

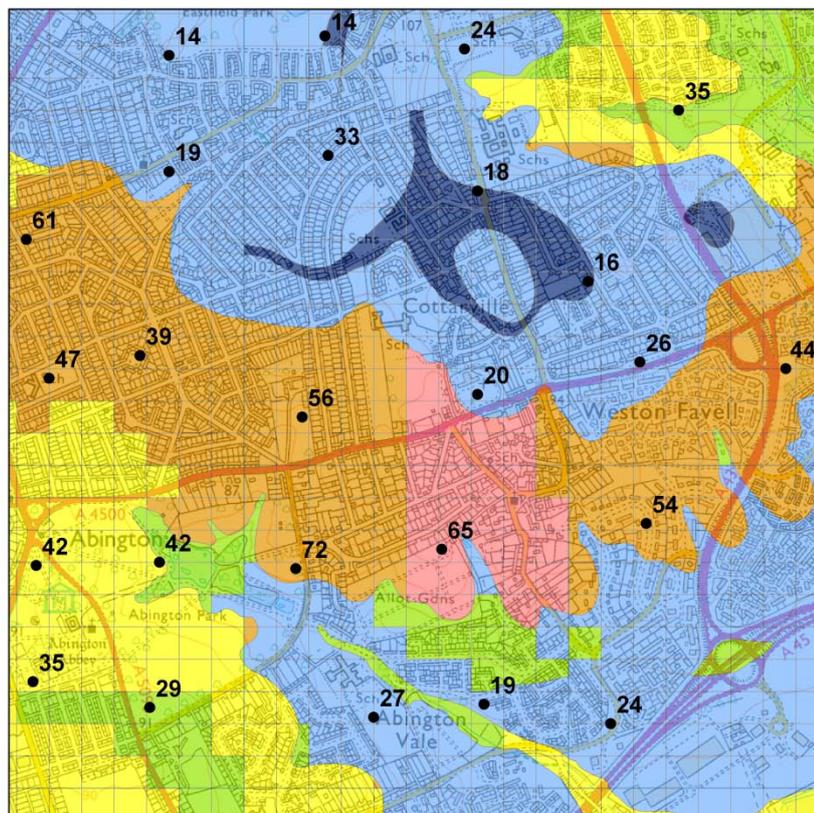


**British
Geological Survey**

NATURAL ENVIRONMENT RESEARCH COUNCIL

User Guide for the BGS Soil Chemistry Data for Environmental Assessments (May 2014)

Open Report OR/14/031



BRITISH GEOLOGICAL SURVEY

OPEN REPORT OR/14/031

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J D Appleton

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Front cover

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

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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 selected potentially harmful elements 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. Estimated bioaccessible As data are provided for some sectors of England and Wales, and bioaccessible Pb data for all of GB.
2. **Measured Urban Soil Chemistry** data (Total As, Cd, Cr, Cu, Ni, Pb, Sn, Zn; 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, Cu, Ni, Pb, Sn, Zn; 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 of selected potentially harmful elements (arsenic, cadmium, chromium, nickel lead) in rural topsoils and of these chemical elements plus copper, tin and zinc in urban topsoils. The methodologies are described briefly in this report and in four scientific papers.

Acknowledgements

Kathryn Lee, Chris Johnson, Mark Cave, 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:

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2 About the Soil Chemistry Data for Environmental Assessments

2.1 BACKGROUND

Potentially harmful chemical elements (PHEs), including arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu) nickel (Ni), lead (Pb), tin (Sn) and zinc (Zn) 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 effects 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 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 (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. Estimated bioaccessible As data are provided for some sectors of England and Wales, and bioaccessible Pb data for all GB.
2. The **BGS MEASURED URBAN SOIL CHEMISTRY** data comprises the locations and concentrations (mg kg^{-1}) of total As, Cd, Cr, Cu, Ni, Pb, Sn and Zn 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 (mg kg^{-1}) of total As, Cd, Cr, Cu, Ni, Pb, Sn and Zn and bioaccessible As and Pb in topsoil derived by spatial interpolation of the MEASURED URBAN SOIL CHEMISTRY data. Estimated bioaccessible As and Pb data are also provided. 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 background' 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, (iii) technical guidance on "normal background" levels of contaminants in soils (DEFRA 2012b-o; Ander et al., 2013) and (iv) Category 4 Screening Levels for Assessment of Land Affected by Contamination (SP1010) 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.

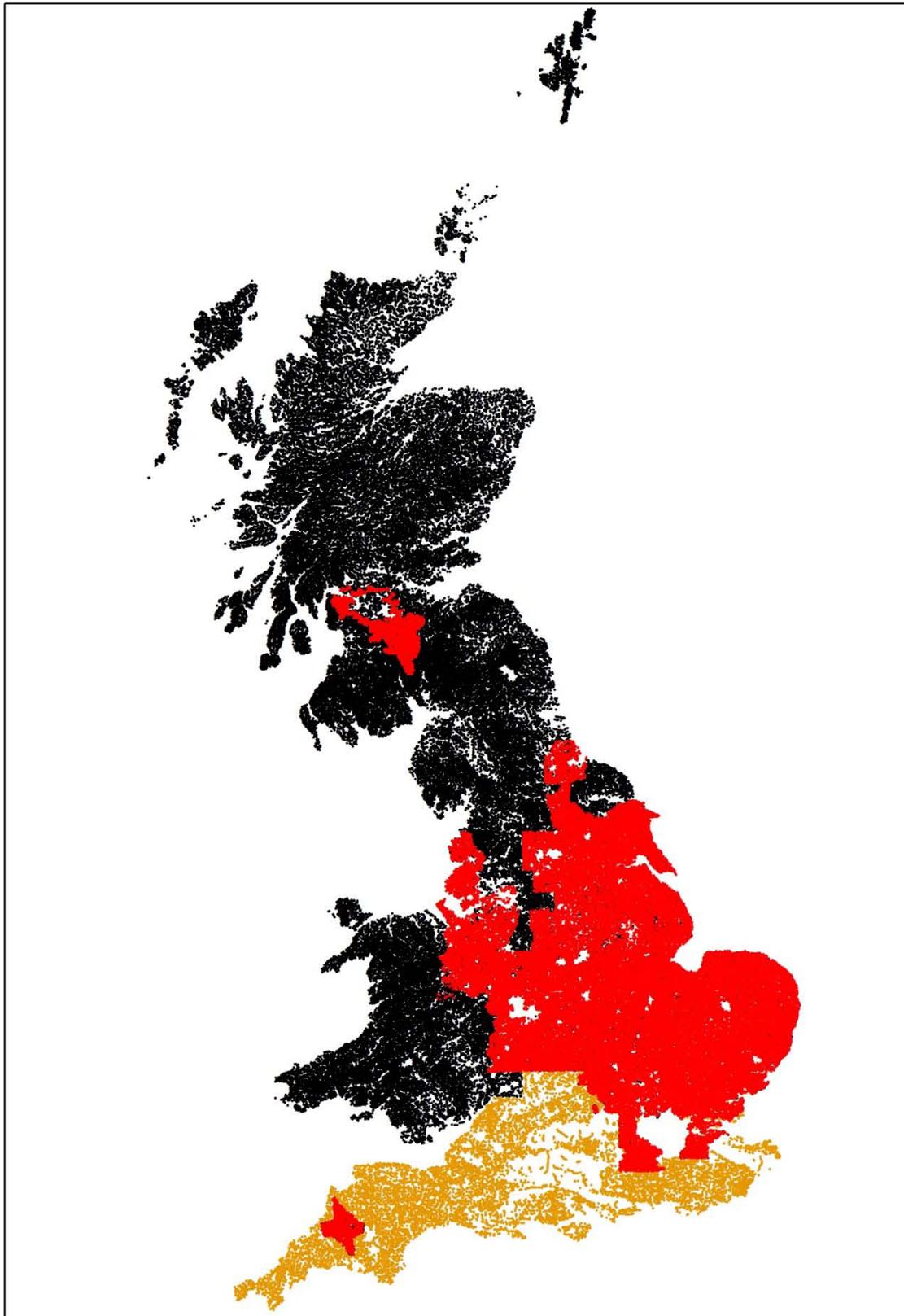


Figure 1 Location of analysed BGS G-BASE rural soil (red dots), G-BASE stream sediment (black dots) and Wolfson stream sediment (orange dots) samples used to produce the Estimated Ambient Background Soil Chemistry data.

