lead (Pb) in a sector of Derby**

#### 7.4.2 Measured Urban Soil Chemistry

**Question:** What are the measured concentrations of total As, Cd, Cr, Ni and Pb in BGS urban topsoil samples located in or close to the search area?

**Answer:** The distribution of measured Pb concentrations is illustrated in the map (Figure 11). Additional maps would be included for As, Cd, Cr and Ni. Measured values for the search area would be presented in a Table.

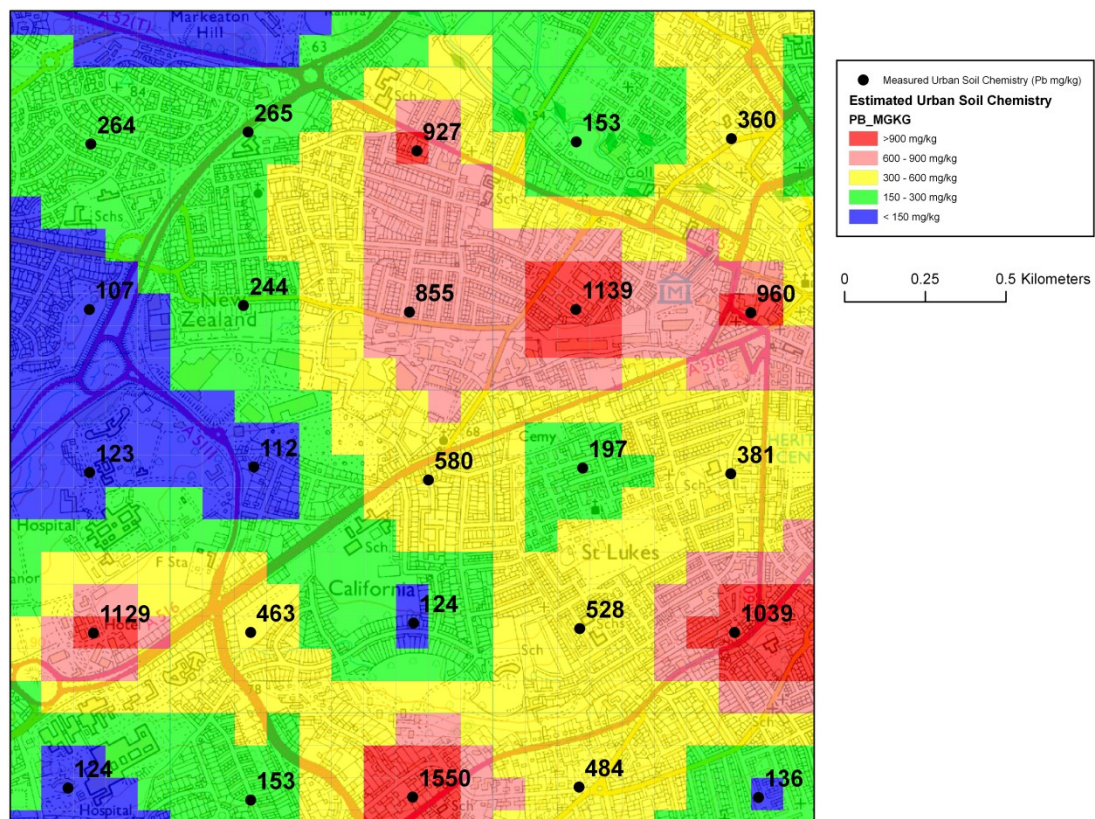
#### 7.4.3 Estimated Urban Soil Chemistry

**Question:** What are the estimated topsoil concentrations of total As, Cd, Cr, Ni and Pb, and bioaccessible arsenic (B-As) and bioaccessible Pb (B-Pb) in the search area?

**Answer**

The BGS estimates for Pb concentrations in topsoils are shown in the map (Figure 11). Additional maps would be included for As, Cd, Cr, Ni, bioaccessible As and bioaccessible Pb.





