British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Gateway to the Earth

Normal Background Concentrations in England and Wales, and comparison with provisional C4SLs

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SoBRA /SAGTA meeting, BAE Systems Farnborough
8th April 2014

Presentation outline

- Overview of the Normal Background Concentration project

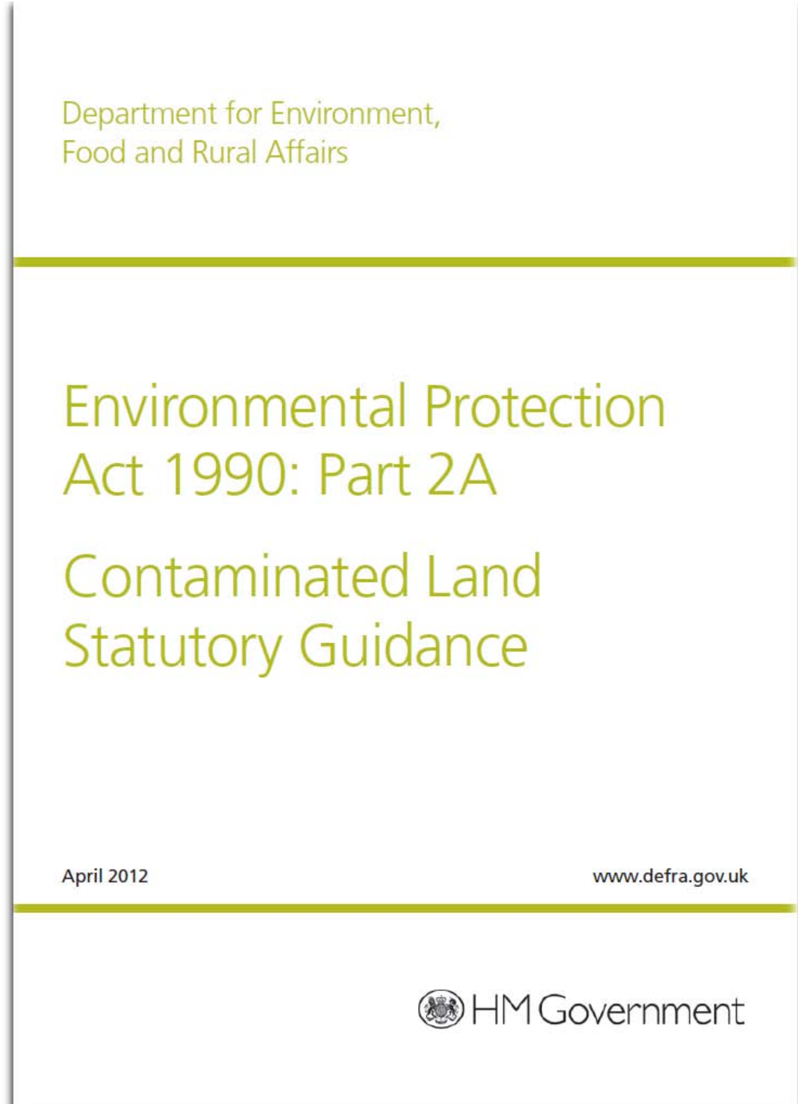
- NBCs in English soils and comparison with C4SL
  - Arsenic
  - Lead

- NBCs in Welsh soils and comparison with C4SL
  - Arsenic
  - Lead

- Summary

Project background – *Work packages 1 to 4*

- Work initially commissioned in support of contaminated land legislation - revised Part 2A Statutory Guidance published by Defra April 2012 (see www.defra.gov.uk/environment/quality/land/)
- Core BGS team – Chris Johnson, Louise Ander, Mark Cave and Barbara Palumbo-Roe
- Expert support – Murray Lark, Barry Rawlins, Don Appleton, Chris Vane, Stephen Lofts and Paul Nathanial (LQM)
- Defra Soils Policy Team and Project Steering Group


Department for Environment, Food and Rural Affairs

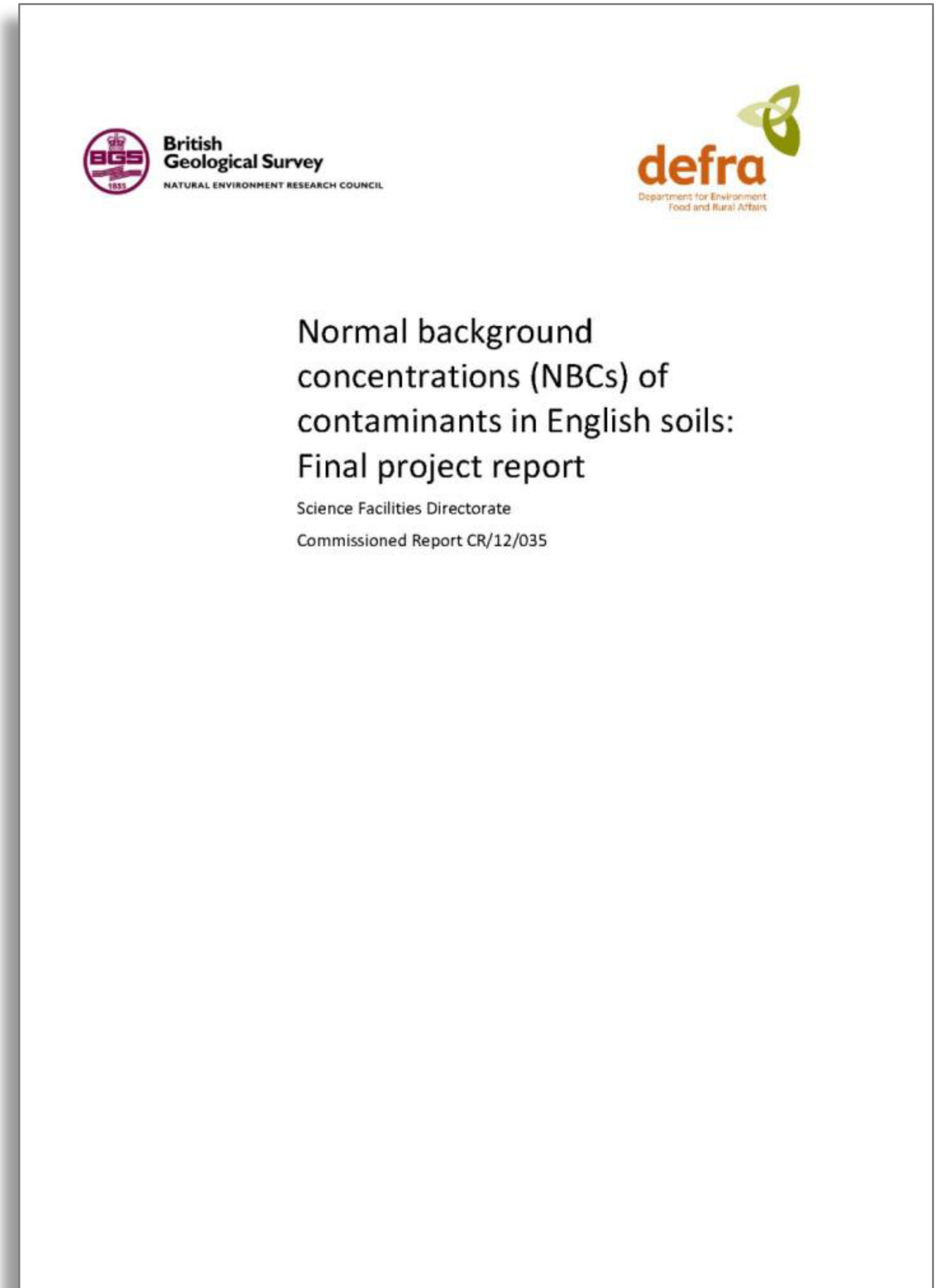
Environmental Protection Act 1990: Part 2A

Contaminated Land Statutory Guidance

April 2012

www.defra.gov.uk

HM Government



British Geological Survey
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defra
Department for Environment Food and Rural Affairs

Normal background concentrations (NBCs) of contaminants in English soils: Final project report

Science Facilities Directorate

Commissioned Report CR/12/035

WP1-4 final project report

Documentation of all data used, methods and NBCs. Reference to other project reports on data and methods.

Technical Guidance Sheets

- Arsenic
- Benzo-[a]-pyrene
- Cadmium
- Copper
- Lead
- Mercury
- Nickel

Part 2A, Environmental Protection Act 1990

Technical Guidance Sheet (TGS) on normal levels of contaminants in English soils

Normal levels of contaminant concentrations in soils are referred to in the contaminated land Statutory Guidance for the Part 2A regime Defra 2012. This Technical Guidance Sheet (TGS) gives an indication as to what arsenic concentrations can be expected in soils based on results from samples systematically collected across England. Normal Background Concentrations (NBCs) can be used along with other criteria (e.g. site investigation data and risk assessments) to help decide whether land is contaminated land as defined by Part 2A, on a site-by-site basis.

The NBCs are not intended to be a tool to be utilised when undertaking works via the planning regime. *They are contaminant concentrations that are seen as typical and widespread in topsoils (depth 0 – 15 cm) and include contributions from both natural and diffuse anthropogenic sources.*

When using this Guidance Sheet, please refer to the section on 'Using Normal Background Concentrations' at the end, the Supplementary Information, and the revised Part 2A Statutory Guidance.

LEAD (Pb)

Technical Guidance Sheet TGS02, July 2012.

Lead (Pb) is a metallic element naturally occurring in trace amounts in the Earth's surface environment with concentrations in rocks averaging 15 mg/kg. Generally, acid igneous rocks (e.g. granites) are higher in Pb than basic ones (e.g. basalts) and concentrations in sedimentary rocks are variable with up to 70 mg/kg in some limestones. With a low melting point, Pb ore minerals are readily smelted and the metal is easily worked. Lead therefore has a long history of use in human activities. In England there are a number of historical lead mining areas (e.g. the Derbyshire Peak District) where there is a legacy of Pb contamination caused by mining and associated activities. Biologically it is considered as a non-essential element and toxic to man and animals through the food chain and soil dust inhalation or ingestion.

Due to the strong affinity to bond with sulphur, Pb associates with sulphur minerals. Therefore, some rocks and soils containing sulphide minerals can be enriched in Pb. The principal Pb mineral is lead sulphide (galena, PbS). Other common minerals are cerussite (lead carbonate, $PbCO_3$) and anglesite (lead sulphate, $PbSO_4$). The solubility of Pb in soil is very low and decreases with increasing soil pH. During the chemical weathering of rocks, Pb sulphides oxidise and Pb becomes bound to soil components such as clay minerals, iron and manganese oxides, organic matter, or may form carbonate and phosphate minerals.

Soil is a major sink for Pb associated with human activity, and, although many original uses of Pb have stopped because of the recognition of its toxic nature to the environment and humans, Pb contamination persists. Historically, Pb was used for plumbing, in paints and most significantly, in terms of diffuse pollution, tetraethyl lead was used in petrol. Reduction of Pb in petrol commenced in the UK from 1986 and was completely eliminated by 2000. Other notable sources of Pb contamination in the environment are from the application of sewage sludge, vehicle parts (e.g. Pb wheel weights), batteries, some plastics and metallic Pb used as flashing on buildings.

NORMAL BACKGROUND CONCENTRATIONS (NBCs)

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

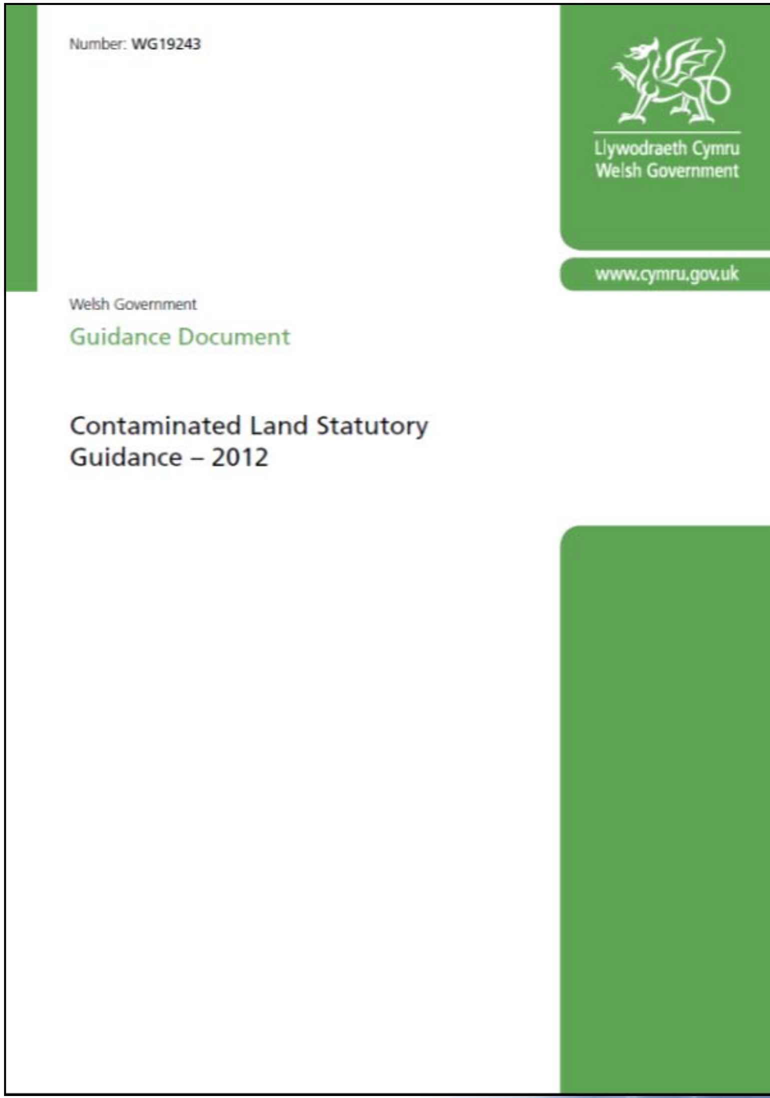
Table 1: NBCs for the lead domains (cited to 2 significant figures, n is number of samples used in the calculation). Lead is determined by laboratory-based X-ray fluorescence spectrometry (XRFS), *i.e.* total Pb in soils sampled from a depth 0 – 15 cm. The NBC is the upper 95% confidence limit of the 95th percentile of the domain data (see supplementary information).

Methods

NBCs are calculated using contaminant data, with demonstrably high levels of quality assurance, for English topsoils systematically collected from a variety of land uses and analysed using certified methods. For this purpose the primary data sets used are the British Geological Survey's G-BASE results and samples collected for the National Soil Inventory (NSI) by the Soil Survey of England and Wales (now the National Soil Resources Institute (NSRI), Cranfield University, UK) (see Figure 1). The G-BASE samples cover both urban and rural locations and all

Project background – *Work package 5*

- Work commissioned in support of contaminated land legislation - revised Part 2A Statutory Guidance published by Defra April 2012 (see www.defra.gov.uk/environment/quality/land/)
- Core BGS team – Chris Johnson, Louise Ander and Mark Cave
- Defra Soils Policy Team
- Welsh Government, Public Health Wales and Natural Resources Wales representatives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Llywodraeth Cymru
Welsh Government

www.cymru.gov.uk

Welsh Government
Guidance Document

Contaminated Land Statutory
Guidance – 2012

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL
Arolwg Daearegol Prydain

Normal background concentrations of contaminants in the soils of Wales. Exploratory data analysis and statistical methods

Science Facilities Directorate

Commissioned Report CR/12/107

WP5 report

Documentation of all data used and methods, including statistical method to be detailed in Mark's talk.