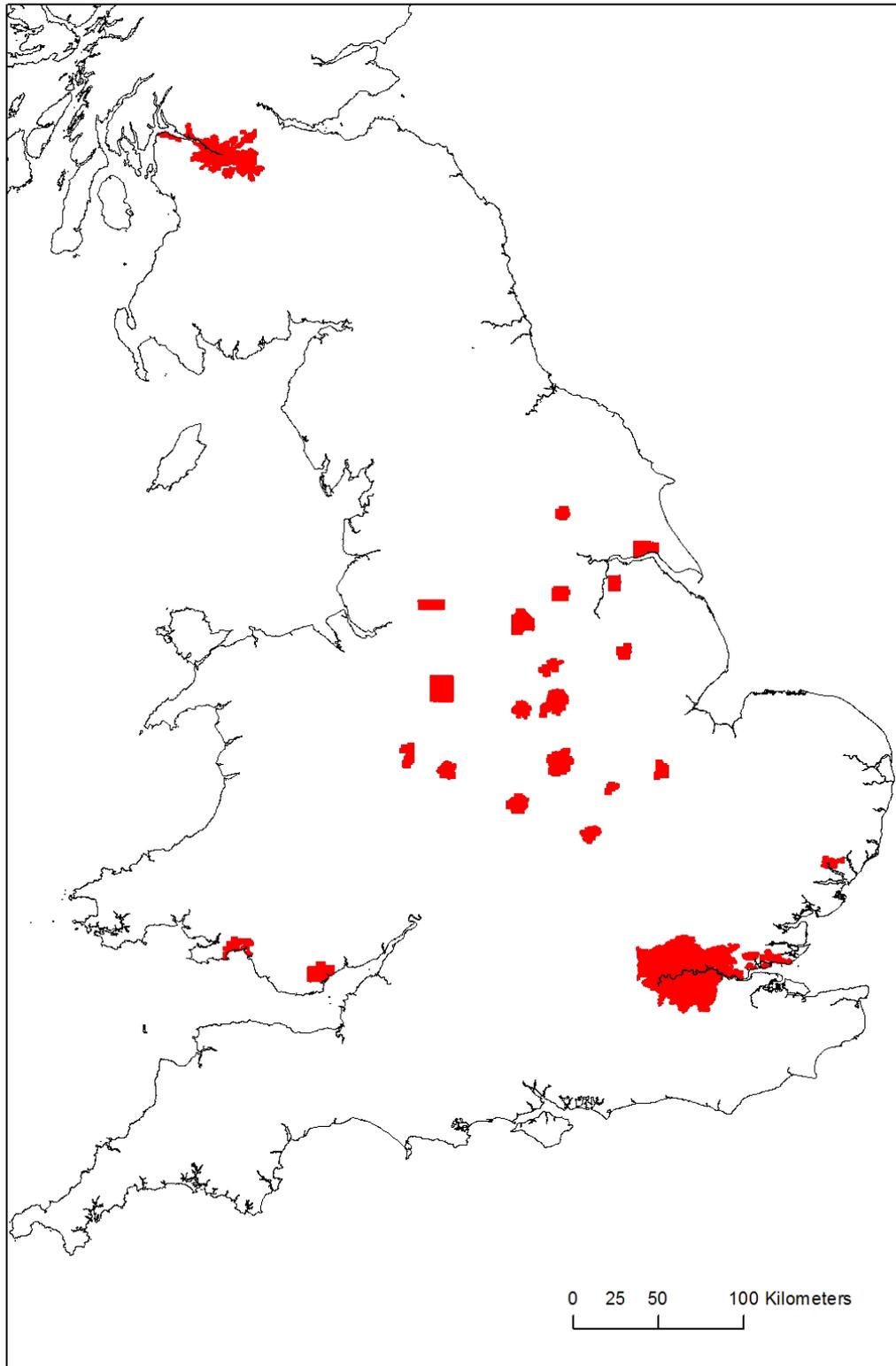


Figure 2 Extent of urban areas included in the Measured and Estimated Urban Soil Chemistry datasets (see Figure 3 for names of urban centres).

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 (mg kg^{-1}) of total As, Cd, Cr, Cu, Ni, Pb, Sn and Zn, 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).
4. Assess whether concentrations may exceed the Category 4 Screening Levels for Assessment of Land Affected by Contamination (DEFRA, 2014).

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
- Cu = copper
- Ni = nickel
- Pb = lead
- Sn = tin
- Zn = zinc
- B-As and B_ARSENIC = bioaccessible arsenic
- B-Pb and B_LEAD = bioaccessible lead
- Topsoil concentrations: As, Cd, Cr, Ni or Pb concentrations (and Cu, Sn and Zn in urban areas) in the <2mm fraction of soil taken from a depth interval of 5-20cm
- mg/kg = concentration (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 As, Cr, Ni dataset

FIELD NAME	FIELD TYPE	DESCRIPTION
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>) data. “London” in this field indicates that no data are available from the London urban area. “RuSoilLond” indicates estimates based on rural soil data within the London urban area; “RuSoilExAs” indicates that rural soil data were used except from arsenic, when sediment data was used.
ARSENIC	String	Estimated concentration of arsenic (mg kg ⁻¹) in topsoil
CHROMIUM	String	Estimated concentration of chromium (mg kg ⁻¹) in topsoil
NICKEL	String	Estimated concentration of nickel (mg kg ⁻¹) in topsoil
RELEASEDAT	String	Dataset title and release date (<i>EW_EstimatedAmbientBackgroundSoilChemistry_AsCrNi_May2014</i> for England and Wales; <i>SC_EstimatedAmbientBackgroundSoilChemistry_AsCrNi_May2014</i> for Scotland)
AS_DOMAIN	String	See section 4.1 for explanation (only for EW; not available for SC)
B_ARSENIC	String	Estimated concentration of bioaccessible arsenic (mg kg ⁻¹) in topsoil (only for EW; not available for SC)

The estimated soil concentrations are classed as follows:

Arsenic: <15, 15-25, 25-35, 35-45, 45-60, 60-120, >120 mg kg⁻¹

Chromium: <20, 20-40, 40-60, 60-90, 90-120, 120-180, >180 mg kg⁻¹

Nickel: <15, 15-30, 30-45, 45-60, 60-80, 80-100, >100 mg kg⁻¹

B_Arsenic: classes depend on domain (see section 4.1 for explanation)

Table 2 Attribute table field descriptions for BGS Estimated Ambient Background Soil Chemistry Cd, Pb dataset

FIELD NAME	FIELD TYPE	DESCRIPTION
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>) data. "London" in this field indicates that no BGS Estimated Ambient Background Soil Chemistry data are available from the London urban area.
CADMIUM	String	Estimated concentration of cadmium (mg kg ⁻¹) in topsoil
LEAD	String	Estimated concentration of lead (mg kg ⁻¹) in topsoil
RELEASEDAT	String	Dataset title and release date (<i>GB_EstimatedAmbientBackgroundSoilChemistry_CdPb_May2014</i>)
PB_DOMAIN	String	See section 4.1 for explanation (only for EW; not available for SC)
B_LEAD	String	Estimated concentration of bioaccessible lead (mg kg ⁻¹) in topsoil (only for EW; not available for SC)

Note: Measured Cd and Pb soil chemistry data interpolated to 500 m grid.

The estimated soil concentrations are classed as follows:

Cadmium: <1.8, 1.8-2.2, 2.2- 3.0, 3.0-6.0, >6.0 mg kg⁻¹

Lead: <100, 100-200, 200-300, 300-600, 600-1200, >1200 mg kg⁻¹

B_Lead: classes depend on domain (see section 4.1 for explanation)

Table 3 Attribute table field descriptions for BGS Measured Urban Soil Chemistry dataset

FIELD NAME	FIELD TYPE	DESCRIPTION
SAMPLENO	Numeric -double	BGS sample number
SAMPLETYP	String	Indicates soil type is a topsoil

E		
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^{-1}) in topsoil
CD_MGKG	Numeric -float	Concentration of cadmium (mg kg^{-1}) in topsoil
CR_MGKG	Numeric -double	Concentration of chromium (mg kg^{-1}) in topsoil
CU_MGKG	Numeric -double	Concentration of copper (mg kg^{-1}) in topsoil
NI_MGKG	Numeric -double	Concentration of nickel (mg kg^{-1}) in topsoil
PB_MGKG	Numeric -double	Concentration of lead (mg kg^{-1}) in topsoil
SN_MGKG	Numeric -double	Concentration of tin (mg kg^{-1}) in topsoil
ZN_MGKG	Numeric -double	Concentration of zinc (mg kg^{-1}) in topsoil
RELEASEDATA	String	Dataset title and release date: <i>GB_MeasuredUrbanSoilChemistry_AsCdCrCuNiPbSnZn_May2014</i>

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 (mg kg^{-1}) in topsoil
CR_MGKG	Numeric-long integer	Estimated concentration of chromium (mg kg^{-1}) in topsoil
NI_MGKG	Numeric-long integer	Estimated concentration of nickel (mg kg^{-1}) in topsoil
B_AS_MGKG	Numeric-float	Estimated concentration of bioaccessible arsenic (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_May2014</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

Table 5 Attribute table field descriptions for BGS Estimated Urban Soil Chemistry data: Cd, Cu, Pb, Sn, Zn and bioaccessible Pb subset

FIELD NAME	FIELD TYPE	DESCRIPTION
CD_MGKG	Numeric-float	Estimated concentration of cadmium (mg kg^{-1}) in topsoil
CU_MGKG	Numeric-long integer	Estimated concentration of copper (mg kg^{-1}) in topsoil
PB_MGKG	Numeric-long integer	Estimated concentration of lead (mg kg^{-1}) in topsoil
SN_MGKG	Numeric-long integer	Estimated concentration of tin (mg kg^{-1}) in topsoil
ZN_MGKG	Numeric-long integer	Estimated concentration of zinc (mg kg^{-1}) in topsoil
B_PB_MGKG	Numeric-long integer	Estimated concentration of bioaccessible lead (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_CdCuPbSbZn_May2014</i>
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Note: Measured soil chemistry data 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 8 potentially harmful elements (As, Cd, Cr, Cu, Ni Pb, Sn and Zn) 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 for As, Cr and Ni 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; DiGMapGB-50 version 3.14) were used to provide a 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 dataset 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).

Since the release in 2009 of first version of the ESTIMATED AMBIENT BACKGROUND SOIL CHEMISTRY DATA, the new National Soil Inventory data for England and Wales (Rawlins et al., 2012) was used to validate the mapping methodology described above. This confirmed that the methodology is optimal for As, Cr and Ni especially where geology is the most important control, such as in areas underlain by ironstones. However, distance weighted interpolation to a 500 m by 500 m grid based on concentrations of the nearest 5 samples is optimal for Cd and Pb, especially at the higher concentrations important for environmental assessments and in areas impacted by mineralisation, mining, and other anthropogenic factors or processes rather than parent material geology.