**Figure 11 Map of BGS Measured Urban Soil Chemistry and Estimated Urban Soil Chemistry data for lead (Pb) for a sector of Derby**

## 7.5 SITE IN KETTERING

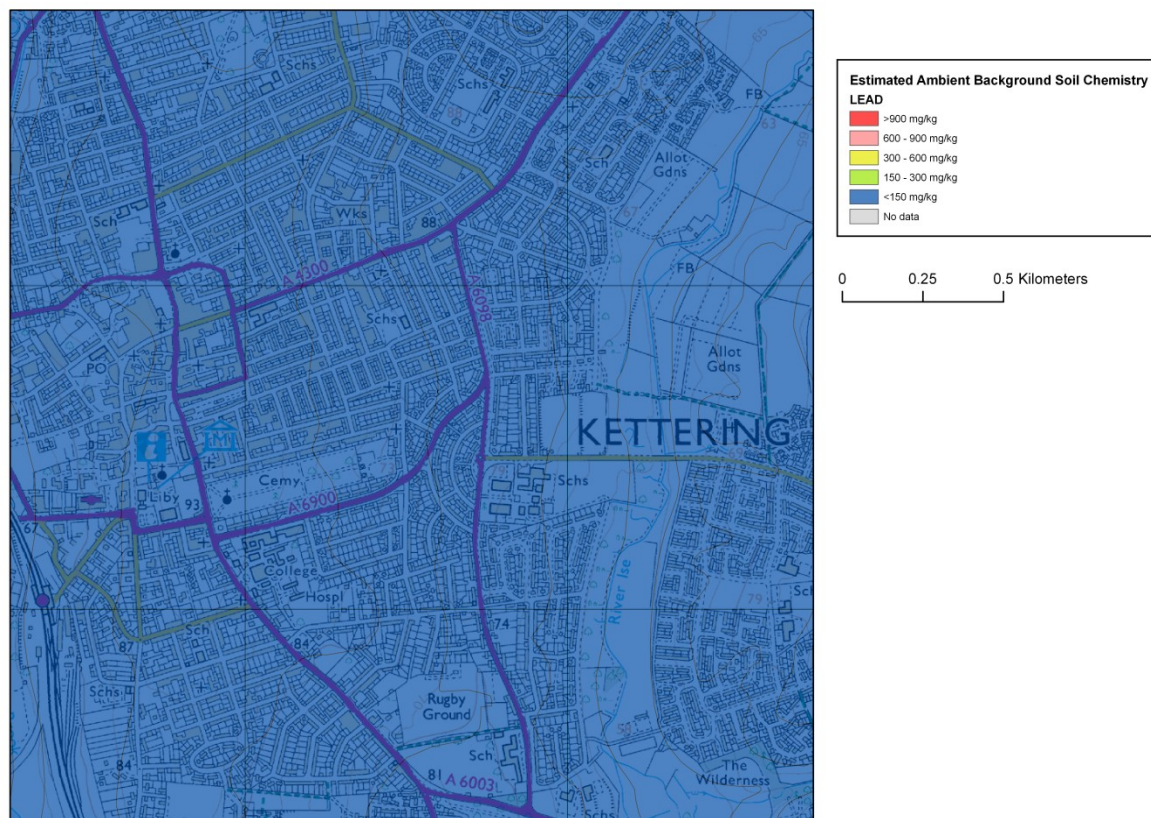
### 7.5.1 Estimated Ambient Background Soil Chemistry