Technical Guidance Sheets

Part 2A, Environmental Protection Act 1990

Technical Guidance on normal levels of contaminants in Welsh soil

Normal levels of contaminant concentrations in soils are referred to in the contaminated land Statutory Guidance for the Part 2A regime (Wales), published by Welsh Government, 2012. This technical guidance gives an indication as to what arsenic concentrations can be expected in soils based on results from samples systematically collected across Wales. Normal Background Concentrations (NBCs) can be used along with other criteria (e.g. site investigation data and risk assessments) to help decide whether land is contaminated land as defined by Part 2A, on a site-by-site basis.

The NBCs are not intended to be a tool to be utilised when undertaking works via the planning regime. *They are contaminant concentrations that are seen as typical and widespread in topsoils (depth 0 – 15 cm) and include contributions from both natural and diffuse anthropogenic sources.*

When using this Guidance, please refer to the section on 'Using Normal Background Concentrations' on page 4, the supplementary information provided by Ander et al. (2013), and the revised Part 2A Statutory Guidance (Wales).

ARSENIC (As)

January 2013.

Arsenic (As) is a chemical element that is naturally found in trace amounts in our environment so, in addition to being referred to as a metalloid, it is a trace element. It is the 20th most abundant element in rocks (1-2 mg/kg) and, due to its reputation as the Victorian's poison of choice, awareness of the harmful aspects of this element to human health is high.

It occurs in many geological materials with the highest concentrations found in arsenic sulphide minerals such as arsenopyrite (FeAsS), as well as an accessory element in other sulphides such as iron pyrites (FeS_2). A significant source of As released into the surface environment is as a result of oxidation of sulphide minerals. Phosphate-rich rocks, ironstones and coal-bearing strata can also contain high levels of As. Overall, As minerals and compounds are generally soluble but the mobility of As can be limited by strong sorption by clays, hydroxides and organic matter. Under normal oxidising conditions the most common form of As in solution is the arsenate oxyanion (containing As^{5+}), under more reducing conditions (e.g. waterlogging) the arsenite oxyanion (containing As^{3+}) is more stable.

General diffuse anthropogenic sources of As are from dust particles and waste materials from historical metalliferous mining, smelting processes and coal burning. In the built environment increased levels of As may be related to specific historical land use, especially metallurgical industries. Chromium-copper-arsenate (CCA) was developed in 1933 as a wood preservative and, although restricted by regulation from 2004, is a potential source of widespread contamination.

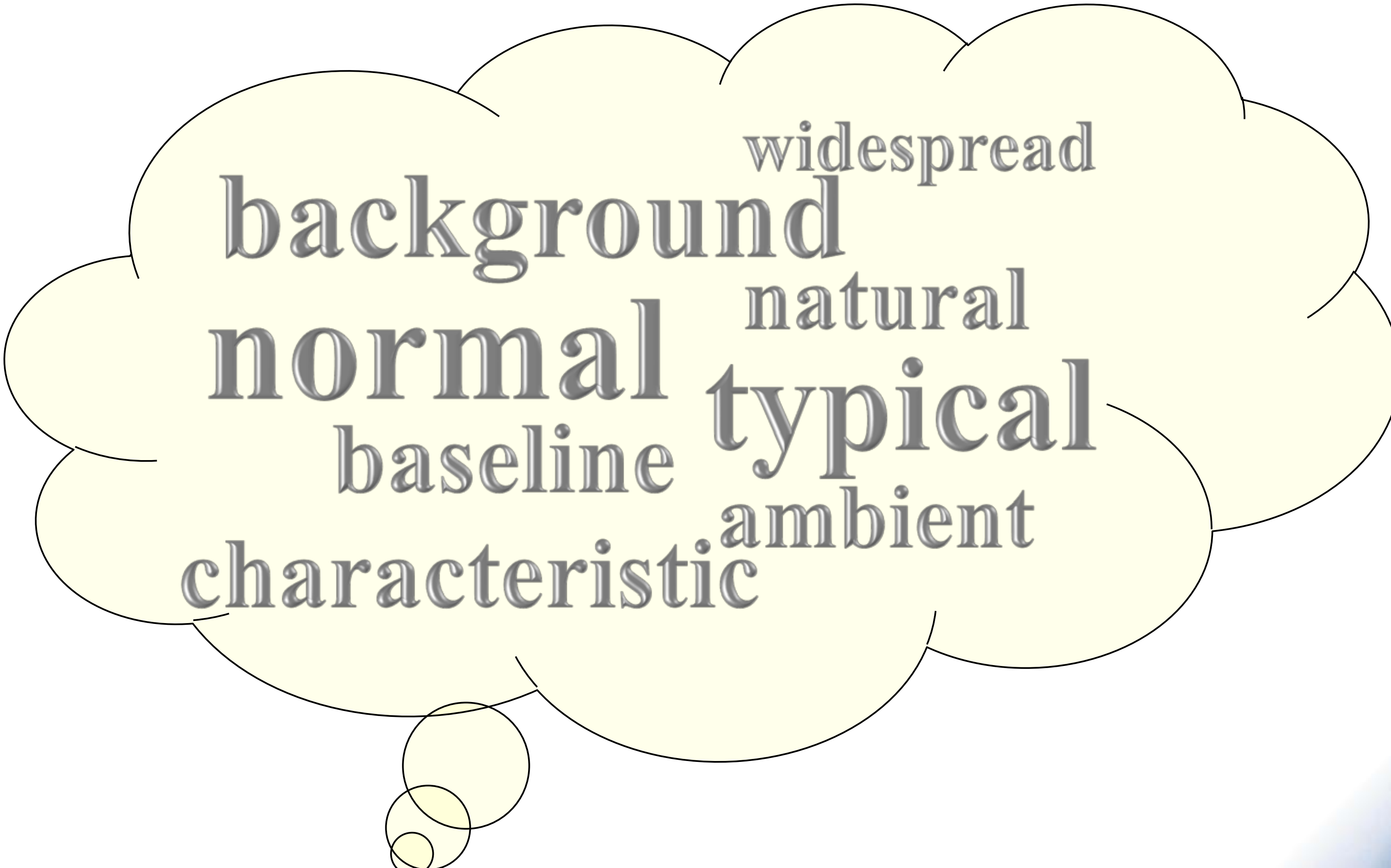
NORMAL BACKGROUND CONCENTRATIONS (NBCs)

Domain	Area (km^2)	Area (%)	NBC (mg/kg)	n
Urban 1	1,200	6	250	342
Mineralisation	1,100	5	67	63
Principal	18,900	89	36	1,270

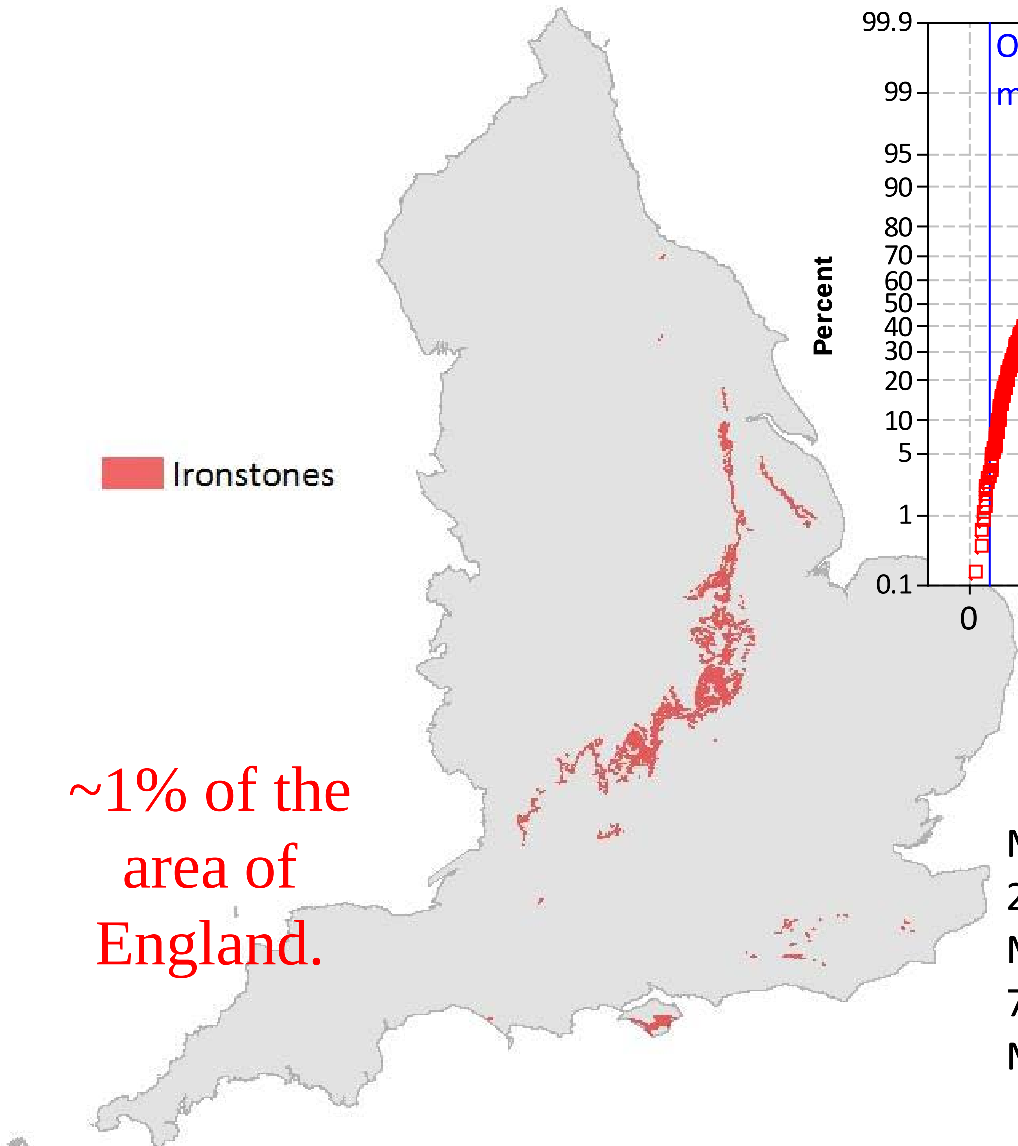
Table 1: NBCs for the arsenic domains (cited to 2 significant figures, n is number of samples used in the calculation). Arsenic is determined by laboratory-based X-ray fluorescence spectrometry (XRFS), *i.e.* total As in soils sampled from a depth 0 – 15 cm. The NBC is the upper 95% confidence limit of the 95th percentile of the domain data.

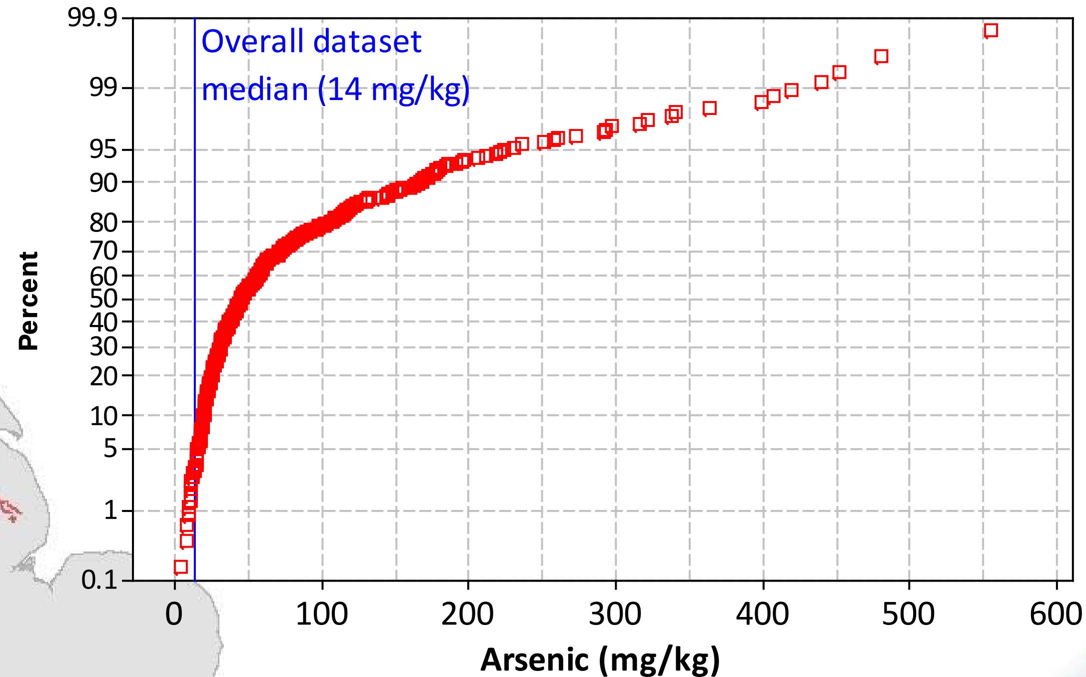
Arsenic
Benzo-[a]-pyrene
Cadmium
Copper
Lead
Mercury
Nickel

WP1 & 2: What are “normal” levels?