Estimated bioaccessible arsenic (B-Arsenic) concentrations (England and Wales only)

Predictive linear regression (LR) modelling between bioaccessible arsenic (B-As) and total arsenic (As) in areas dominated by Jurassic ironstones and associated clays and limestones (AS_DOMAIN = "Ironstone_Plus") was used to estimate B-As from total As concentrations using the following formula: $B-As = 0.0513 \text{ total As}$ (Appleton et al., 2012b). The "Ironstone_Plus" domain includes all the sedimentary ironstones in England and Wales (the "ironstone" domain of Ander et al., (2011, 2013) plus the Upper Lias Whitby Mudstone Formation and the Middle Lias Dyrham Formation where they occur adjacent to the Northampton Sand and Marlstone Rock Formations. These are included because they have relatively enhanced total arsenic concentrations (in some cases caused by downslope movement of ironstone derived soil and rock fragments) and the ironstone bioaccessibility model (Appleton et al., 2012b) included soil samples from these two units. The only other non-urban domain for which BGS holds sufficient bioaccessibility As data is for the mineralisation domain in SW England (AS_DOMAIN = "SW_Mineralisation") for which B-As was estimated using the formula: $B-As = 0.147 \text{ total As}$ (based on data in South West England). The extent of the mineralisation domain is detailed in Ander et al. (2011, 2013).

Insufficient relevant data are currently available to estimate bioaccessible arsenic for other domains in England and Wales or anywhere in Scotland.

Estimated bioaccessible lead (B-Lead) concentrations (England and Wales only)

Predictive linear regression (LR) modelling between bioaccessible Pb (B-Pb) in urban and mineralisation domains (Appleton et al., 2012c; Appleton et al., 2013) 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 urban areas and lead mineralised domains, apart from lead mineralised domains associated with Carboniferous (Dinantian) Limestone. B-Pb was estimated from total Pb concentrations using the following formula: $B-Pb = 0.613 \text{ total Pb}$ derived from data for combined urban and Pb mineralisation domains (PB_DOMAIN = Not DINLM). Pb bioaccessibility is slightly lower where lead mineralisation is associated with Lower Carboniferous Limestone (PB_DOMAIN = DINLM) when $B-Pb = 0.508 \text{ total Pb}$ was used (Appleton et al., 2012c, 2013).

Bootstrap resampling was used to define the 95th percentile uncertainty limits for the As and Pb bioaccessibility linear regression models, following the procedure reported in Appleton et al. (2013), except that intercepts were set to zero. This information indicates that there is a 95% probability that a topsoil sample with 1000 mg/kg total Pb in an urban domain will have a bioaccessible Pb concentration of between 630 and 738 mg/kg (median 676 mg/kg).

Table 6 95th percentile confidence limits for slopes of bioaccessibility linear regression models for As and Pb domains

Domain (element)	Lower confidence interval (2.5 th percentile)	Median	Upper confidence interval (97.5 th percentile)
Jurassic Ironstone (As)	0.041	0.053	0.065
SW England mineralised (As)	0.111	0.147	0.194
Urban and Rookhope (Pb)	0.630	0.676	0.738
Lower Carboniferous Limestone (DINLM) (Pb)	0.462	0.509	0.567

4.2 MEASURED URBAN SOIL CHEMISTRY DATA

This dataset comprises the locations and concentrations (mg kg⁻¹) of total As, Cd, Cr, Cu, Ni, Pb, Sn and Zn, 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), copper (Cu), nickel (Ni), lead (Pb) and zinc (Zn) 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 km² 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 Tables 5 and 6. 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.

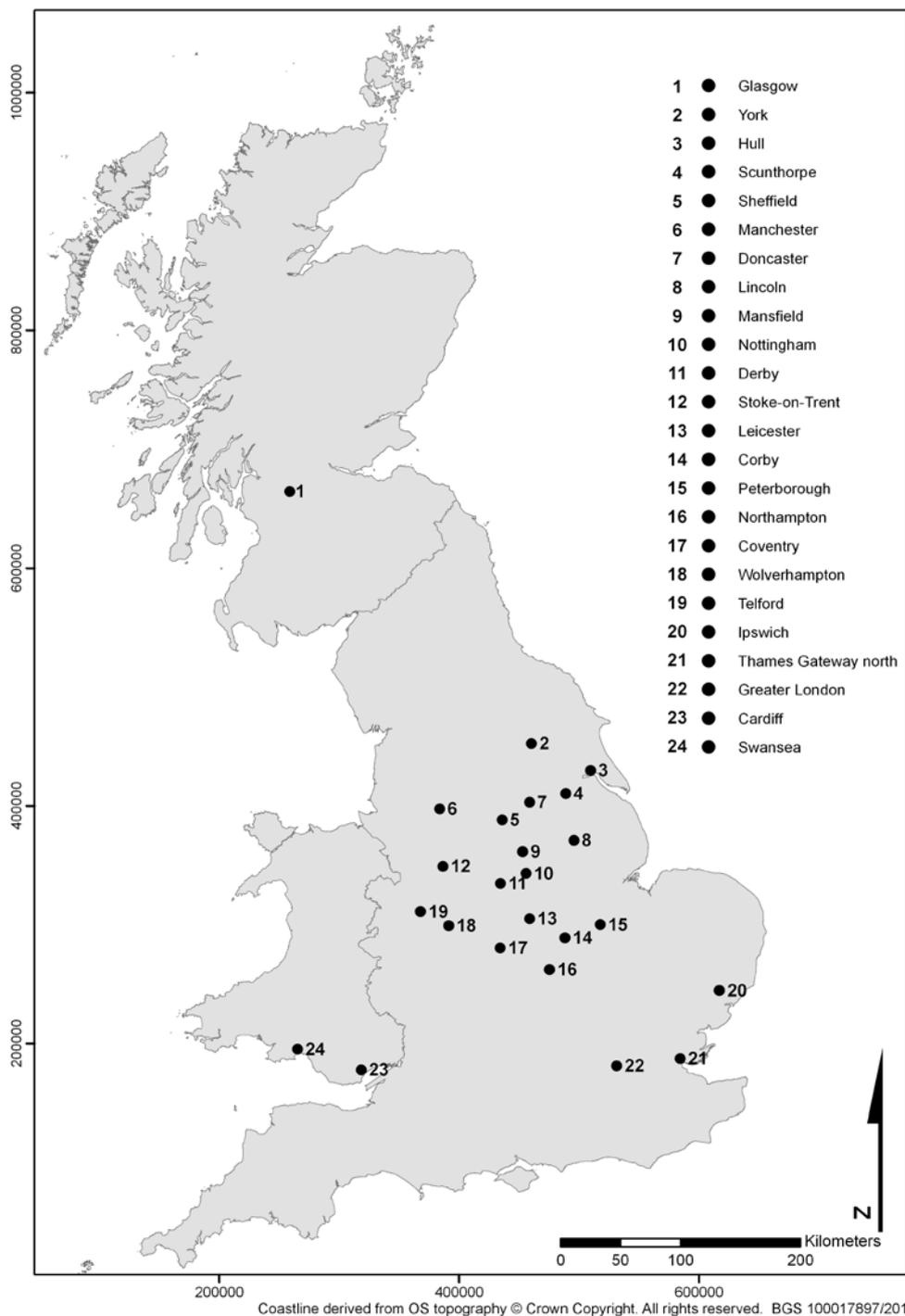


Figure 3 Urban centres with G-BASE topsoil data ¹

¹ data for urban centres 21 (Greater London Authority) and 22 (Brentwood, Basildon, Canvey Island, Southend, Tilbury and Grays) are combined under the LOND area code in Tables 5 and 6

Table 7 Number (No.) of urban topsoil samples and area summary statistics for As, Cd, Cr and Cu (concentrations in mg kg⁻¹)

Urban area	AREA	No.	Min. As	Max. As	Ave. As	Min. Cd	Max. Cd	Ave. Cd	Min. Cr	Max. Cr	Ave. Cr	Min. Cu	Max. Cu	Ave. Cu
Cardiff	CARD	506	6	149	18	0.1	100.6	0.9	28	2933	86	4	2020	54
Corby	CORB	133	11	90	23	0.3	4.0	0.3	56	233	94	11	908	32
Coventry	COVE	390	2	105	10	0.3	8.6	0.5	25	426	66	10	464	48
Derby	DERB	275	6	63	16	0.3	12.5	2.4	29	312	70	16	659	56
Doncaster	DONC	279	2	73	15	0.1	6.7	0.6	16	354	64	9	1300	55
Glasgow ¹	GLAS	2557	0	856	11	0.1	16.0	0.5	22	5402	118	2	3834	74
Hull	HULL	406	4	211	24	0.1	5.3	0.5	30	2121	91	6	1163	76
Ipswich	IPSW	200	5	48	13	0.1	4.8	0.5	18	115	39	4	1263	37
Leicester	LEIC	652	4	84	14	0.3	9.3	0.5	42	771	86	11	508	39
Lincoln	LINC	214	4	63	15	0.1	1.6	0.4	20	118	45	5	367	32
London ²	LOND	7209	1	161	17	0.1	165.2	0.9	13	2094	79	3	5326	70
Manchester	MANC	300	3	1008	28	0.3	80.3	1.4	29	1252	92	7	2160	125
Mansfield	MANS	257	4	73	14	0.1	9.9	0.8	15	243	53	5	1876	46
Northampton	NORT	275	8	107	34	0.3	134.1	0.9	53	4304	129	7	1073	34
Nottingham	NOTT	635	4	86	13	0.1	14.2	0.8	22	182	61	9	912	46
Peterborough	PETE	272	7	35	18	0.3	3.8	0.3	41	187	83	12	270	35
Scunthorpe	SCUN	196	3	178	26	0.1	30.9	0.6	12	1218	66	3	433	23
Sheffield	SHEF	575	5	243	25	0.1	6.8	0.8	32	1291	120	10	1661	83
Stoke	STOK	745	4	146	17	0.1	51.8	0.9	20	394	68	8	1880	54
Swansea	SWAN	368	8	2161	79	0.1	61.9	2.9	13	562	72	5	1597	177
Telford	TELF	291	5	58	12	0.1	32.6	2.3	25	133	65	9	457	40
Wolverhampton	WOLV	284	5	160	20	0.1	69.0	1.8	37	1189	95	16	3278	153
York	YORK	191	4	93	12	0.1	8.1	0.6	23	607	57	7	267	42