#### Question

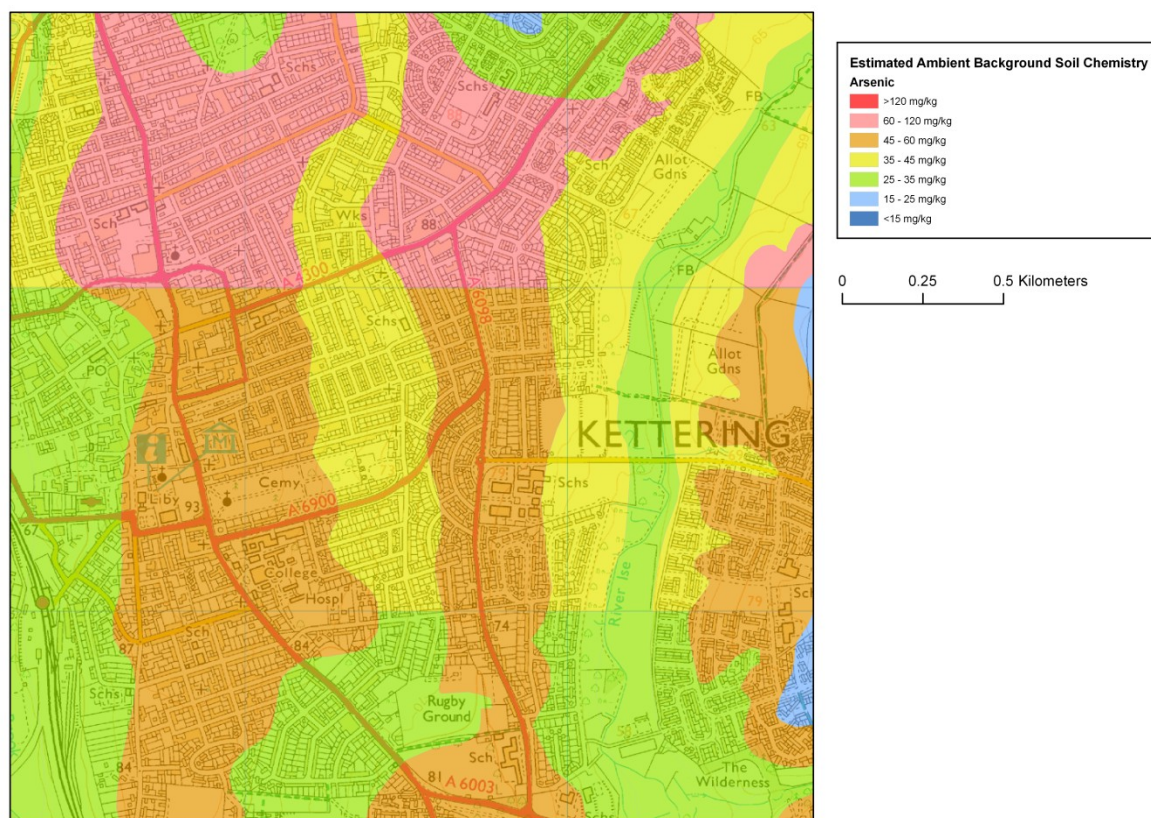
What is the estimated ambient background concentration of As, Cd, Cr, Ni and Pb in the search area?

#### Answer

The maps illustrate the estimated ambient background concentrations ( $\text{mg kg}^{-1}$ ) Pb (Figure 12) and of As (Figure 13) interpolated from BGS rural soil data, in the search area. Additional maps would be included for Cd, Cr and Ni. *If the search area is in an urban area, then As, Cd, Cr, Ni and Pb concentrations are likely to be significantly higher than indicated by the estimated ambient background concentrations.*



**Figure 12 Map of Estimated Ambient Background Soil Chemistry data for lead (Pb) in a sector of Kettering**



**Figure 13 Map of Estimated Ambient Background Soil Chemistry data for arsenic (As) in a sector of Kettering**



## 7.5.2 Measured Urban Soil Chemistry

**Question:** What are the measured concentrations of total As, Cd, Cr, Ni and Pb in BGS urban topsoil samples located in or close to the search area?

**Answer:** No urban soil chemistry data is available for the search area. *If the search area is in an urban area, then As, Cd, Cr, Ni and Pb concentrations are likely to be significantly higher than indicated by the estimated ambient background concentrations.*

## 7.5.3 Estimated Urban Soil Chemistry

**Question:** What are the estimated concentrations of total As, Cd, Cr, Ni, Pb, bioaccessible As and bioaccessible Pb in or close to the search area?

**Answer:** No urban soil chemistry data is available for the search area. *If the search area is in an urban area, then As, Cd, Cr, Ni and Pb concentrations are likely to be significantly higher than indicated by the estimated ambient background concentrations.*