Arsenic and ironstone parent material



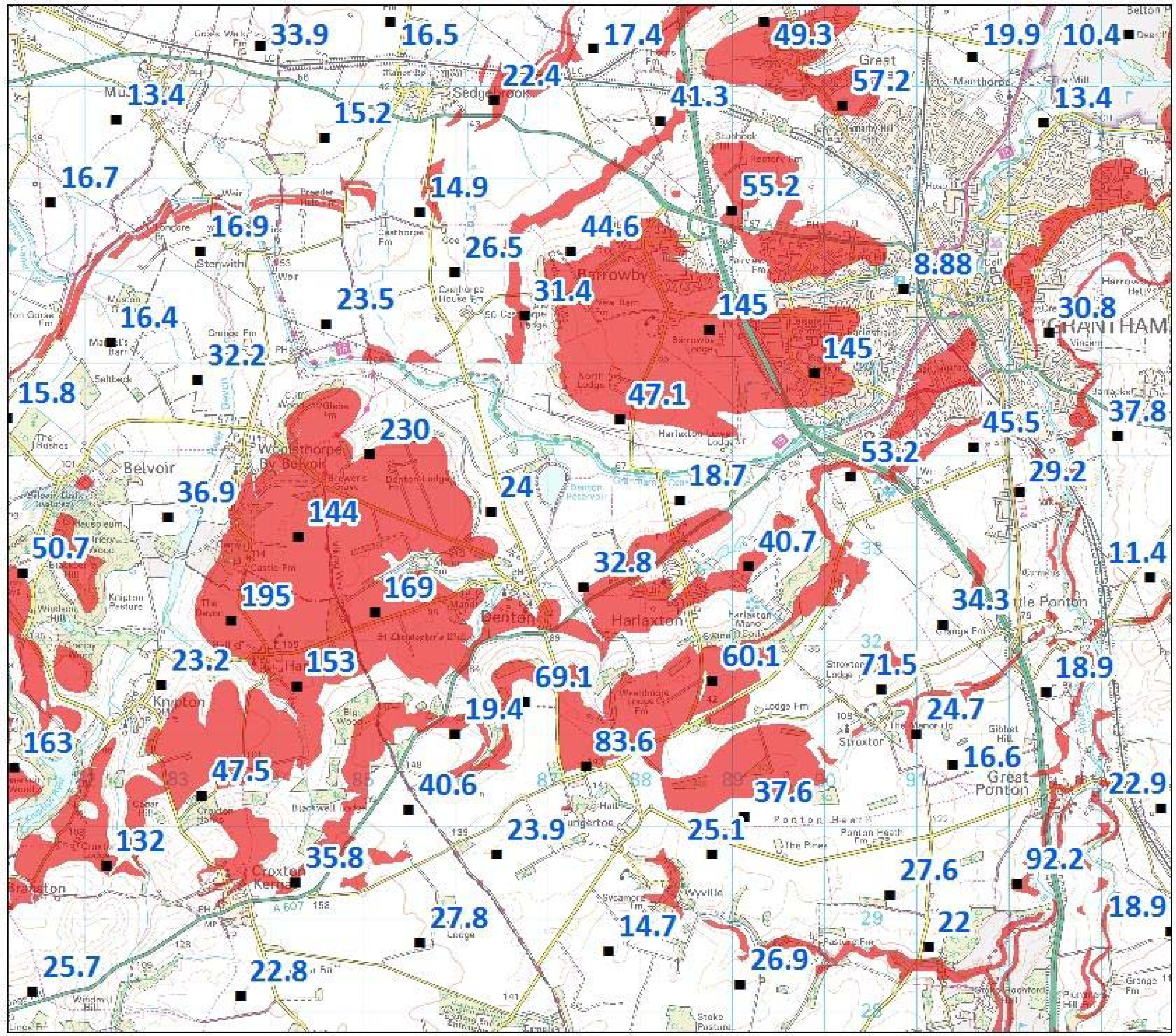


~1% of the area of England.

Minimum	4.05	Mean	72.9
25th percentile	27.8	Skewness	2.8
Median	45.0	Count	437
75th percentile	83.4		
Maximum	555		

Arsenic and ironstone parent material

Example of spatial detail from Grantham area, Lincolnshire and individual sample point arsenic concentration (mg/kg).

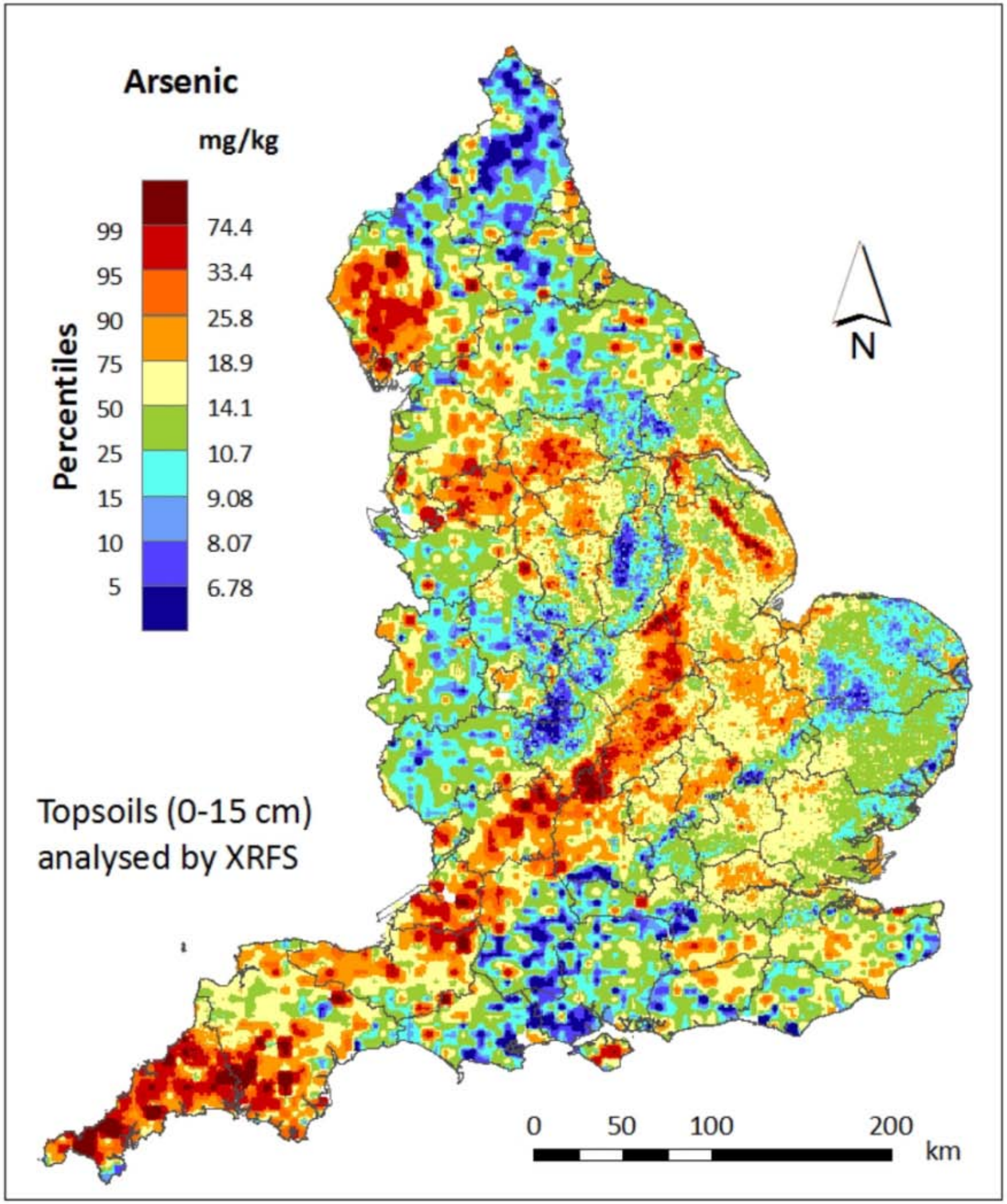


Summary of C4SLs

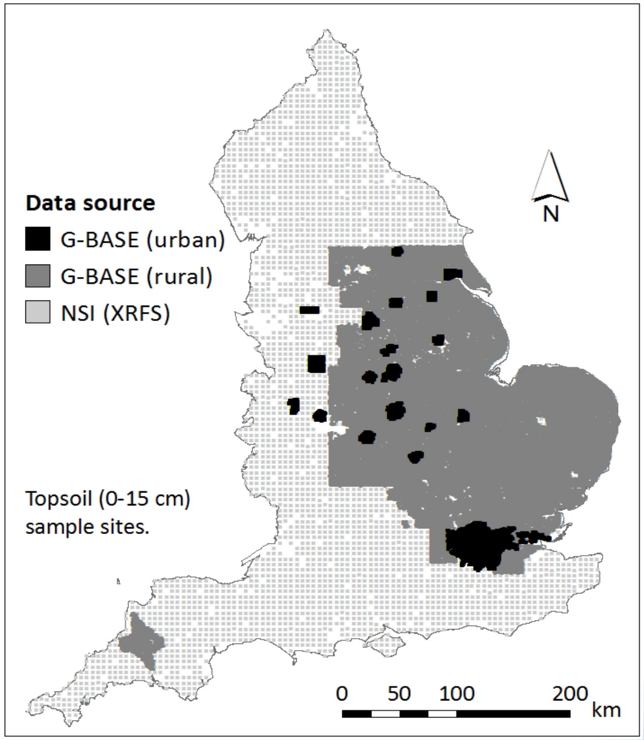
Substance	Arsenic	Benzene	Benzo(a) pyrene	Cadmium	Chromium VI	Lead
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
Residential (with home-grown produce)	37	0.87	5	26	21	200
Residential (without home-grown produce)	40	3.3	5.3	149	21	310
Allotments	49	0.18	5.7	4.9	170	80
Commercial	640	98	76	410	49	2330
Public Open Space 1	79	140	10	220	23	630
Public Open Space 2	168	230	21	880	250	1300

English examples

As
Arsenic



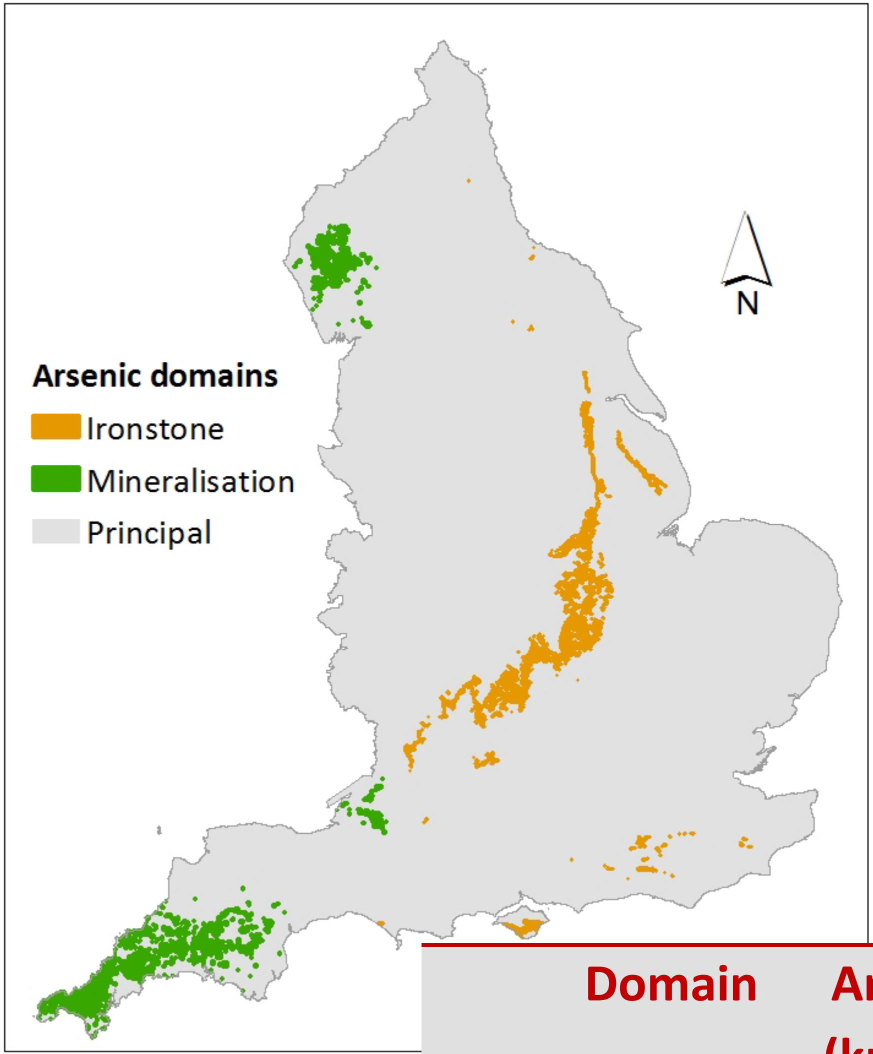
Arsenic
mg/kg
Percentiles
99
95
90
75
50
25
15
10
5
74.4
33.4
25.8
18.9
14.1
10.7
9.08
8.07
6.78
N
Topsoils (0-15 cm)
analysed by XRFS
0
50
100
200
km

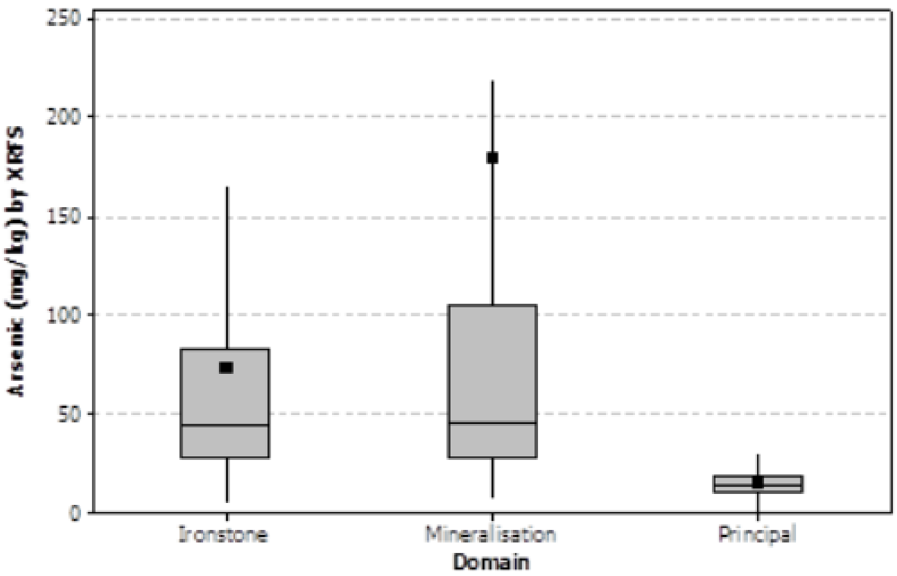


Data source
G-BASE (urban)
G-BASE (rural)
NSI (XRFS)
N
Topsoil (0-15 cm)
sample sites.
0
50
100
200
km