¹Glasgow includes satellite towns including Greenock, Dumbarton, East Kilbride, Motherwell and Cumbernauld ²Greater London includes satellite towns Brentwood, Basildon, Canvey Island, Southend, Tilbury and Grays

Table 8 Number (No.) of urban topsoil samples and area summary statistics for Ni, Pb, Sn and Zn (concentrations in mg kg⁻¹)

Urban area	AREA	No.	Min. NI	Max. NI	Ave. NI	Min. PB	Max. PB	Ave. PB	Min. SN	Max. SN	Ave. SN	Min. ZN	Max. ZN	Ave. ZN
Cardiff	CARD	506	8	482	35	20	8158	190	2	423	19	44	12000	285
Corby	CORB	133	16	64	31	18	438	49	0	72	4	64	1640	141
Coventry	COVE	390	7	157	25	19	976	108	2	444	14	32	835	128
Derby	DERB	275	12	180	34	21	2052	321	3	114	10	54	2363	255
Doncaster	DONC	279	6	181	26	19	1115	127	1	174	10	24	1634	167
Glasgow ¹	GLAS	2557	2	951	49	10	9676	179	1	634	17	7	5148	204
Hull	HULL	406	7	157	38	10	3450	241	2	937	32	22	6938	258
Ipswich	IPSW	200	3	54	15	12	954	119	1	106	8	10	1424	119
Leicester	LEIC	652	10	87	28	16	2053	109	1	150	13	41	809	137
Lincoln	LINC	214	3	74	17	16	1516	109	1	267	12	10	1117	104
London ²	LOND	7209	2	506	28	11	10000	280	1	1041	24	1	10095	216
Manchester	MANC	300	5	137	32	20	2687	270	3	351	29	25	1784	230
Mansfield	MANS	257	3	114	21	16	1354	121	2	207	11	15	1314	179
Northampton	NORT	275	6	77	30	25	656	82	2	81	8	22	812	125
Nottingham	NOTT	635	5	158	30	13	1810	155	2	188	12	19	1351	199
Peterborough	PETE	272	14	65	30	14	761	68	0	112	7	47	896	121
Scunthorpe	SCUN	196	2	214	23	9	3877	93	1	141	5	12	12000	211
Sheffield	SHEF	575	9	520	45	21	5277	252	2	286	20	28	3005	213
Stoke	STOK	745	3	141	28	7	4809	171	1	598	15	5	2959	177
Swansea	SWAN	368	8	384	52	23	10000	413	3	887	57	48	12000	678
Telford	TELF	291	7	172	36	25	1153	144	1	99	7	50	5736	479
Wolverhampton	WOLV	284	11	283	44	27	3047	247	4	335	29	67	8146	551
York	YORK	191	6	92	22	25	2877	224	2	247	13	29	1017	147

¹Glasgow includes satellite towns including Greenock, Dumbarton, East Kilbride, Motherwell and Cumbernauld ²Greater 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, Cu, Ni, Pb, Sn and Zn, and bioaccessible As and Pb concentrations (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 As, Cd, Cr, Cu, Ni, Pb, Sn and Zn concentrations, whose distribution in most urban areas is not usually strongly controlled by the underlying geology (soil parent material). In Corby, Northampton and Scunthorpe, the distribution of As, Cr and Ni is strongly controlled by the underlying geology so parent material mapping was used (see below for details).

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.

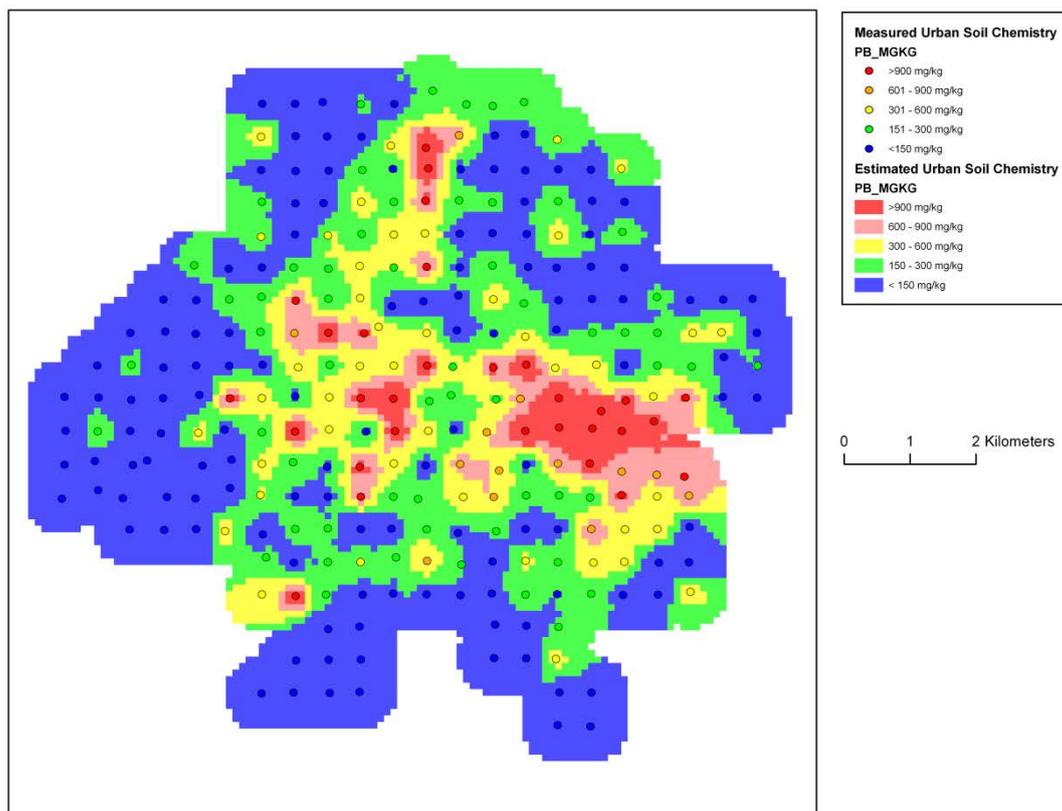


Figure 4 Distribution of measured and estimated total lead (mg kg^{-1}) in the <2 mm fraction of topsoils in the Derby urban area²

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

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

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).

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^{-1}). 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.

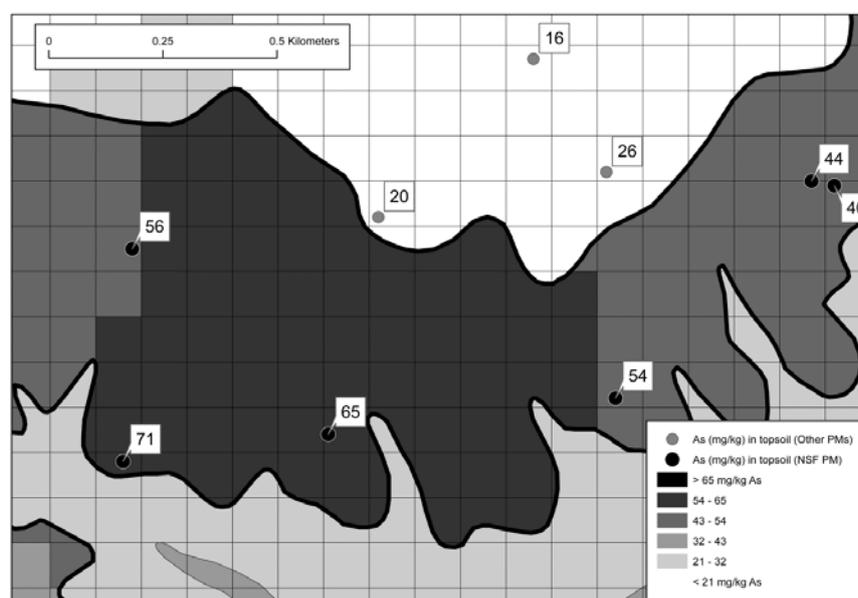


Figure 5 Geochemical mapping using PM-grouped data (see text for explanation)

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.

Version released October 2012: 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, were given estimated soil chemistry values in the October 2012 version using recently released G-BASE rural soil chemistry data.

Version released May 2014: The As, Cr and Ni data are the same as the October 2012 version except that estimated bioaccessible As (B-Arsenic) concentrations are included for ironstone and SW England mineralisation domains in England and Wales only, as explained in section 4.1 above. In rural areas, geology is still the most important control of As, Cr and Ni at higher concentrations, so 1-km\PM mapping is the most accurate interpolation method. For Cd and Pb the May 2014 version is completely revised because (1) 500m grid IDW interpolation was substituted for 1-km\PM interpolation because validation tests showed that this method is more accurate at higher Cd and Pb concentrations when the distribution of these elements is controlled mainly by mineralisation, mining and other anthropogenic factors/processes rather than by parent material (geology); (2) additional topsoil data was available for the area around London and the Clyde basin; and (3) Estimated bioaccessible Pb (B-Lead) data is also included in the data set.

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 7.

Table 9 Magnitude of differences between version 1 and version 2 Measured (Point Source) element concentrations as a result of data conditioning

Element	v1 (mg kg ⁻¹)	v2 (mg kg ⁻¹)	v1 (mg kg ⁻¹)	v2 (mg kg ⁻¹)
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).