## 7.6 SITE IN SWANSEA

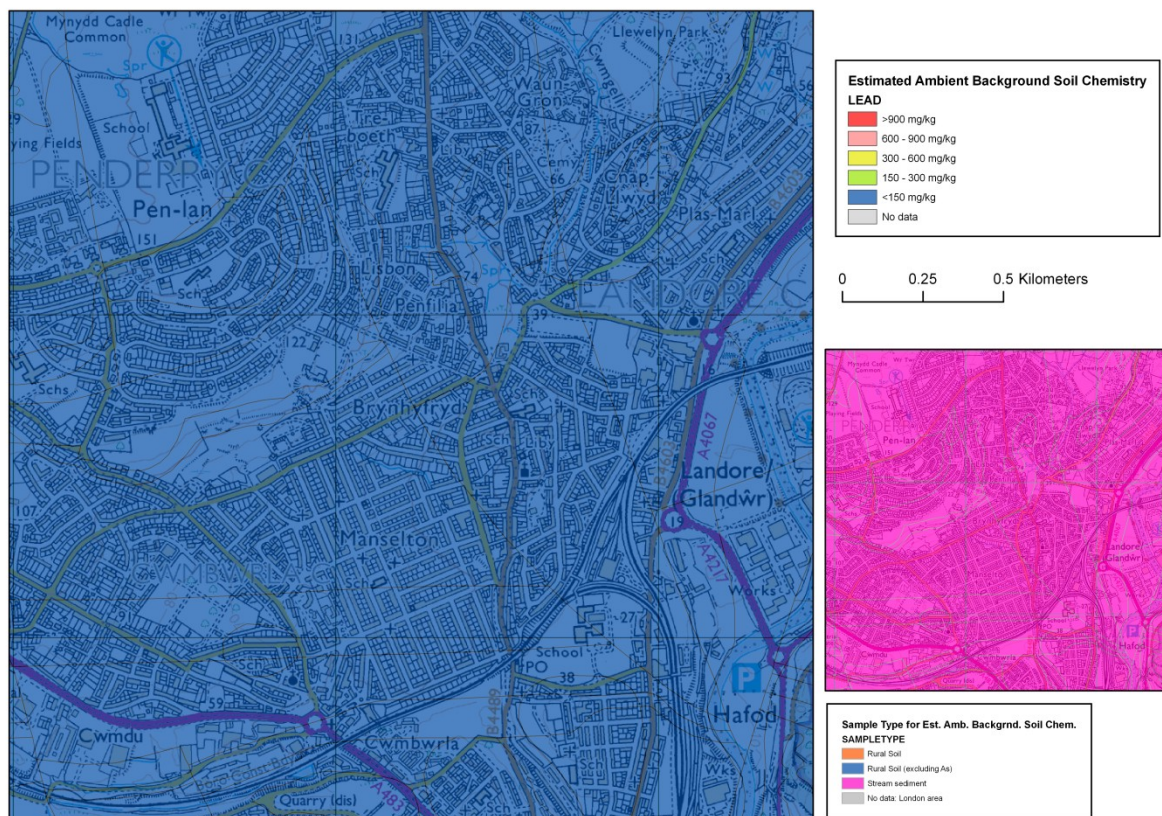
### 7.6.1 Estimated Ambient Background Soil Chemistry

#### Question

What is the estimated ambient background concentration of As, Cd, Cr, Ni and Pb in the search area?

#### Answer

The map (Figure 14) shows the estimated ambient background concentration of Pb ( $\text{mg kg}^{-1}$ ), interpolated from BGS stream sediment data, in the search area. Additional maps would be included for As, Cd, Cr and Ni. *If the search area is in an urban area, then As, Cd, Cr, Ni and Pb concentrations are likely to be significantly higher than indicated by the estimated ambient background concentrations.*



**Figure 14 Map of Estimated Ambient Background Soil Chemistry data for lead (Pb) in a sector of Swansea**

### 7.6.2 Measured Urban Soil Chemistry

**Question:** What are the measured concentrations of total As, Cd, Cr, Ni and Pb in BGS urban topsoil samples located in or close to the search area?