Domain data summary

As
Arsenic



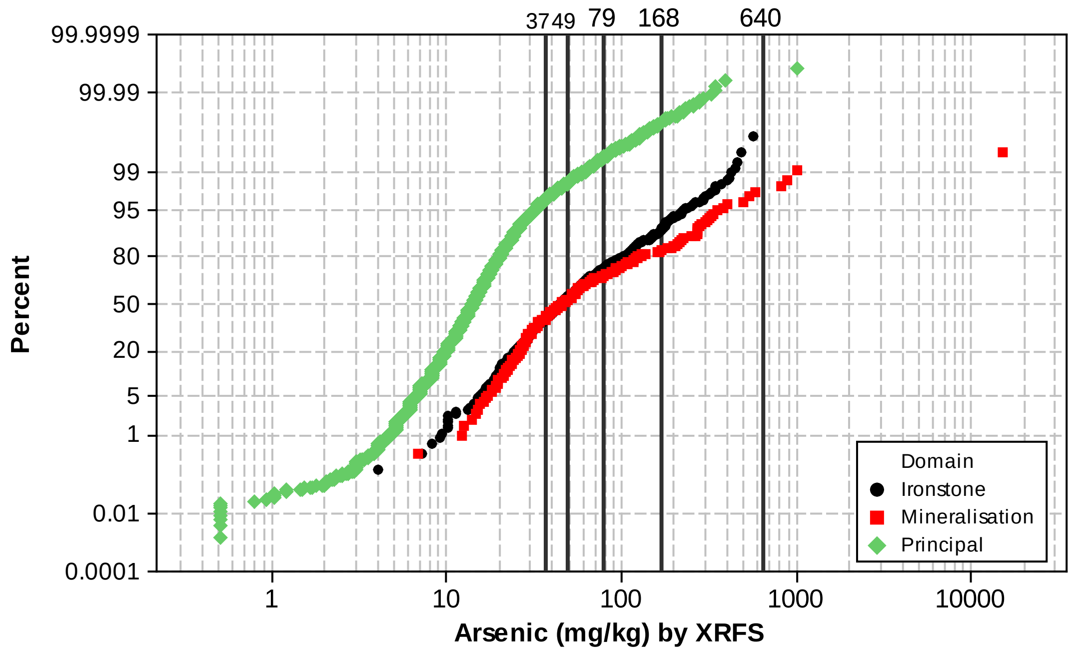


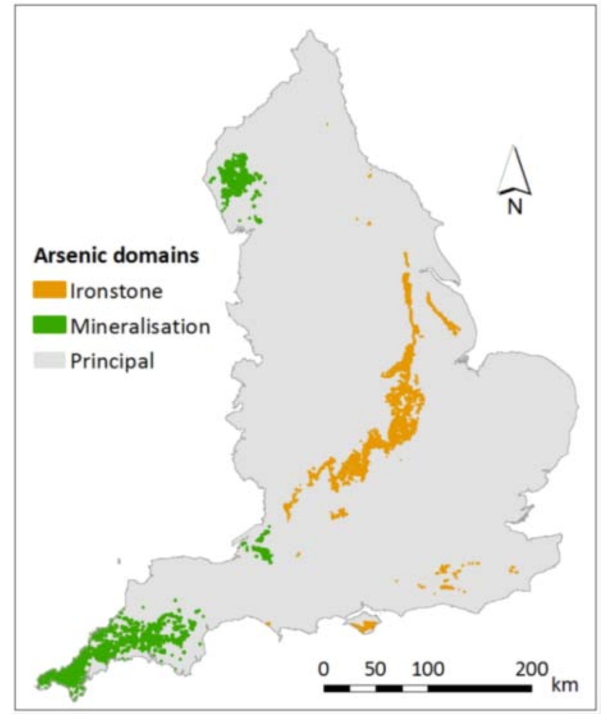
Domain	Area (km^2)	Area (%)	NBC (mg/kg)	n
Ironstone	1,300	1	**220**	437
Mineralisation	2,300	2	**290**	187
Principal	129,300	97	**32**	41,509

NBC and C4SL comparison

As
Arsenic

Arsenic in English soil: all data used in NBC calculations

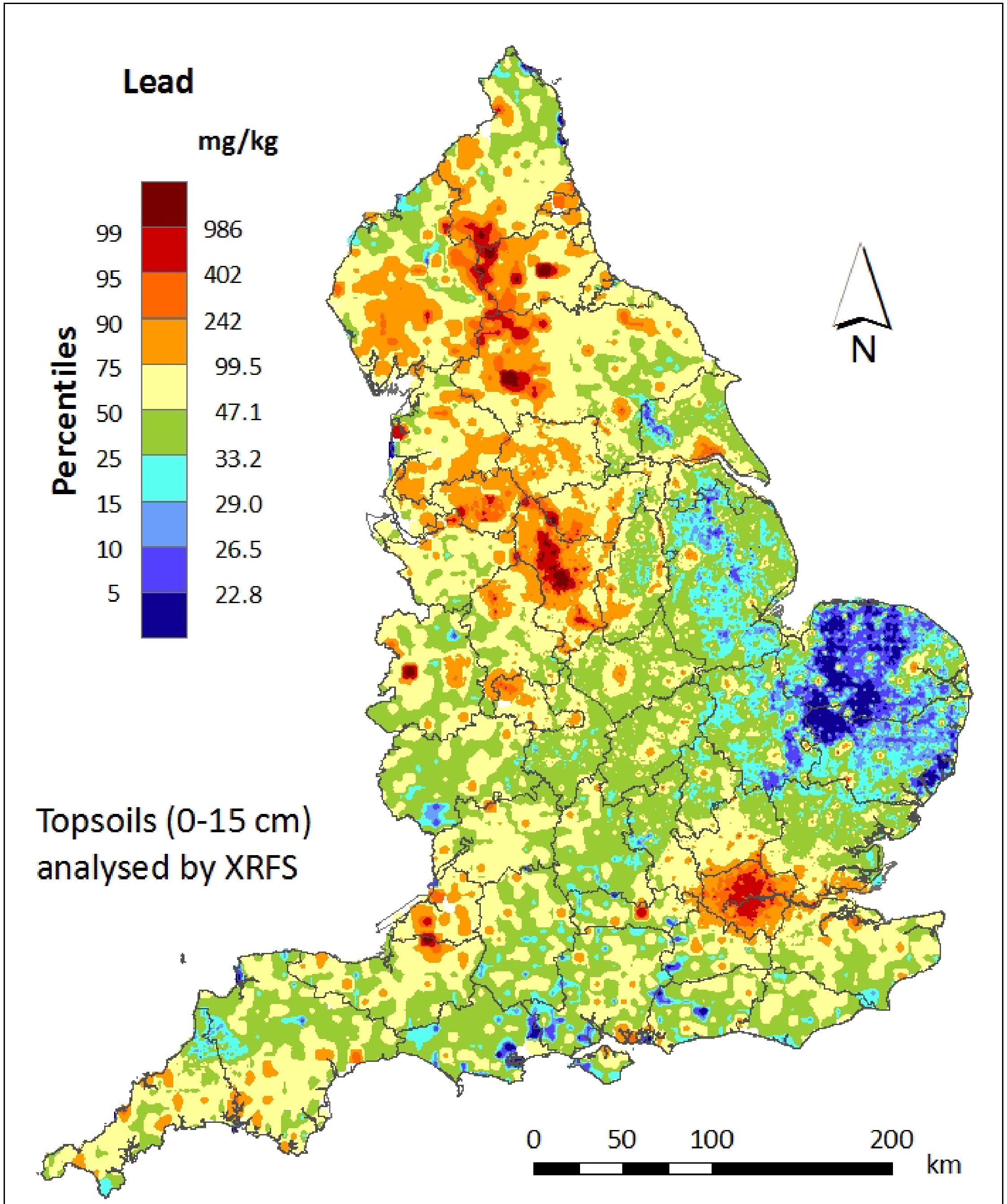


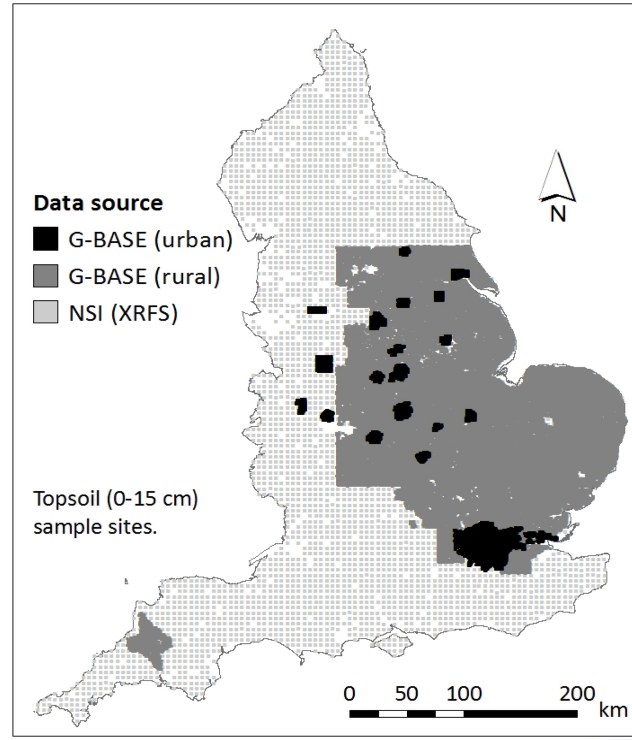


Comparison with range of C4SL values

Due to their similar data distribution, approximately 50% of the Ironstone and Mineralisation domain samples exceed 49 mg/kg.

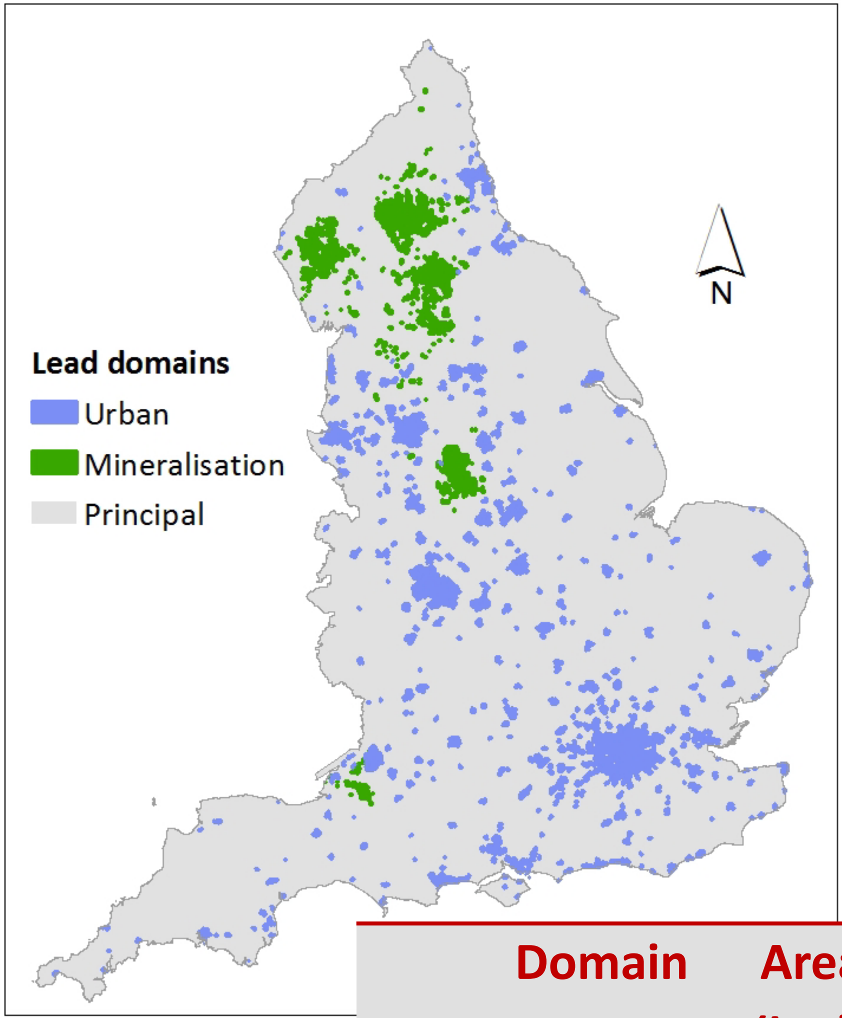
Pb
Lead

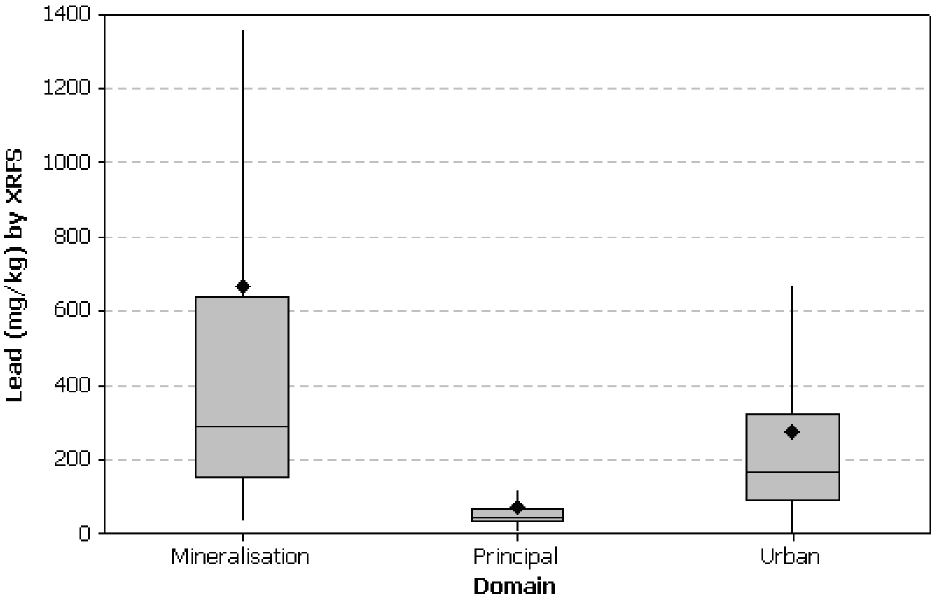

Lead
mg/kg
Percentiles
99
95
90
75
50
25
15
10
5
986
402
242
99.5
47.1
33.2
29.0
26.5
22.8
N
Topsoils (0-15 cm)
analysed by XRFS
0
50
100
200
km


Data source
G-BASE (urban)
G-BASE (rural)
NSI (XRFS)
Topsoil (0-15 cm)
sample sites.
N
0
50
100
200
km

Domain data summary

Pb
Lead

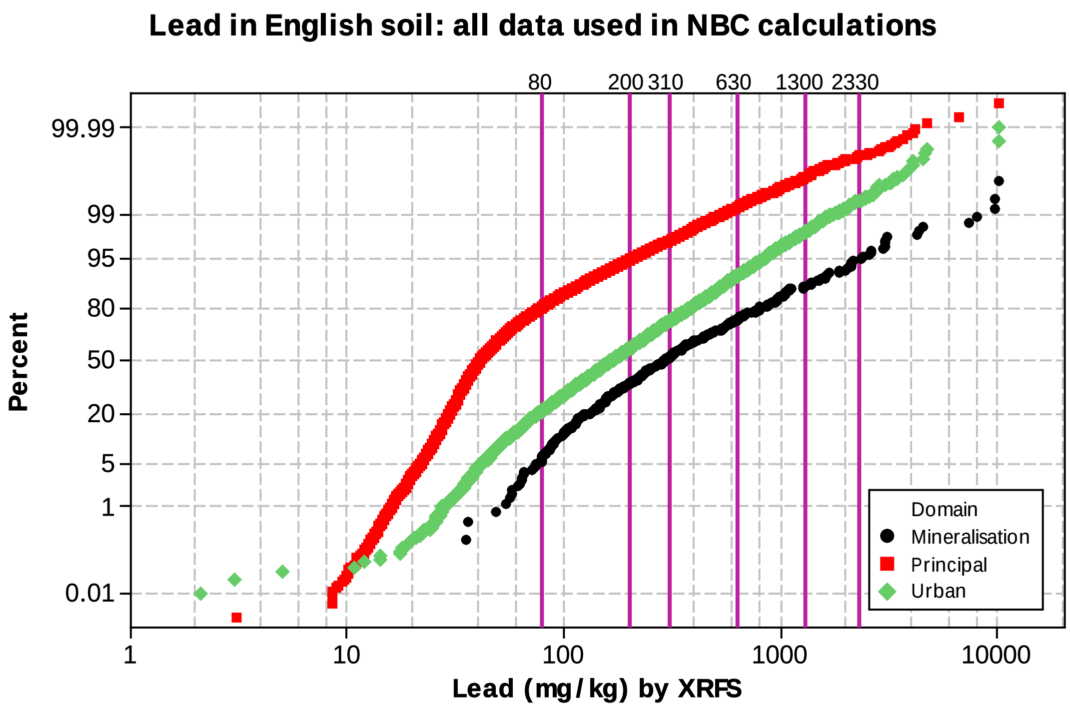


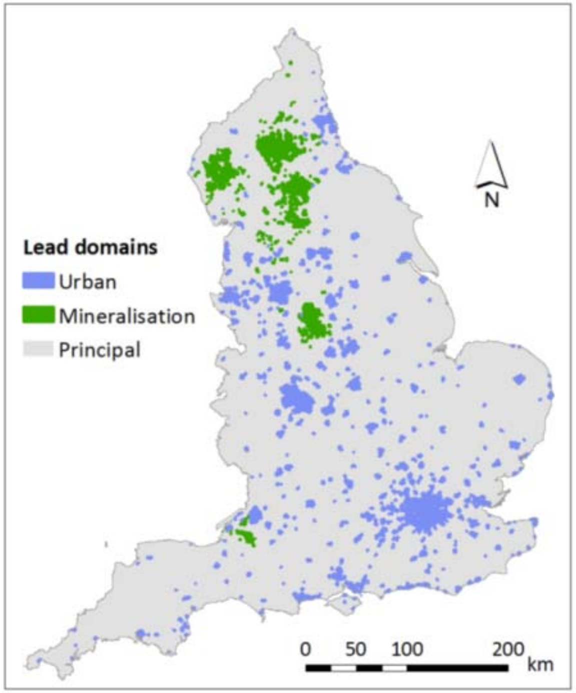


Domain	Area (km²)	Area (%)	NBC (mg/kg)	n
Urban	5,400	4	**820**	7,529
Mineralisation	2,900	2	**2,400**	347
Principal	124,600	94	**180**	34,257