Version 4 (released May 2014): Urban soil samples from Cardiff, Doncaster, Lincoln, Mansfield, Nottingham, Scunthorpe, Sheffield, Stoke, Swansea, Telford, Wolverhampton and York have been reanalysed and this new data is used in version 4. Data for two other potentially harmful elements (Copper (Cu) and zinc (Zn)) are included in v4 together with data for tin (Sn), which is a useful indicator of anthropogenic contamination. The Glasgow urban area now includes data for satellite towns such as Greenock, Dumbarton, East Kilbride, Motherwell and Cumbernauld. This increases the number of soil samples for Glasgow from 1381 in v3 to 2557 in v4. The number of soil samples in some of the other urban areas (Tables 5 and 6) are marginally different from v3 as a result of corrections being made to the BGS geochemical database.

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, Cu, Pb, Sn and Zn 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, Cu, Ni, Pb, Sn 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 geochemical data in the possession of the British Geological Survey at the time the data set was created (May 2014). 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 (May 2014).

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 (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.*

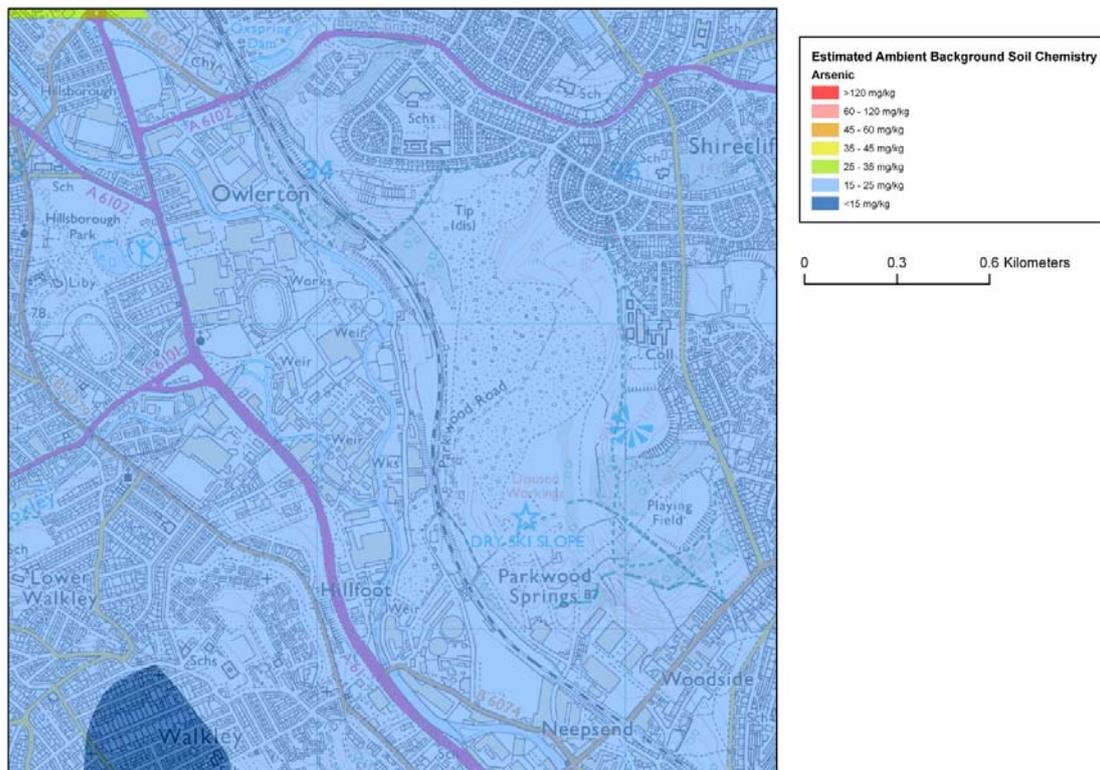


Figure 6 Map of Estimated Ambient Background Soil Chemistry data for arsenic (As) in a sector of Sheffield

7.2.2 Measured Urban Soil Chemistry

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

Answer: The concentrations (mg kg⁻¹) of As, Cd, Cr, Cu, Ni, Pb, Sn and Zn 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, Cu, Ni, Pb, Sn and Zn

EASTING	NORTHING	AS_MGKG	CD_MGKG	CR_MGKG	CU_MGKG	NL_MGKG	PB_MGKG	SN_MGKG	ZN_MGKG
434280	389240	12	0.3	96	72	39	126	8	176
433400	389750	25	0.7	95	207	39	192	13	207
433750	389240	20	1.3	118	72	43	162	15	189
433740	389750	49	0.5	146	115	70	158	9	128
434760	390740	12	0.1	142	44	45	119	10	145
433240	389220	47	1.1	95	118	41	559	28	236
434840	389660	11	0.1	108	47	49	64	5	124
433960	390210	24	0.6	75	55	27	146	9	161
433250	390760	31	0.5	88	100	40	258	36	294
434780	388700	11	2.1	777	262	87	304	22	396
434750	389240	29	0.6	96	107	53	1203	25	228
433250	390260	30	0.2	86	64	26	194	16	152
434250	390250	22	0.7	178	80	68	178	9	205
434250	390750	23	0.4	112	60	46	116	12	161
434250	389790	75	4.4	578	547	346	1370	148	866
433750	390750	58	0.8	135	156	60	447	19	236
434760	390270	52	0.9	124	117	60	303	34	173
435230	390750	29	0.4	110	71	51	283	12	206
435240	388750	31	0.8	124	70	51	150	13	198
435250	389250	16	0.3	86	39	38	83	7	113
435250	389730	33	1.1	104	105	53	316	37	194
435250	390260	12	0.6	103	44	51	91	7	138
434240	388750	11	0.8	64	232	21	166	10	103
433770	388780	13	0.4	53	29	19	84	8	111
433250	388740	13	0.4	95	29	21	90	6	101

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.

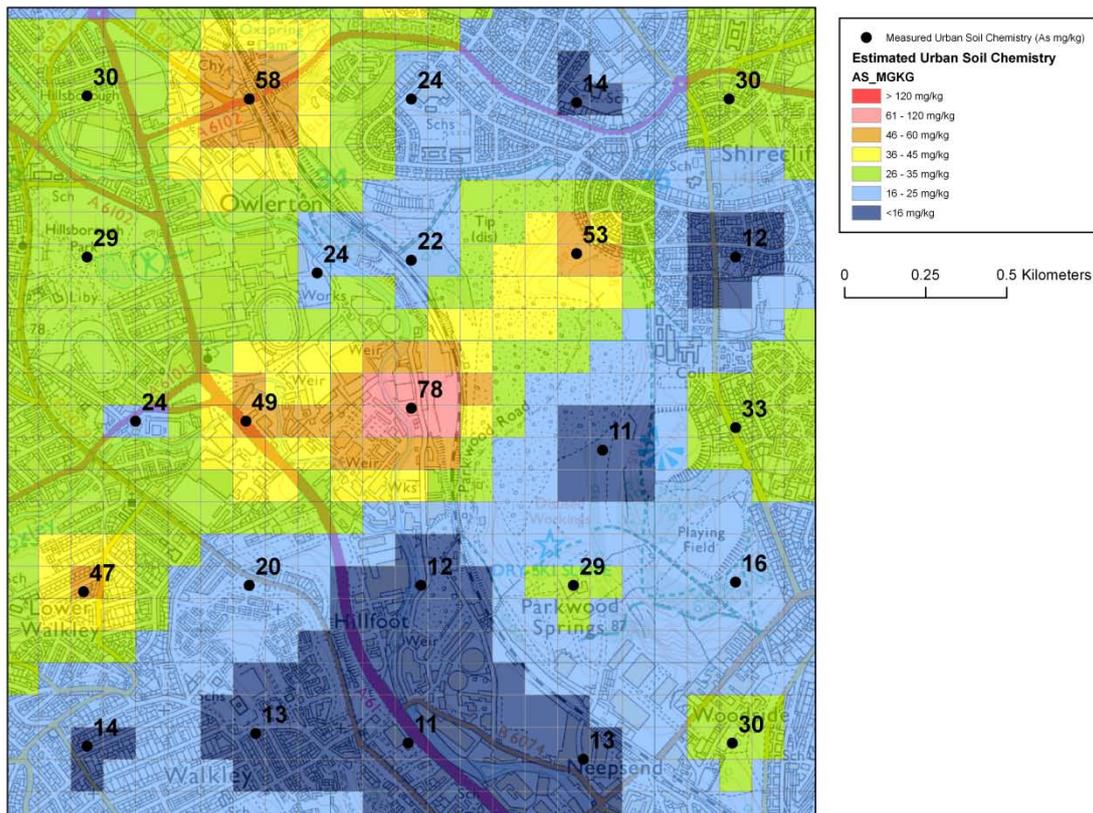


Figure 7 Map of BGS Measured Urban Soil Chemistry and Estimated Urban Soil Chemistry data for arsenic (As) in a sector of Sheffield (map based on v3 data; v4 based on reanalysed soil samples is almost identical).