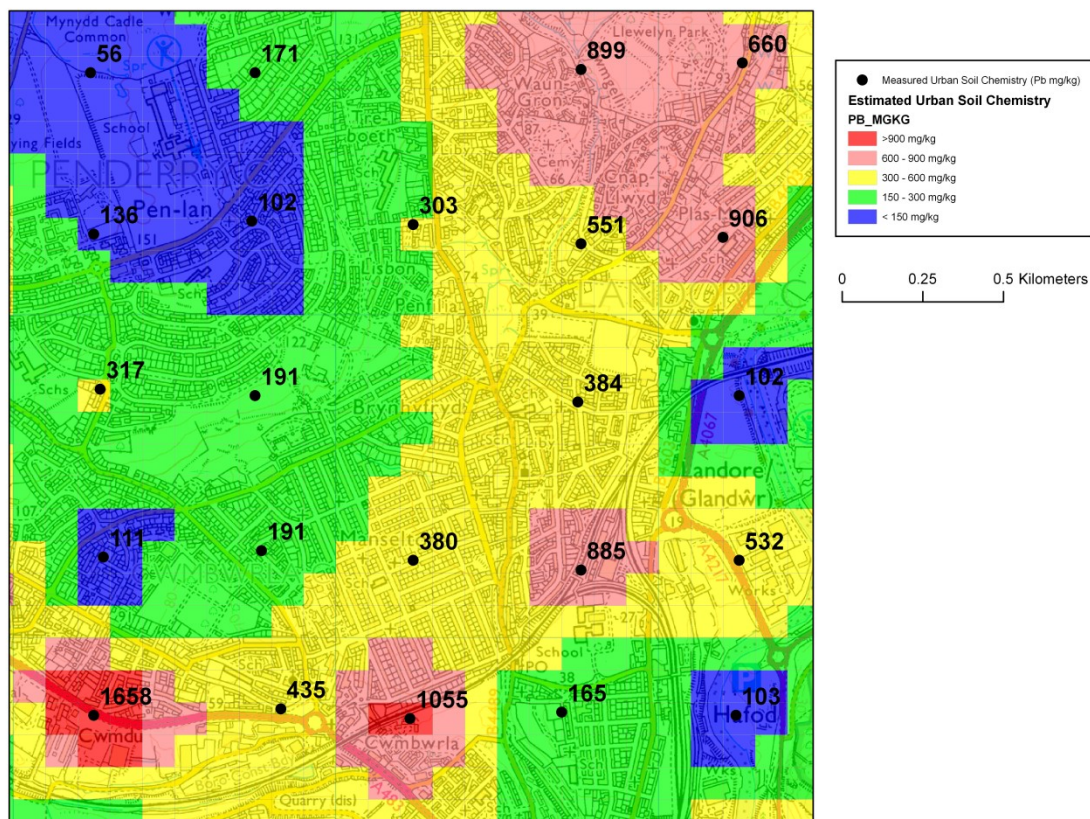
**Answer:** The distribution of measured Pb concentrations is illustrated in the map (Figure 15). Additional maps would be included for As, Cd, Cr, and Ni. Measured values for the search area would be presented in a Table.

### 7.6.3 Estimated Urban Soil Chemistry

**Question:** What are the estimated topsoil concentrations of total As, Cd, Cr, Ni and Pb, and bioaccessible arsenic (B-As) and bioaccessible Pb (B-Pb) in the search area?

**Answer**

The BGS estimates for Pb concentrations in topsoils are shown in the map (Figure 15). Additional maps would be included for As, Cd, Cr, Ni, bioaccessible As and bioaccessible Pb.



**Figure 15 Map of BGS Measured Urban Soil Chemistry and Estimated Urban Soil Chemistry data for lead (Pb) in a sector of Swansea**

## 7.7 SITE IN LONDON

### 7.7.1 Estimated Ambient Background Soil Chemistry

#### Question

What is the estimated ambient background concentration of As, Cd, Cr, Ni and Pb in the search area?

#### Answer

The BGS currently does not have Estimated Ambient Background Soil Chemistry data for the London area.

### 7.7.2 Measured Urban Soil Chemistry

**Question:** What are the measured concentrations of total As, Cd, Cr, Ni and Pb in BGS urban topsoil samples located in or close to the search area?

**Answer:** The distribution of measured Pb concentrations is illustrated in the map (Figure 16). Additional maps would be included for As, Cd, Cr and Ni. Measured values for the search area would be presented in a Table.