NBC and C4SL comparison

Pb
Lead



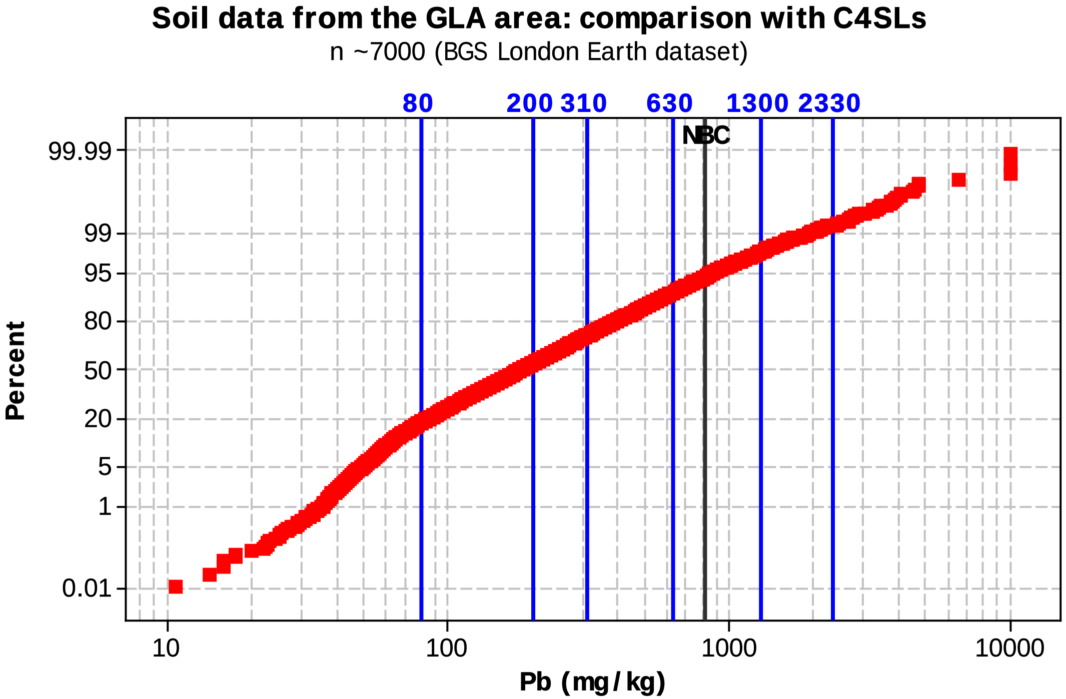


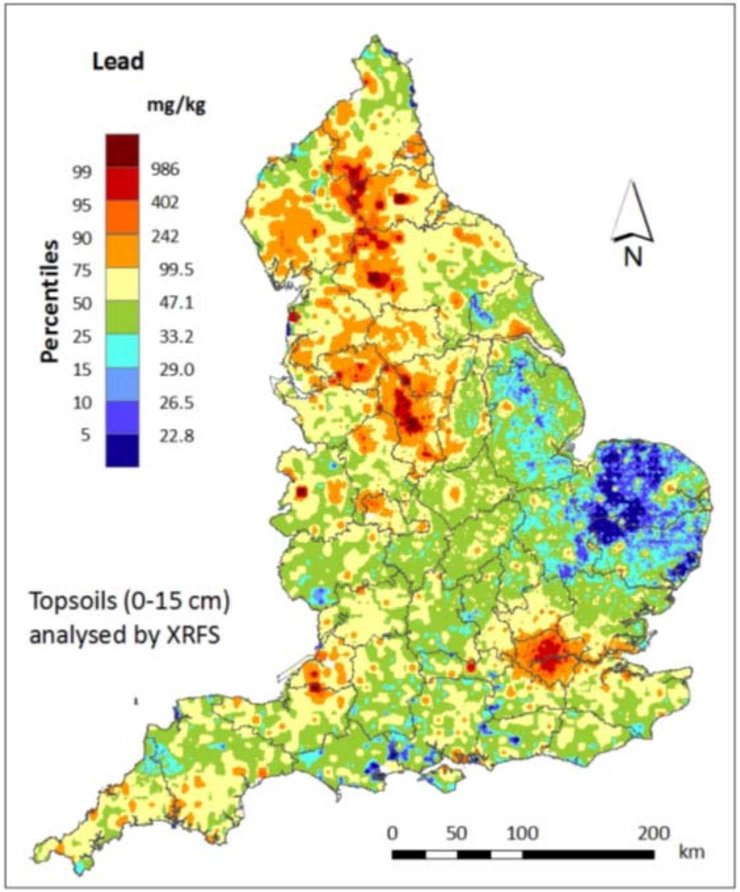
Comparison with range of C4SL values

Approximately 80% of the samples from the Principal domain are below 80 mg/kg.

NBC and C4SL comparison

Pb
Lead

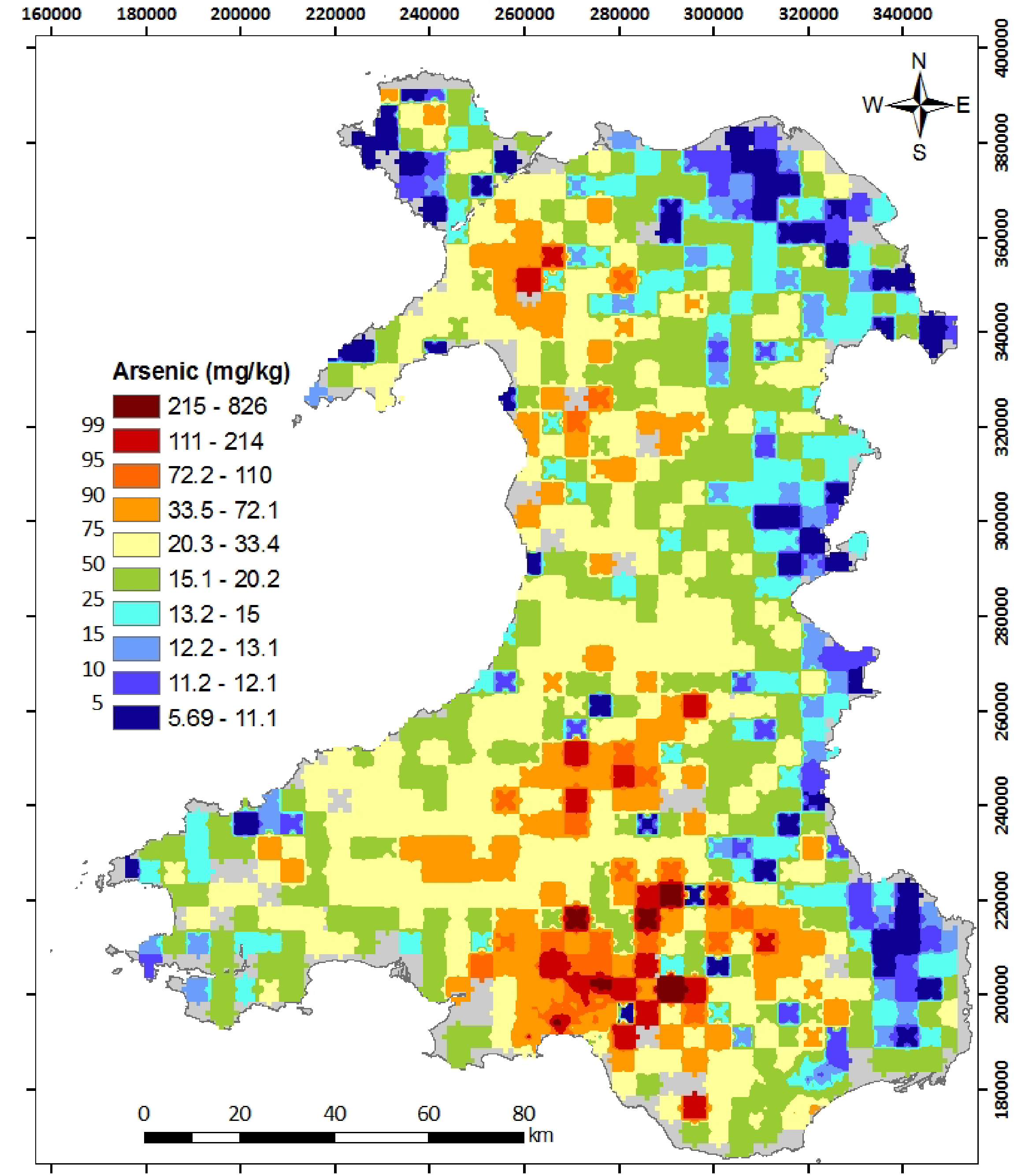




Comparison with range of C4SL values

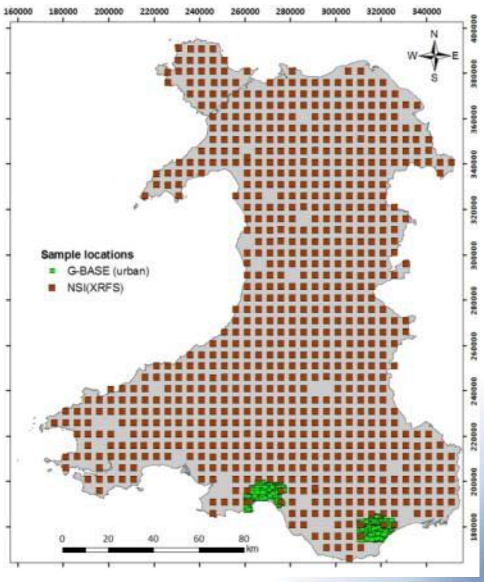
Here using only data from within the Greater London Authority (GLA) area. All data used here was included in the NBC domain calculations.