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 (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.*

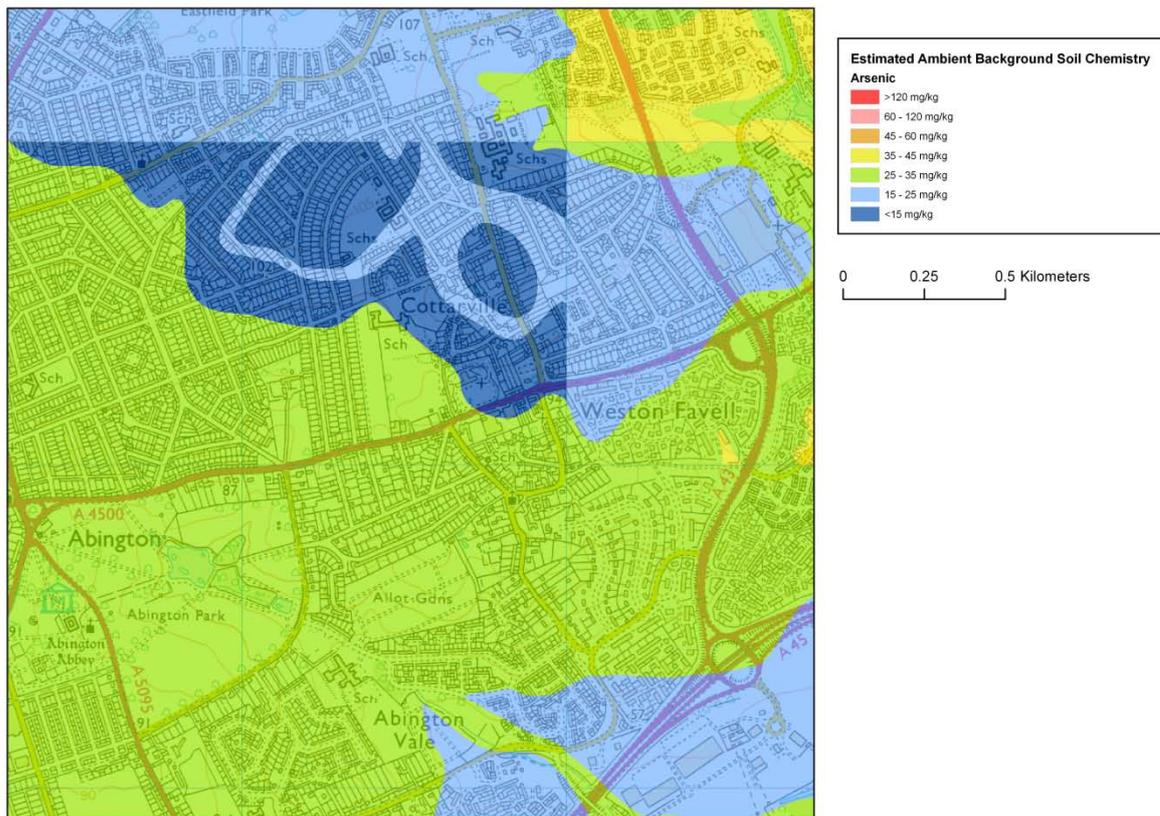


Figure 8 Map of BGS Estimated Ambient Background Soil Chemistry data for arsenic (As) in a sector of Northampton

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 (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

EASTING	NORTHING	AS_MGKG	CD_MGKG	CR_MGKG	CU_MGKG	NI_MGKG	PB_MGKG	SN_MGKG	ZN_MGKG
478610	261740	66	0.3	193	36	60	124	6	225
479240	261820	55	0.3	191	22	51	52	2	190
478180	262150	57	0.3	120	18	35	48	2	113
479130	261200	24	0.3	76	20	23	42	4	85
478720	262850	18	0.3	77	27	21	93	14	81
479220	262320	26	0.3	86	31	26	76	5	106
479060	262570	16	0.3	87	26	27	47	4	80
478720	262220	20	0.3	71	15	13	47	6	52
478400	261220	27	0.3	115	28	35	71	5	127
478160	261680	71	0.3	146	18	38	49	3	117
478740	261260	20	0.3	108	20	35	36	4	102
477740	261700	42	0.3	125	25	37	73	4	119
477710	261250	29	0.3	94	29	28	73	5	111
477680	262340	39	0.3	80	22	18	71	6	120
478260	262960	33	0.3	87	35	24	125	10	144
477770	262910	19	0.3	113	27	24	86	66	137

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.

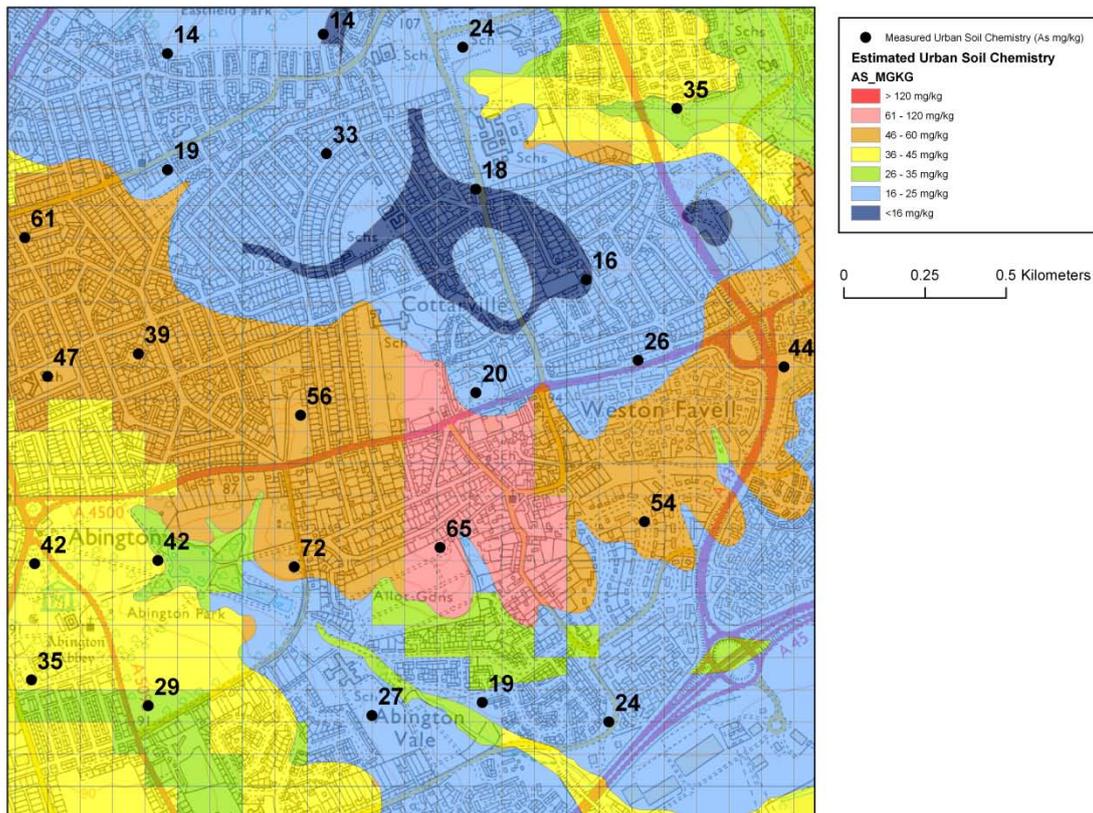


Figure 9 Map of BGS Measured Urban Soil Chemistry and Estimated Urban Soil Chemistry data for arsenic (As) for a sector of Northampton

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 (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.*

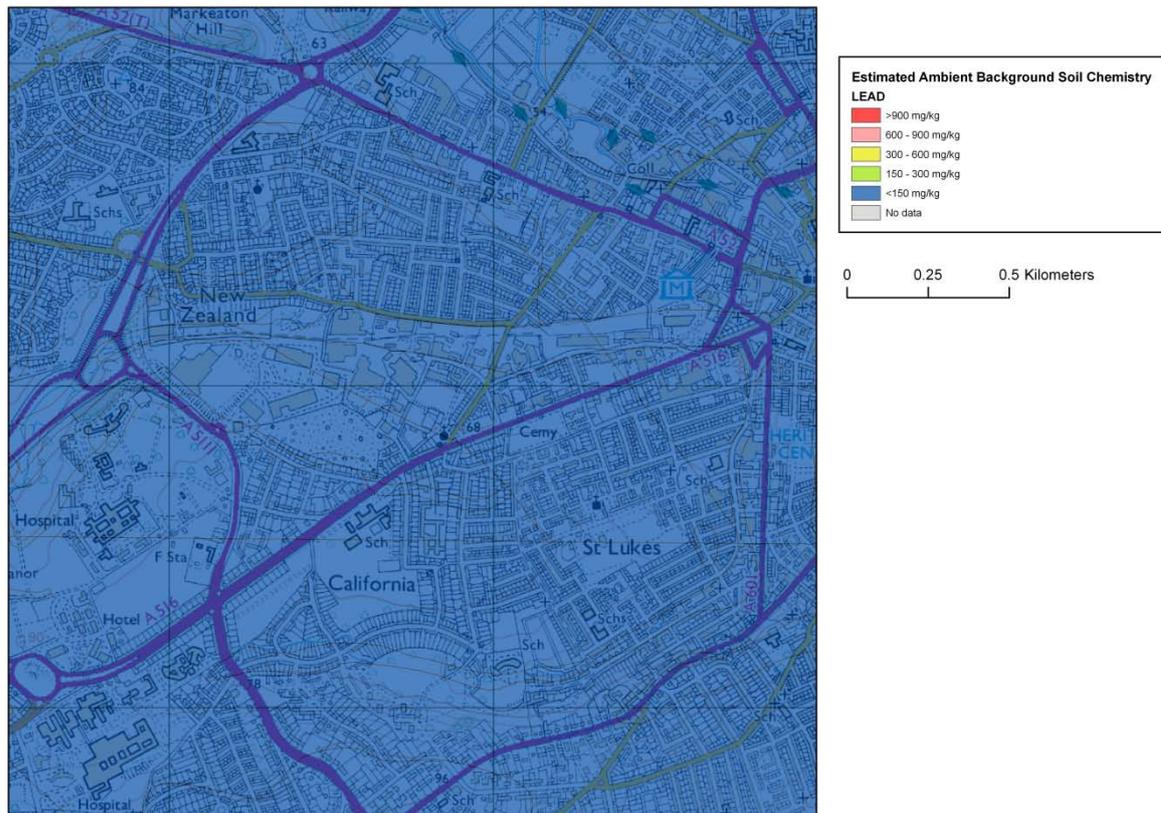


Figure 10 Map of Estimated Ambient Background Soil Chemistry data for lead (Pb) in a sector of Derby

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.