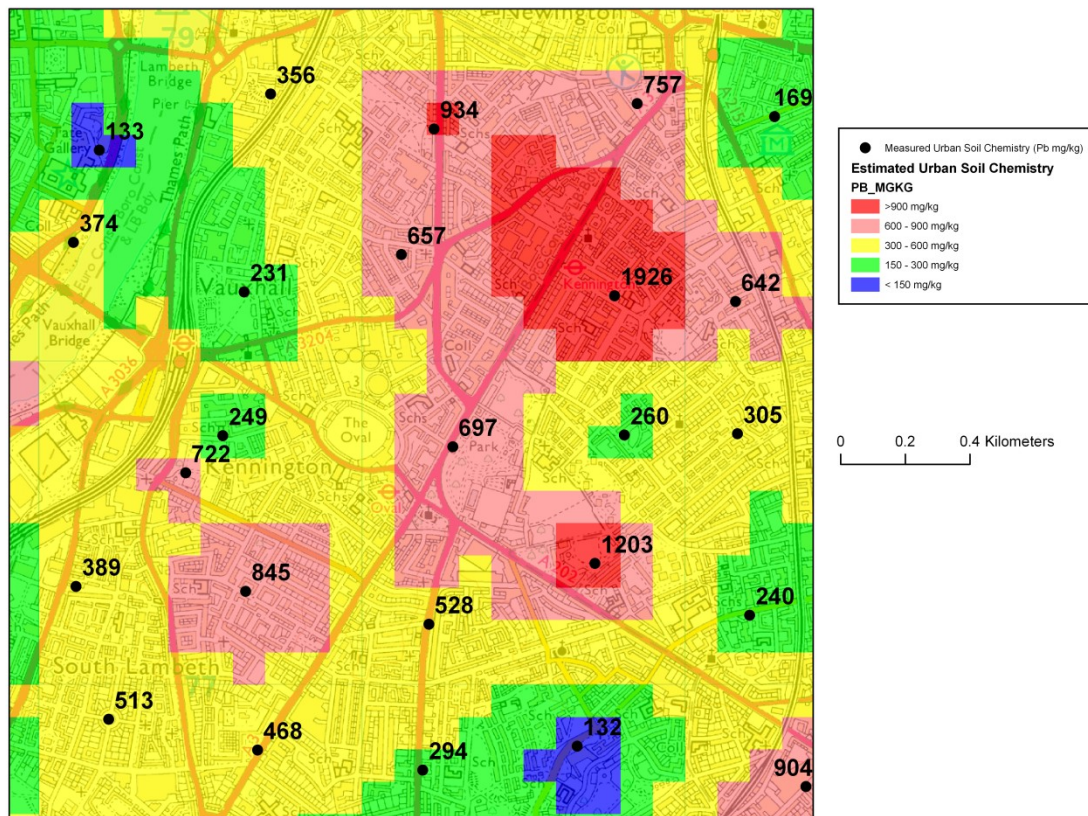


### 7.7.3 Estimated Urban Soil Chemistry

**Question:** What are the estimated topsoil concentrations of total As, Cd, Cr, Ni and Pb, and bioaccessible arsenic (B-As) and bioaccessible Pb (B-Pb) in the search area?

**Answer**

The BGS estimates for Pb concentrations in topsoils are shown in the map (Figure 16). Additional maps would be included for As, Cd, Cr, Ni, bioaccessible As and bioaccessible Pb.



**Figure 16 Map of BGS Measured Urban Soil Chemistry and Estimated Urban Soil Chemistry data for lead (Pb) in a sector of London**

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## Glossary

*Anthropogenic* Related to, or resulting from the influence of human beings on the natural environment. Created by people or caused by human activities.

*Ambient Background Concentration* In this report *ambient background concentration* (ABC) is the estimated concentration of a chemical element in an area principally derived from geogenic sources and processes with a contribution, in some areas, from anthropogenic sources and processes. The estimated ABC is derived from the measured concentrations in soil or stream sediment samples collected from rural areas.

*Bioaccessible* Bioaccessibility testing is an *in vitro* chemical test developed to produce a conservative estimate of bioavailability. The bioaccessibility and hence bioavailability of any contaminant bound to the soil depends on the soil type, soil properties, particle size, the contaminant and the manner in which the contaminant entered the soil.

**Bioavailable** The bioavailable fraction of a chemical element in soil is the fraction that is absorbed into the body following soil ingestion. The measurement of bioavailability of PHEs in soil requires *in vivo* testing using humans or animal surrogates, which is a time consuming, costly and ethically challenging process.

**Defra** Department for Environment, Food and Rural Affairs.

**Geogenic** Related to the natural, non-living world including rocks, mineralization; pertaining to a geological origin.

**Normal Background Concentration** A term defined by Defra for Statutory Guidance (Defra, 2012a) to indicate normal contaminant concentrations in specific domains. The principal domains are urban; mineralisation and mining related activities; and ironstones (geogenic) (Johnson et al., 2012).

**PHE** Potentially harmful chemical elements (PHEs), including arsenic (As), cadmium (Cd), chromium (Cr), nickel (Ni) and lead (Pb), occur in the environment and under certain circumstances can be harmful to plants, animals or people.

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