Welsh examples

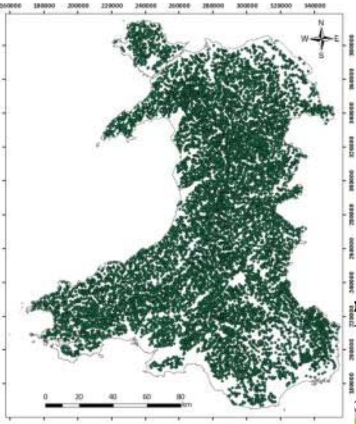


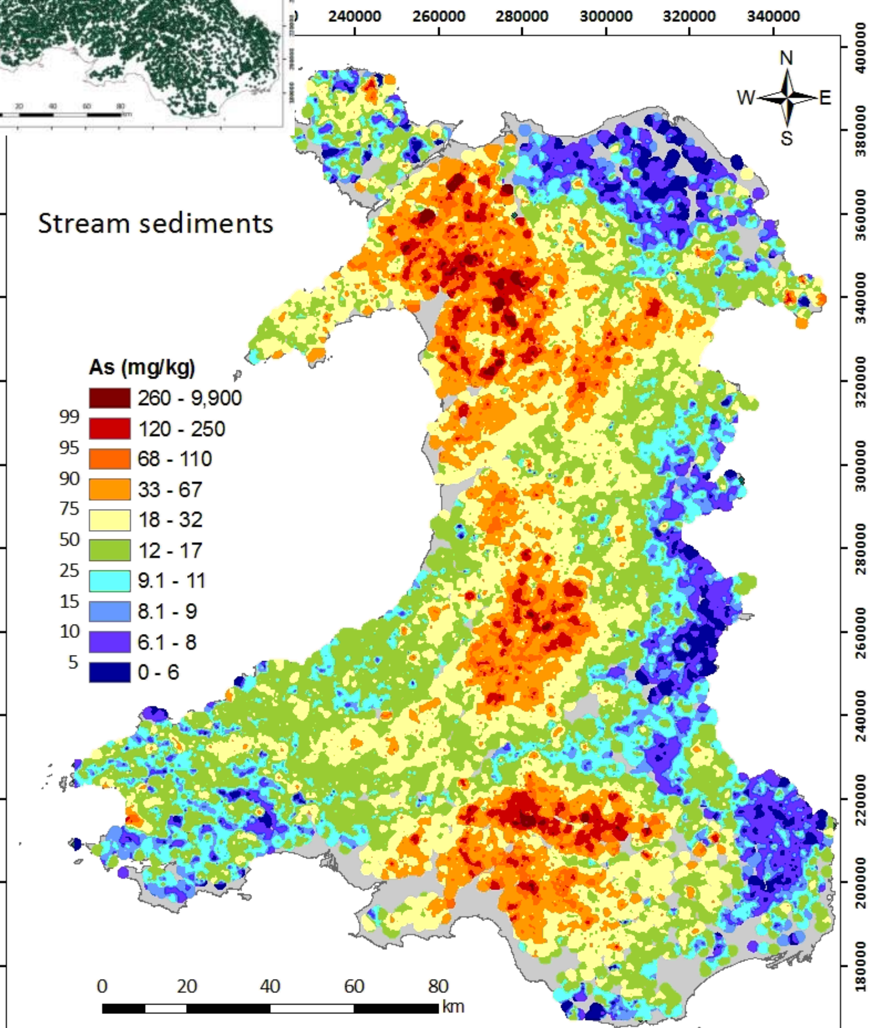
As Arsenic

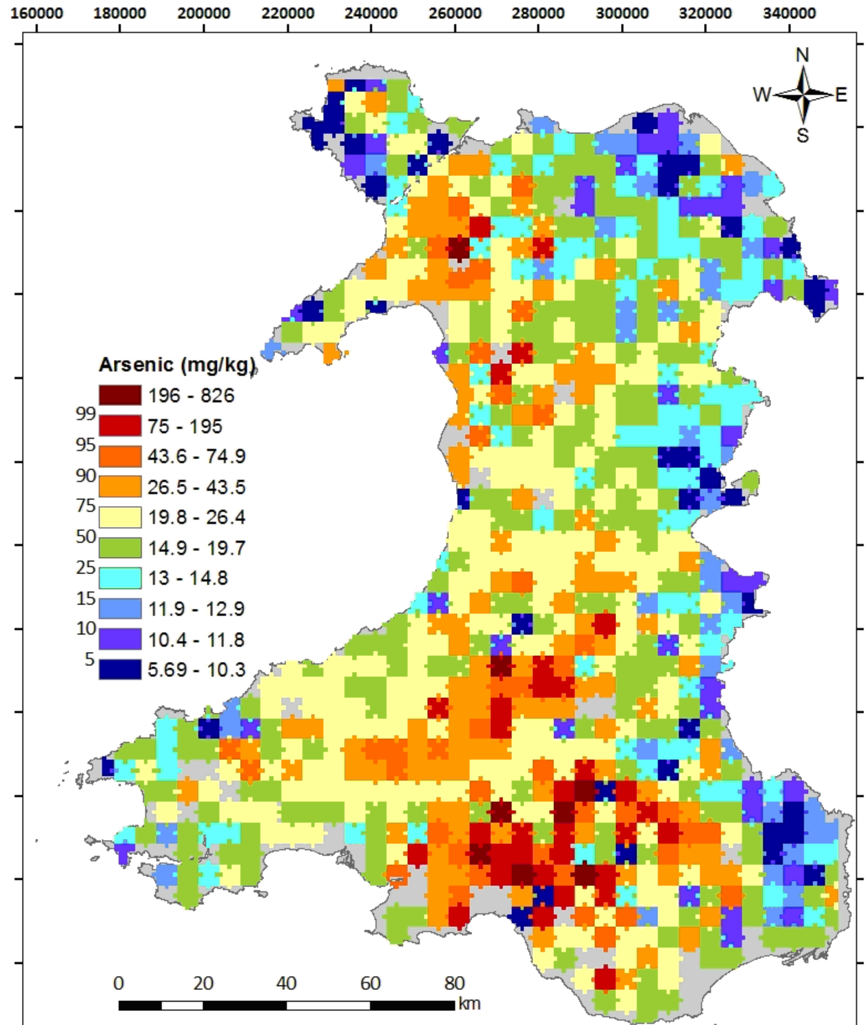
Location	Samples
Total	1675
NSI(XRFS)	798
G-BASE urban	877
Cardiff	*507*
Swansea	*370*



As
Arsenic

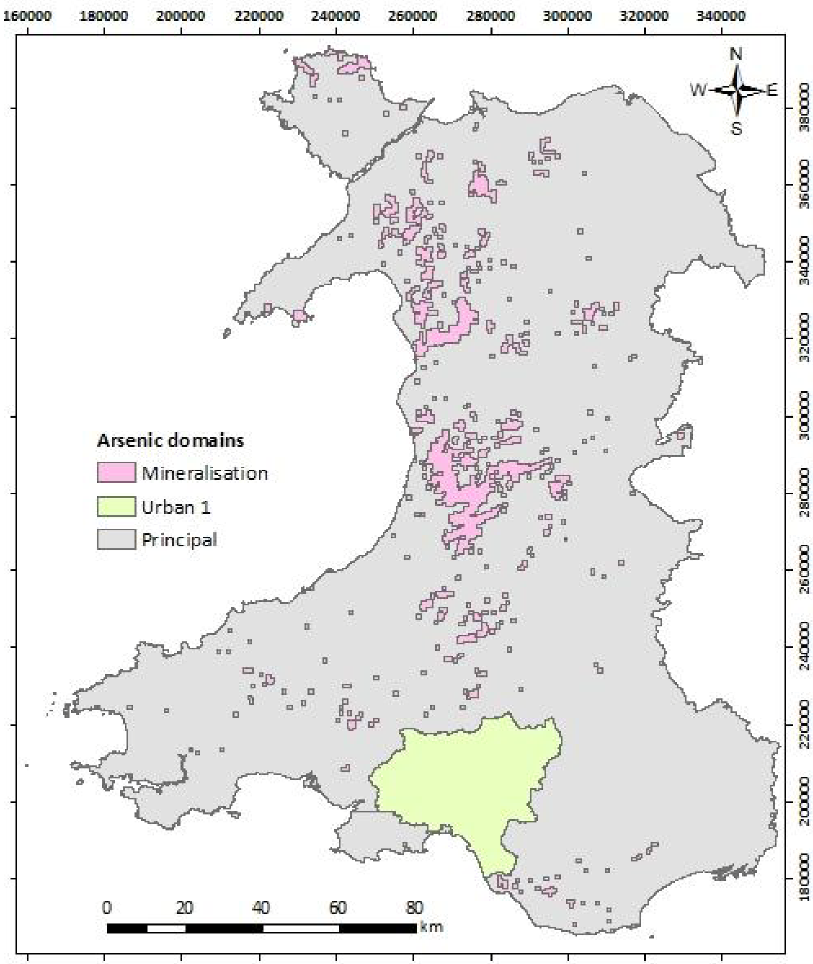


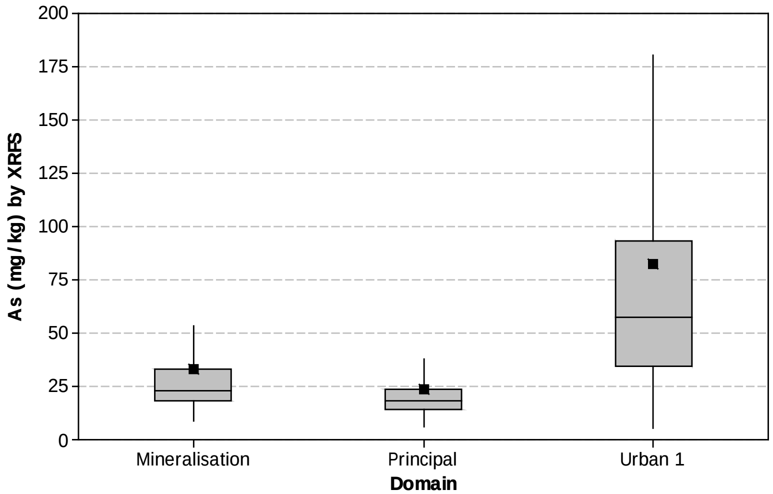

Stream sediments
As (mg/kg)
260 - 9,900
120 - 250
68 - 110
33 - 67
18 - 32
12 - 17
9.1 - 11
8.1 - 9
6.1 - 8
0 - 6
99
95
90
75
50
25
15
10
5
N
W
E
S
0
20
40
60
80
km


Arsenic (mg/kg)
196 - 826
75 - 195
43.6 - 74.9
26.5 - 43.5
19.8 - 26.4
14.9 - 19.7
13 - 14.8
11.9 - 12.9
10.4 - 11.8
5.69 - 10.3
99
95
90
75
50
25
15
10
5
N
W
E
S
0
20
40
60
80
km

Domain data summary

As
Arsenic





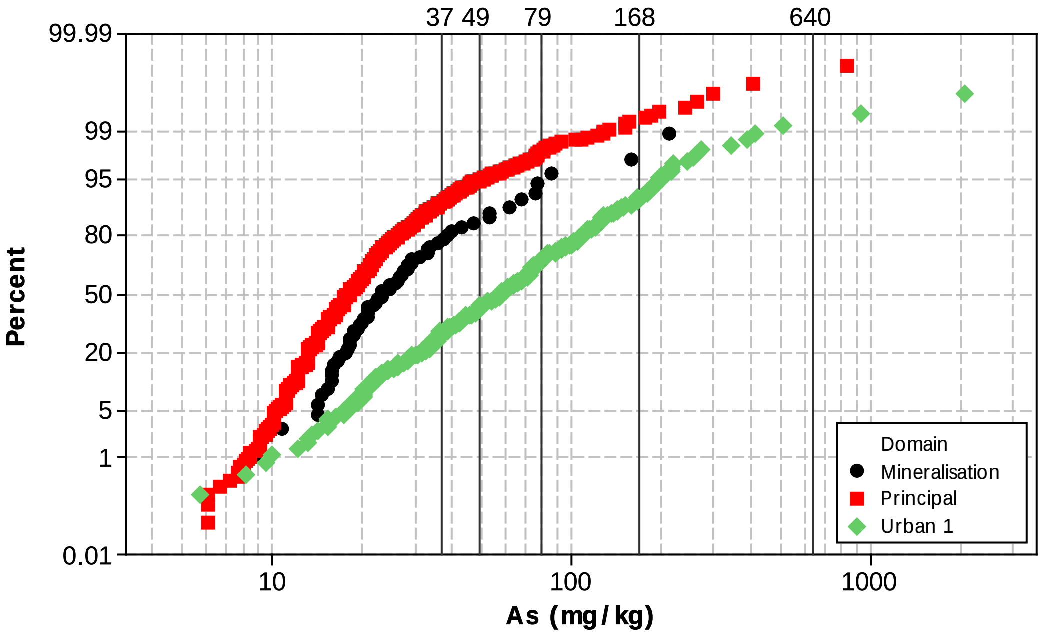
Area name	Number	Mean	Minimum	25th percentile	Median	75th percentile	Maximum	Skewness
Mineralisation	63	33.4	8.72	18.0	23.2	33.4	210	4
Urban 1	342	82.7	5.69	34.5	57.4	93.2	2062	11
Principal	1270	23.8	6.06	14.1	18.1	23.6	826	15

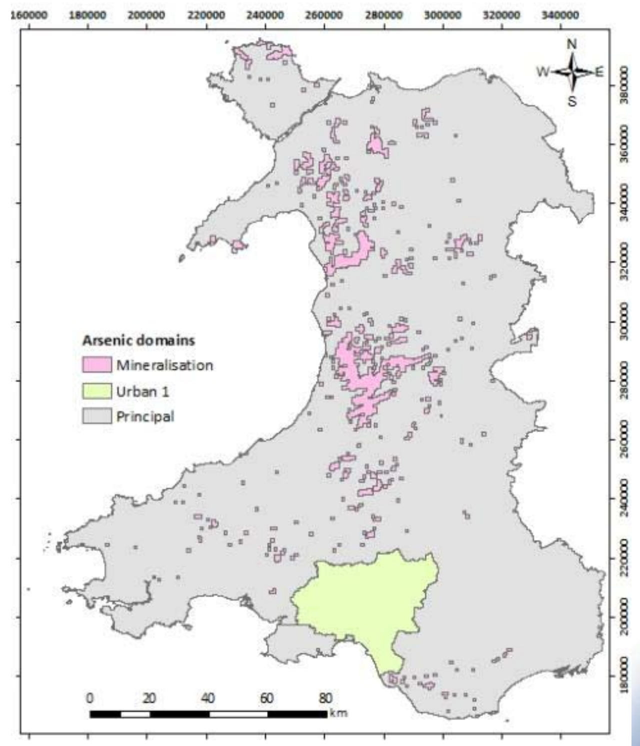
Summary statistics for the As (mg/kg) domain data

NBC and C4SL comparison

As
Arsenic

Arsenic in Welsh soil: all data used in NBC calculations





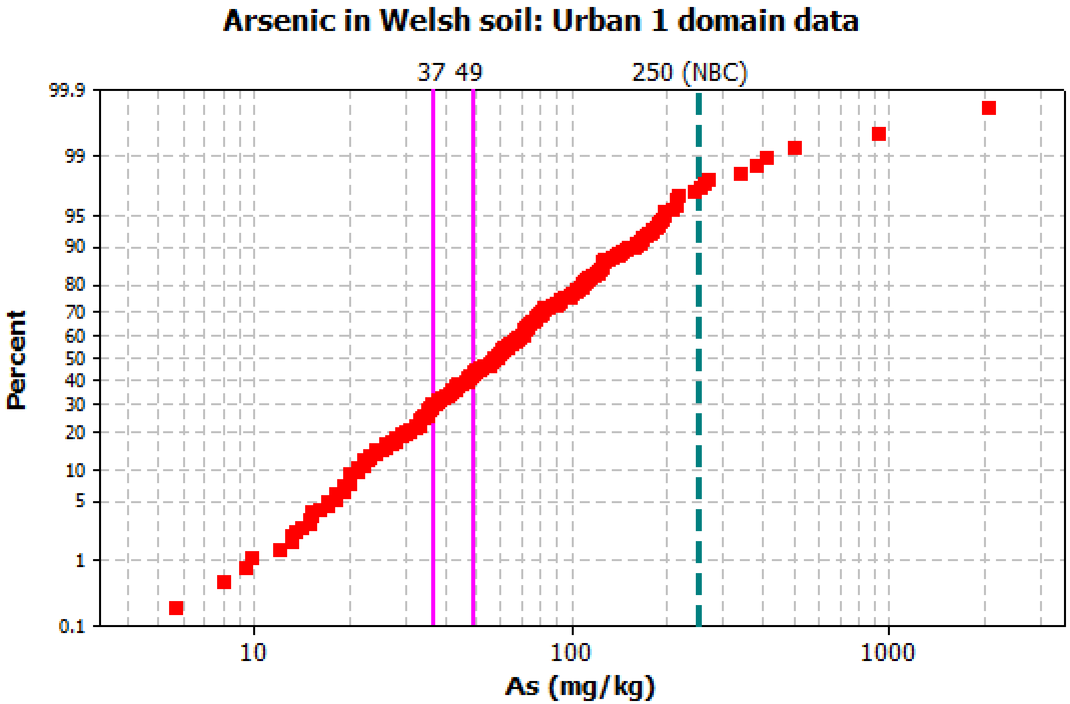
Comparison with range of C4SL values

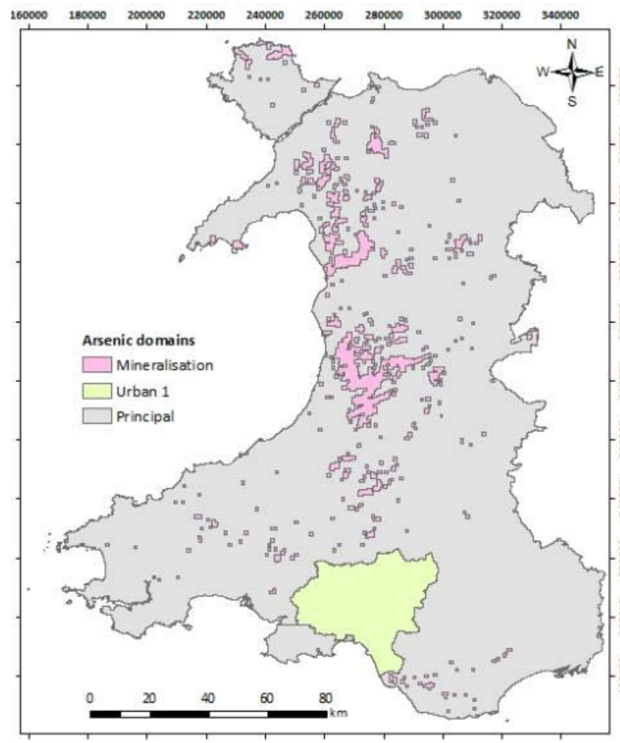
Can see that it is the Urban 1 domain which most frequently exceeds the lower C4SL values.