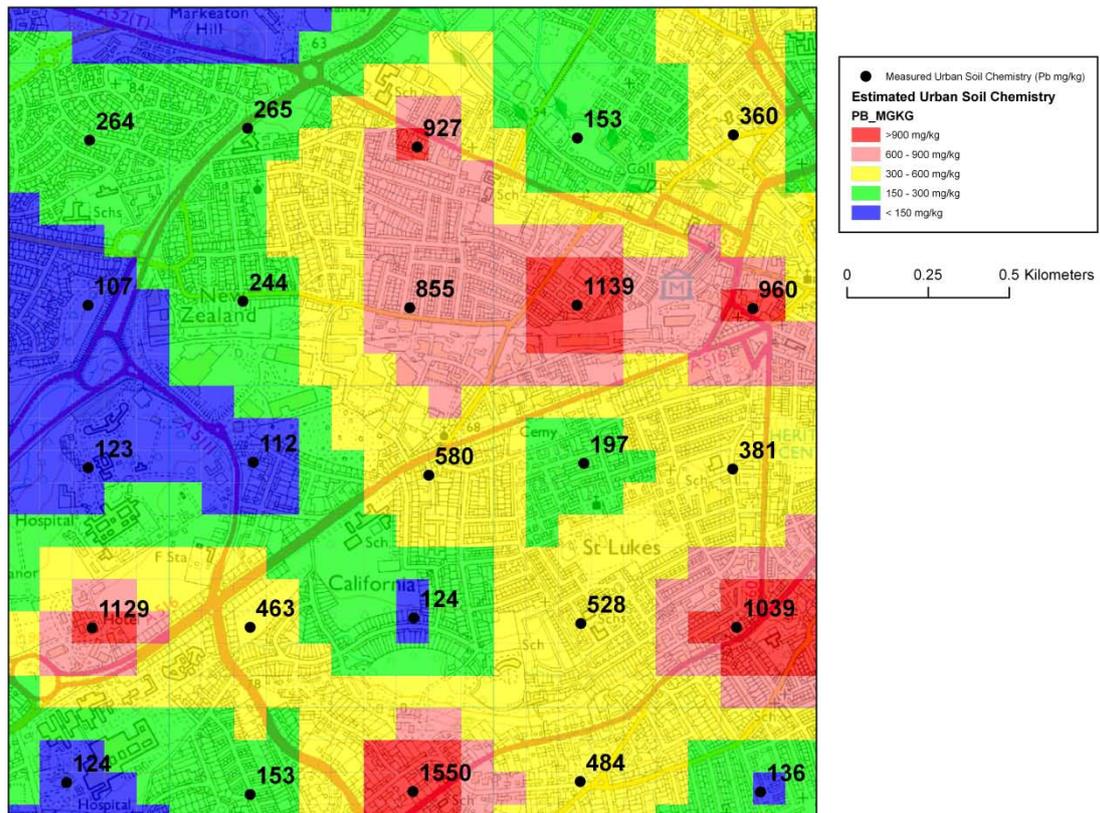


Figure 11 Map of BGS Measured Urban Soil Chemistry and Estimated Urban Soil Chemistry data for lead (Pb) for a sector of Derby

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 (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.*

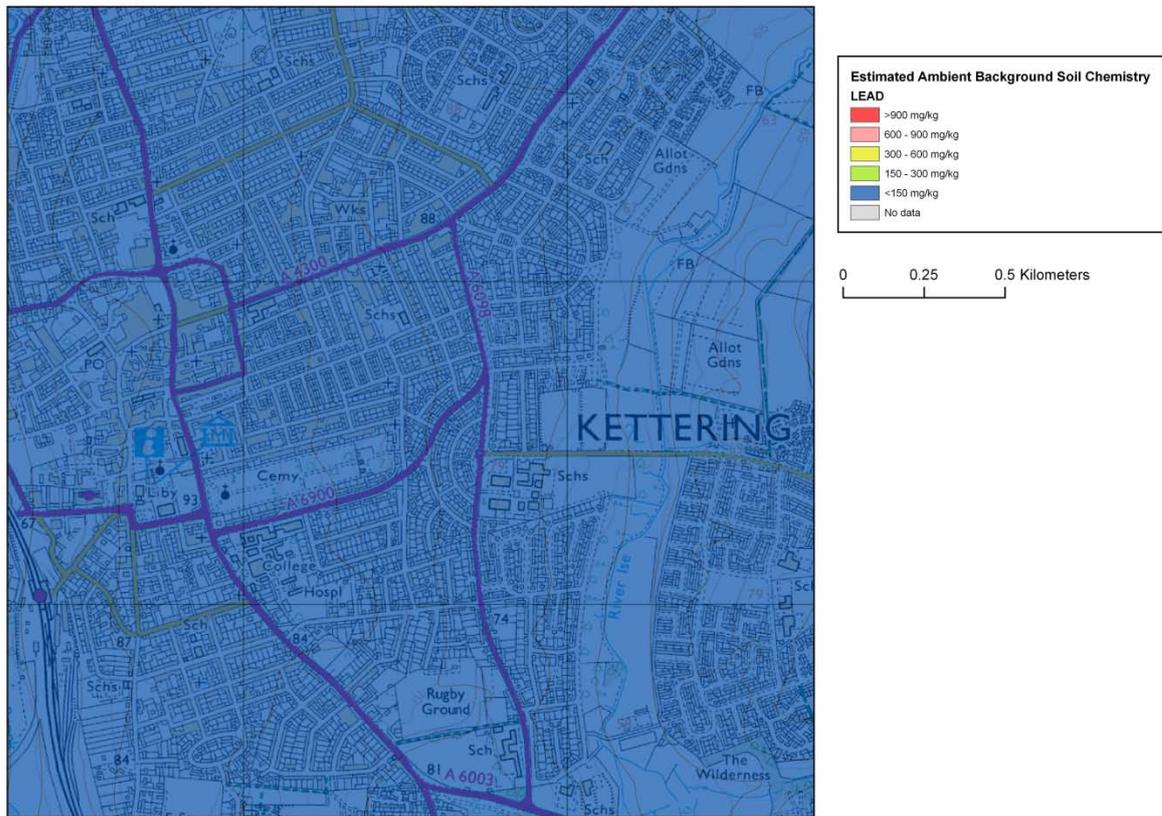


Figure 12 Map of Estimated Ambient Background Soil Chemistry data for lead (Pb) in a sector of Kettering

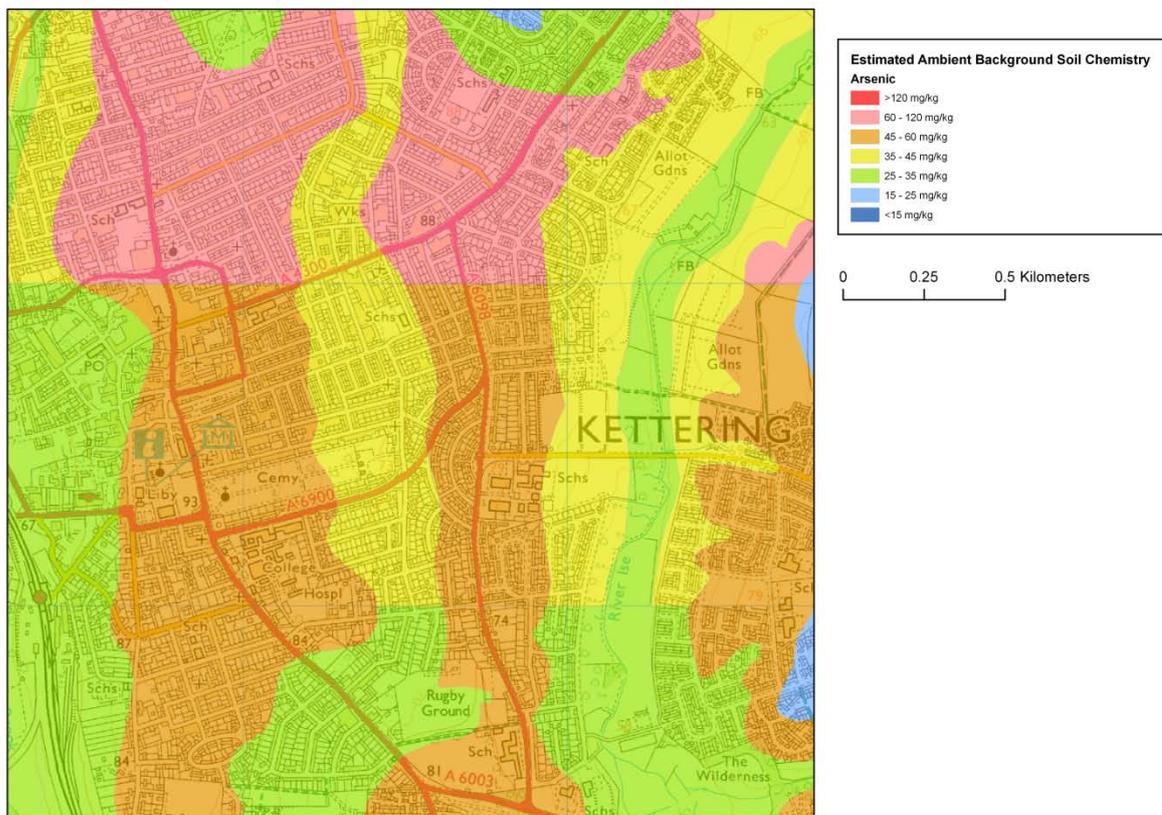


Figure 13 Map of Estimated Ambient Background Soil Chemistry data for arsenic (As) in a sector of Kettering