NBC and C4SL comparison

As

Arsenic

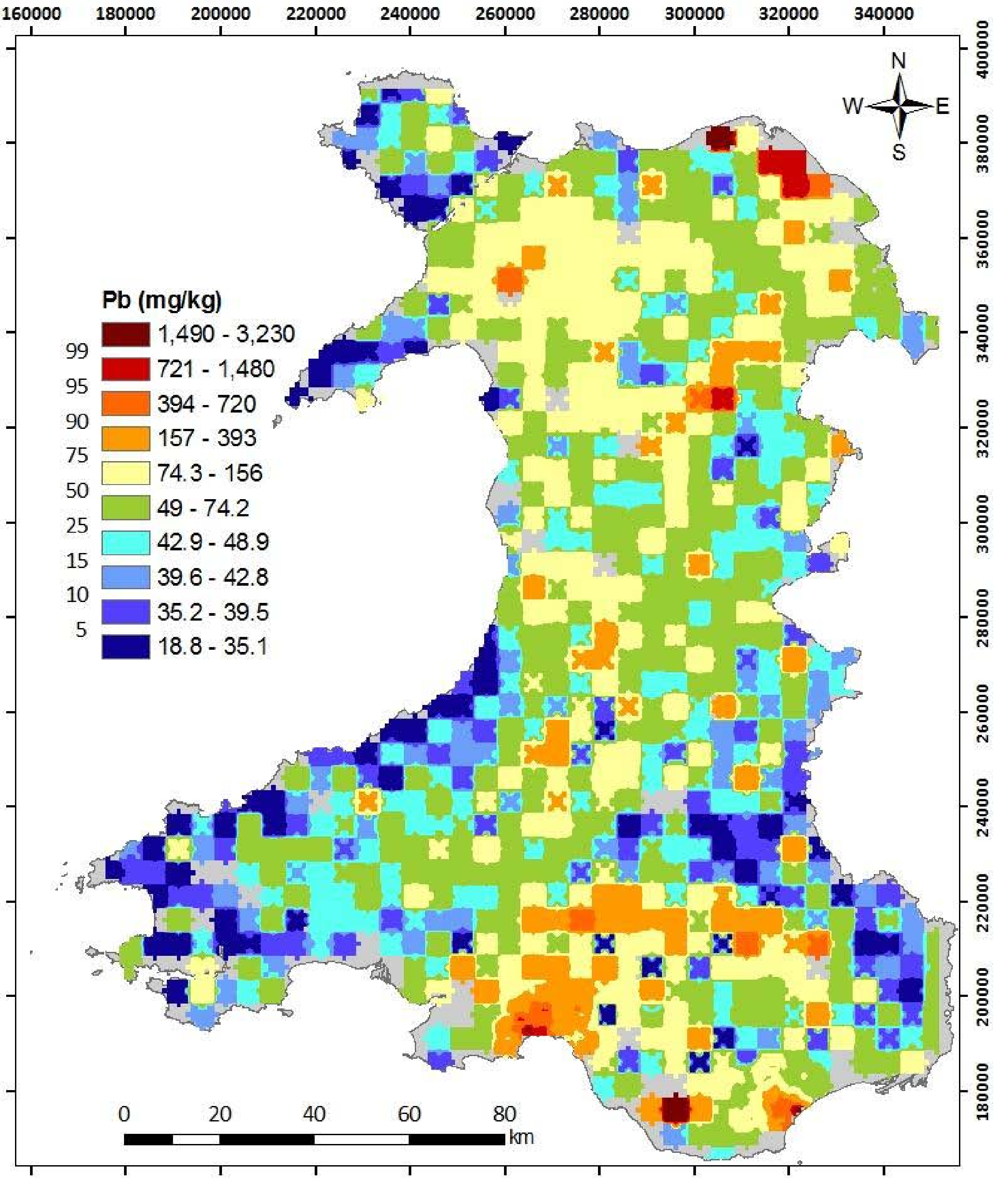




Comparison with residential with home grown produce C4SL

In the Urban 1 domain 241 of 342 samples (70%) have an arsenic concentration ≥ 37 mg/kg.

Pb
Lead



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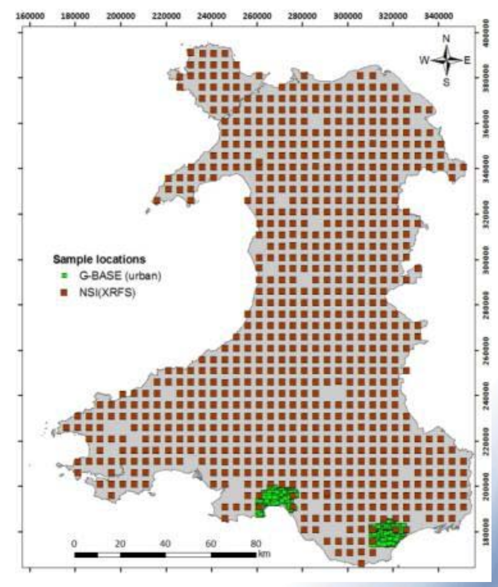
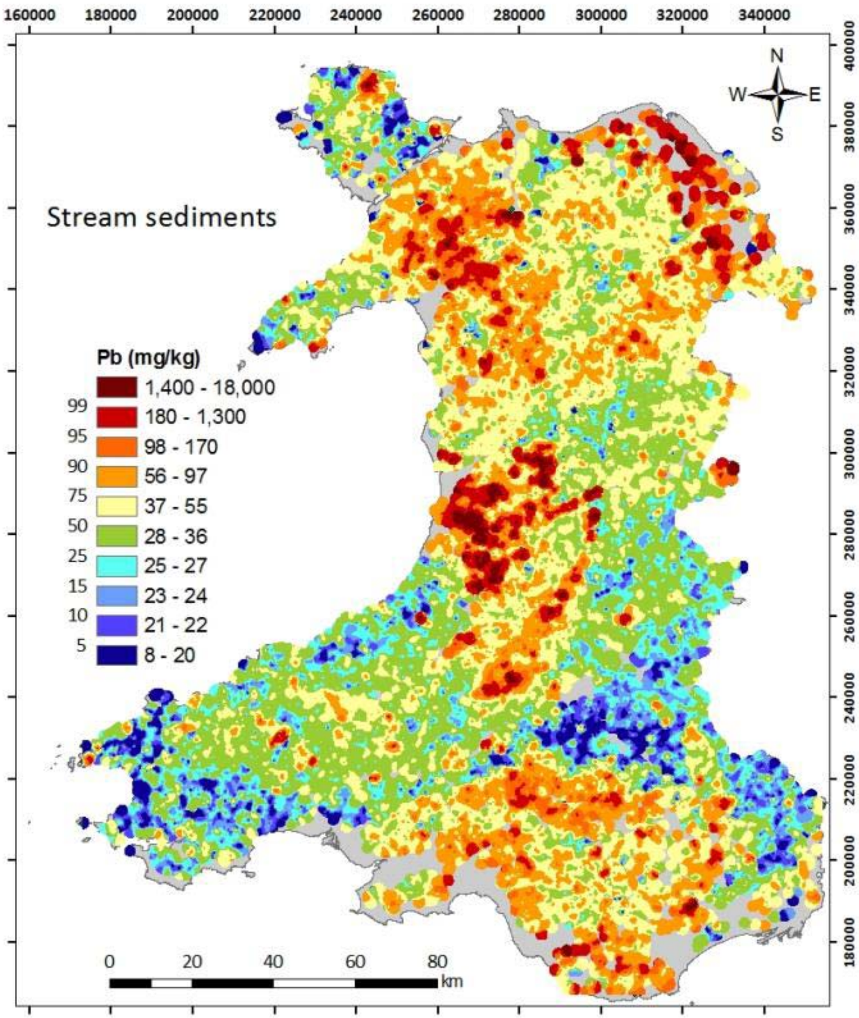
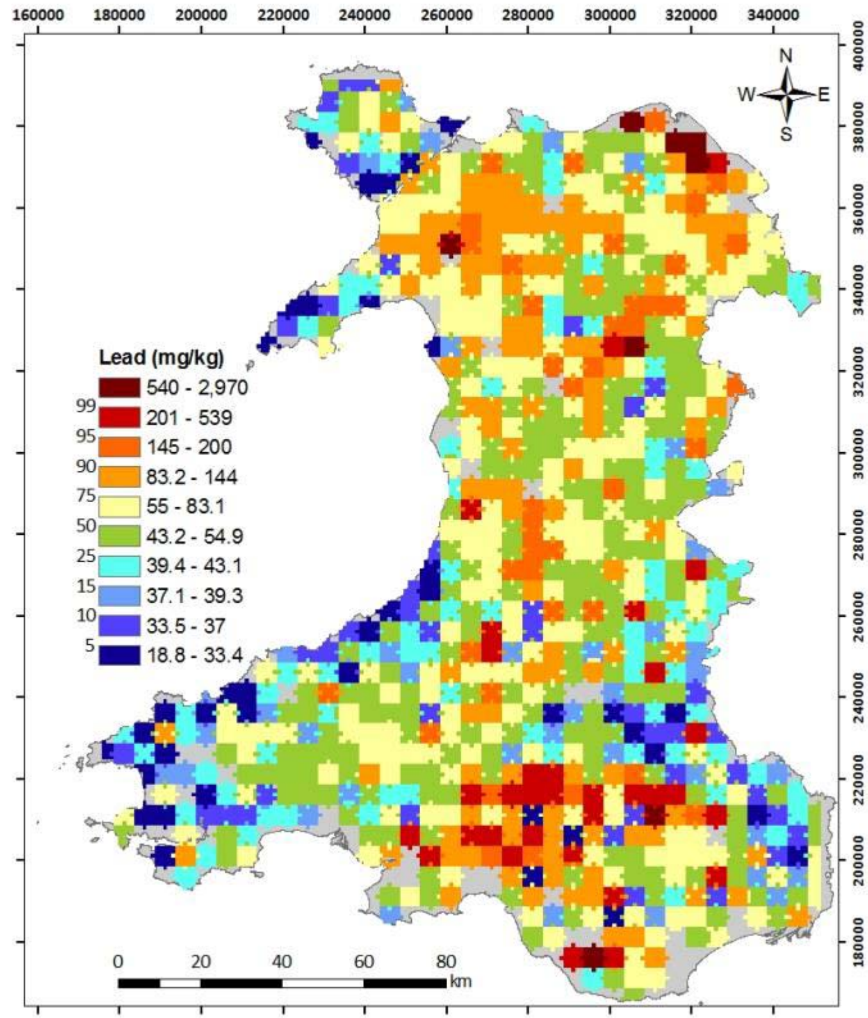


Pb
Lead

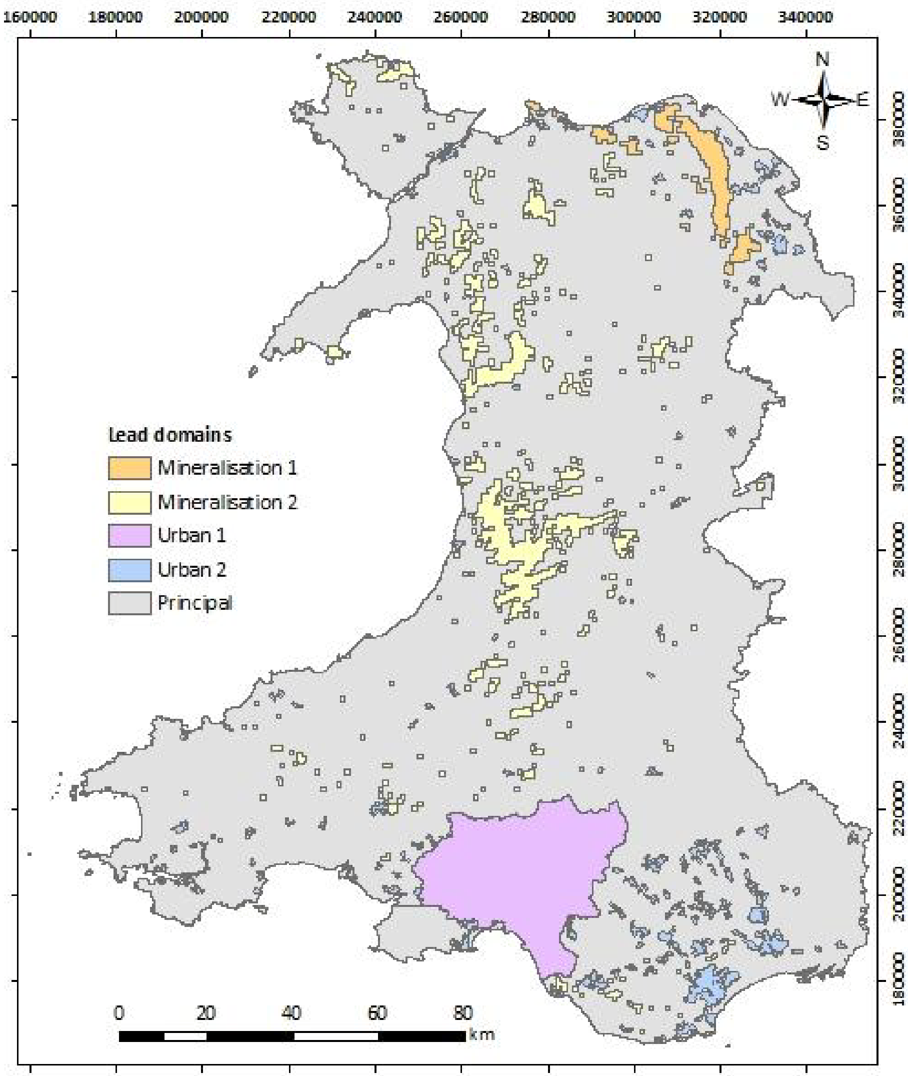


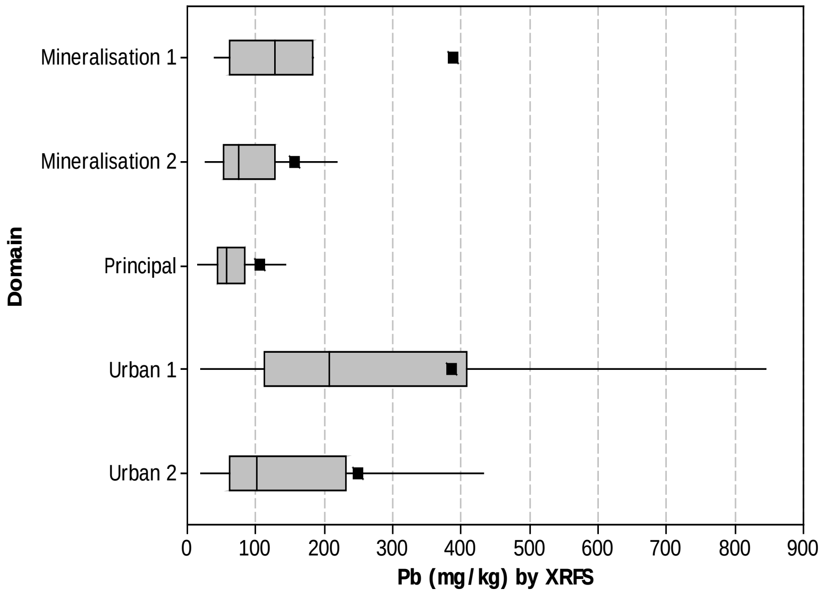
Stream sediments
Pb (mg/kg)
1,400 - 18,000
180 - 1,300
98 - 170
56 - 97
37 - 55
28 - 36
25 - 27
23 - 24
21 - 22
8 - 20
99
95
90
75
50
25
15
10
5
N
W
E
S
0
20
40
60
80
km
160000
180000
200000
220000
240000
260000
280000
300000
320000
340000
400000
380000
360000
340000
320000
300000
280000
260000
240000
220000
200000
180000