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 (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.*

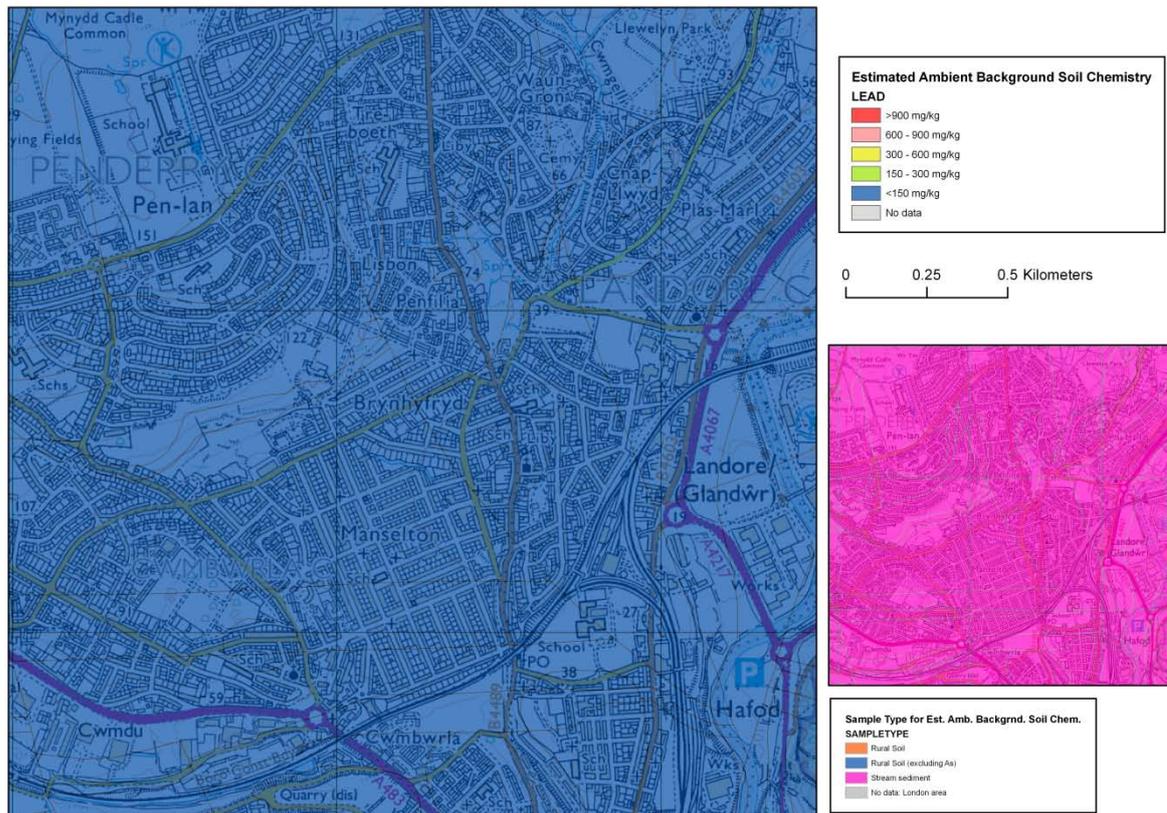


Figure 14 Map of Estimated Ambient Background Soil Chemistry data for lead (Pb) in a sector of Swansea

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.

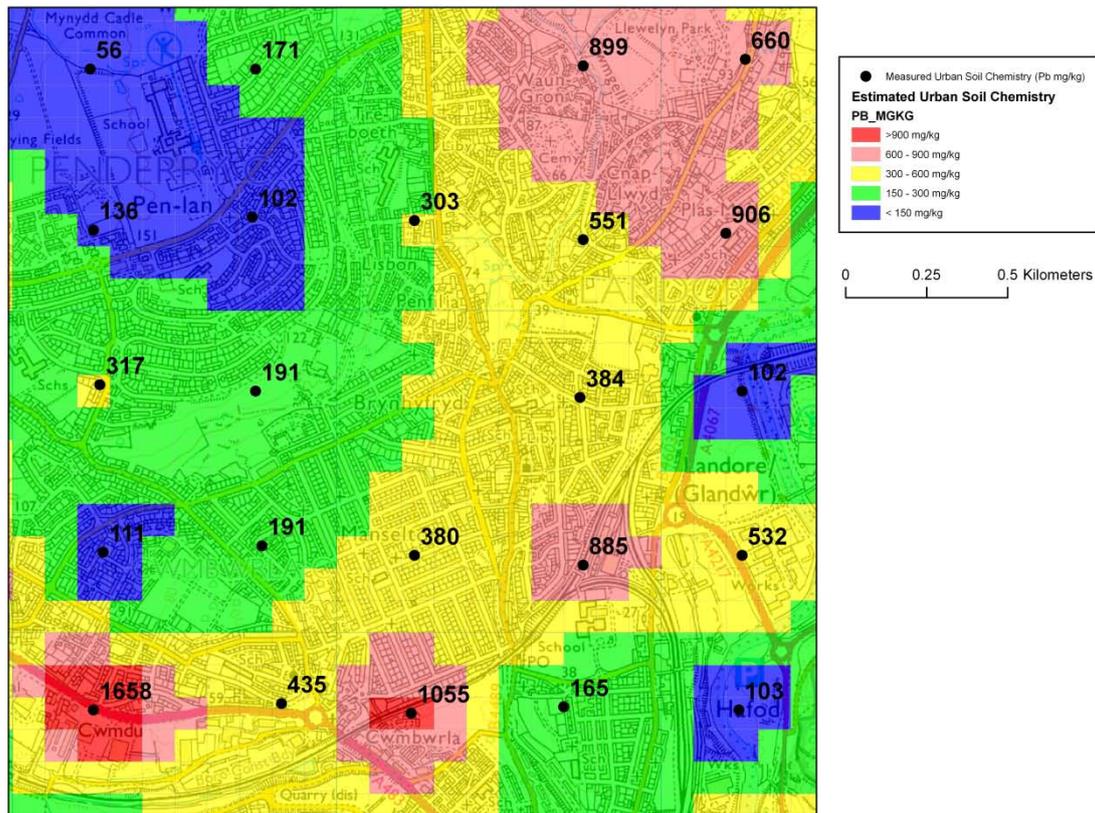


Figure 15 Map of BGS Measured Urban Soil Chemistry and Estimated Urban Soil Chemistry data for lead (Pb) in a sector of Swansea (based on v3 data; v4 reanalysed Pb data are about 5% lower than the v3 data)

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 this part of 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.

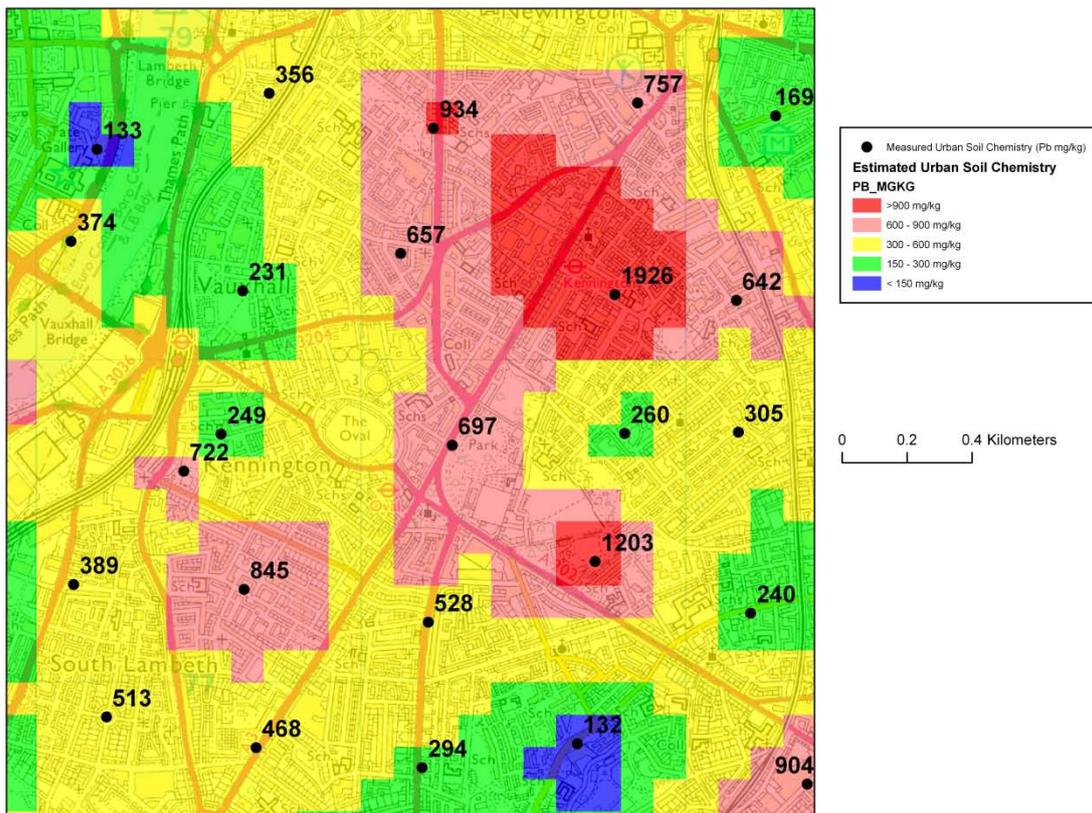


Figure 16 Map of BGS Measured Urban Soil Chemistry and Estimated Urban Soil Chemistry data for lead (Pb) in a sector of London

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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.

SGV Soil Guideline Value. Generic assessment criteria used as screening tools in generic quantitative human health risk assessment (DEFRA-EA, 2002b-g; Environment Agency 2009a-e; DEFRA, 2012a).

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