Lead (mg/kg)
540 - 2,970
201 - 539
145 - 200
83.2 - 144
55 - 83.1
43.2 - 54.9
39.4 - 43.1
37.1 - 39.3
33.5 - 37
18.8 - 33.4
99
95
90
75
50
25
15
10
5
N
W
E
S
0
20
40
60
80
km
160000
180000
200000
220000
240000
260000
280000
300000
320000
340000
400000
380000
360000
340000
320000
300000
280000
260000
240000
220000
200000
180000

Pb
Lead

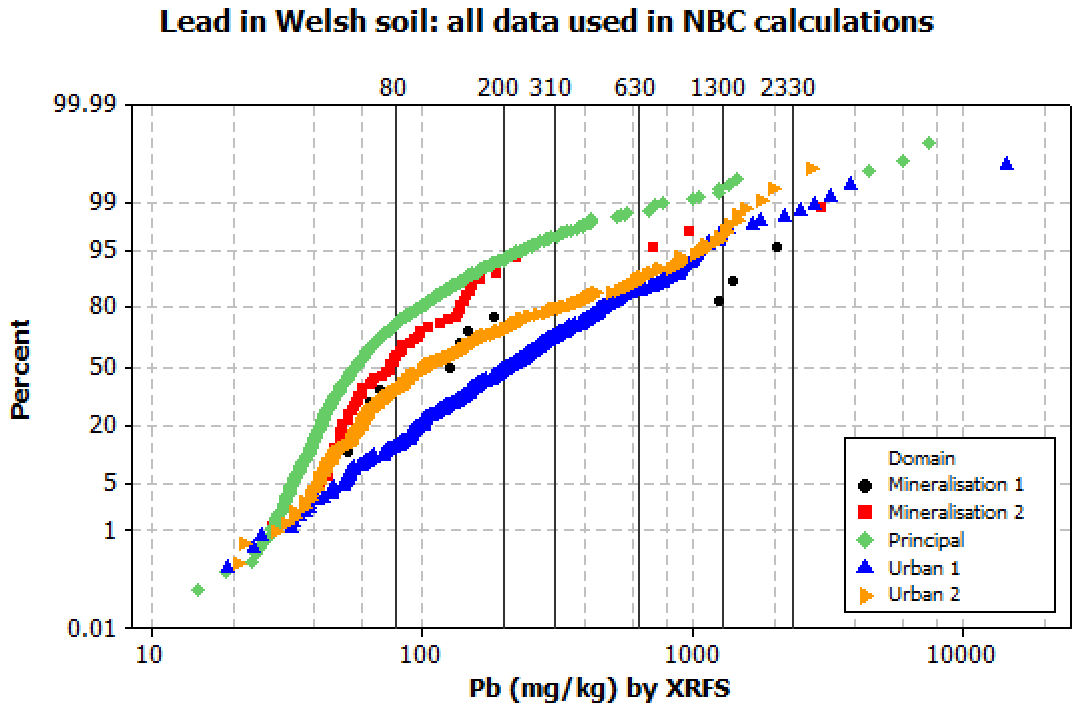


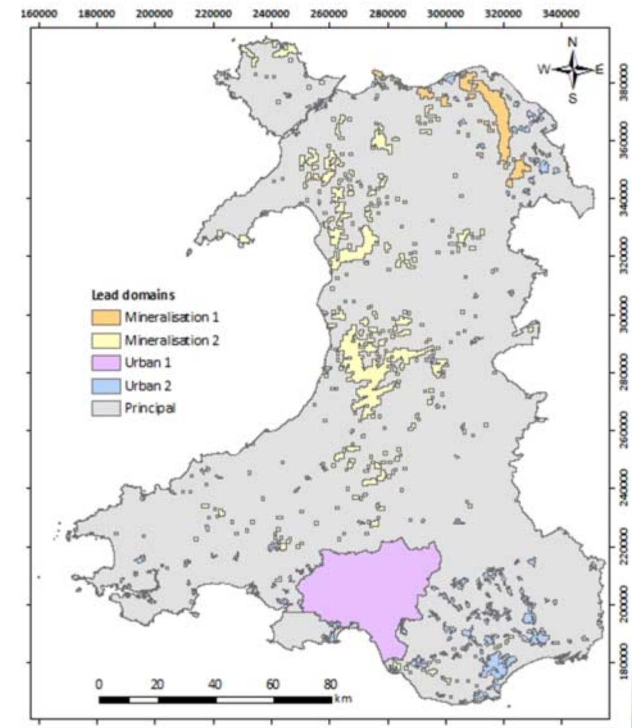


Contaminant	Domain	NBC (mg/kg)	Samples (n)	Area (km^2)	Area (%)
Lead	Principal	**230**	966	18200	86
	Mineralisation 1	*n.d.**	15	200	1
	Mineralisation 2	**280**	61	1100	5
	Urban 1	**1300**	342	1200	6
	Urban 2	**890**	291	500	2

NBC and C4SL comparison

Pb
Lead

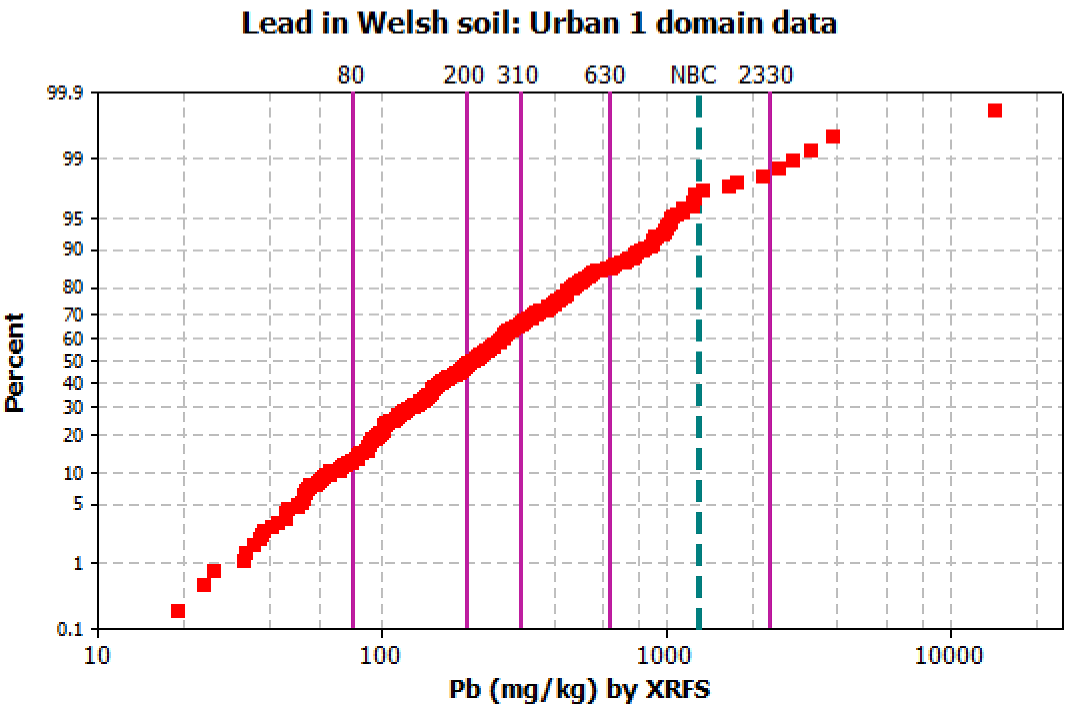


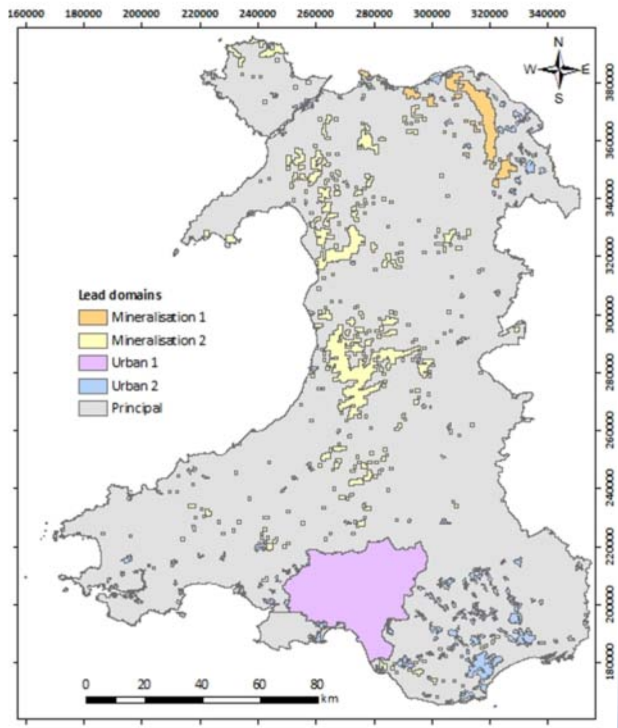


Comparison with range of C4SL values
Can see that it is the Urban 1 domain which most frequently exceeds the lower C4SL values, especially allotments (80 mg/kg).

NBC and C4SL comparison

Pb
Lead

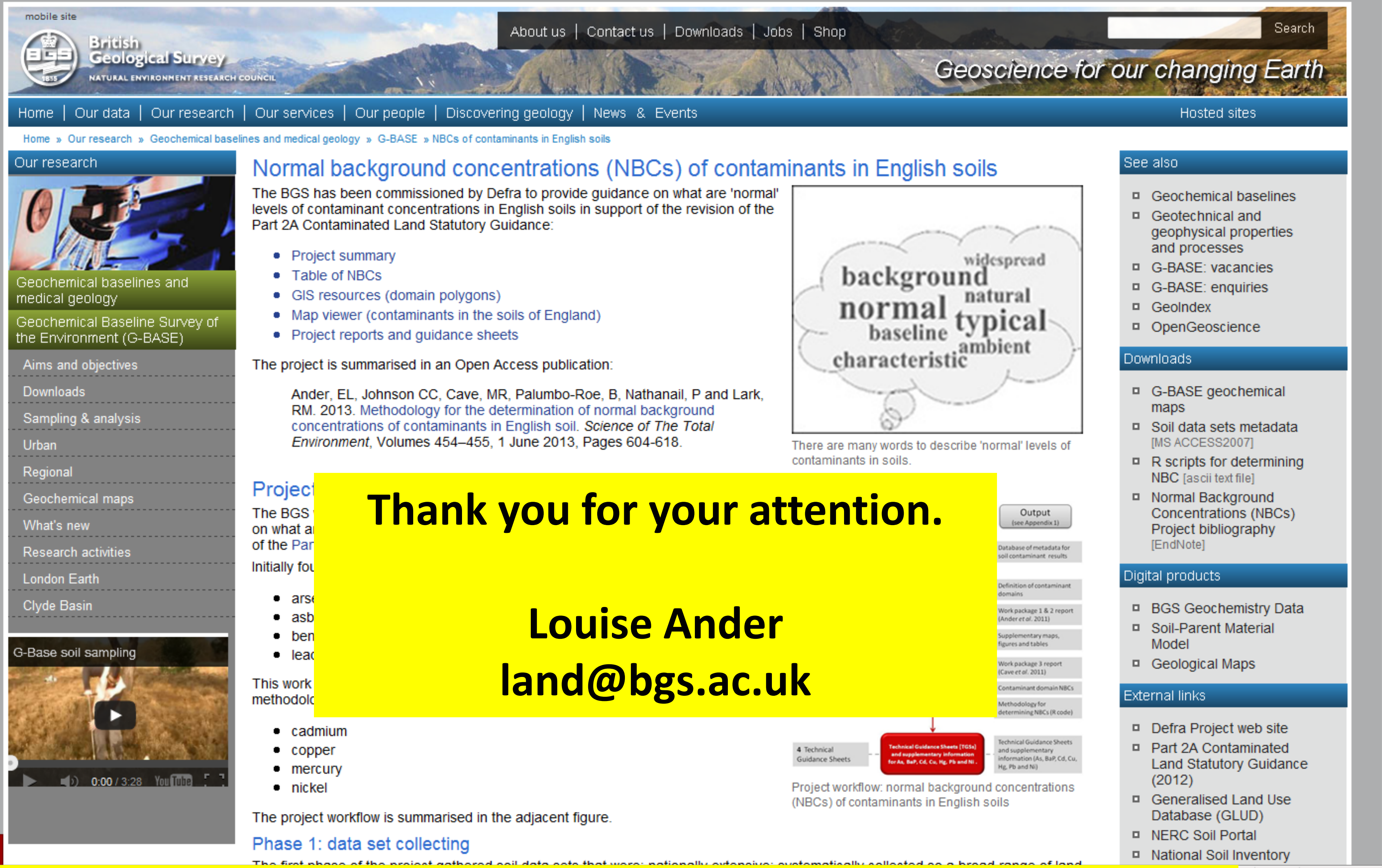




Comparison with lower C4SL values
In the Urban 1 only 43 of 342 (13%) have a soil lead concentration <80 mg/kg, and 33% are >310 mg/kg (residential).

NBCs for Welsh soils

Contaminant	Domain	NBC (mg/kg)	Samples (n)	Area (km^2)	Area (%)
Arsenic	Principal	**36**	1270	18900	89
	Mineralisation	**67**	63	1100	5
	Urban 1	**250**	342	1200	6
BaP#	Principal	**0.5**	71	20600	97
	Urban	**3.6**	32	600	3
Cadmium	Principal	**1.4**	681	18700	88
	Mineralisation 1	*n.d.**	15	200	1
	Mineralisation 2	**2.2**	57	1100	5
	Urban 1	**6.2**	45	1200	6
Copper	Principal	**43**	966	18400	87
	Mineralisation	**96**	76	1100	5
	Urban 1	**550**	342	1200	6
	Urban 2	**170**	291	500	2
Mercury	Principal	**0.25**	104	20600	97
	Urban	*n.d.**	7	600	3
Nickel	Principal	**40**	1327	19800	94
	Basic	*n.d.**	6	200	<1
	Urban 1	**120**	342	1200	6
Lead	Principal	**230**	966	18200	86
	Mineralisation 1	*n.d.**	15	200	1
	Mineralisation 2	**280**	61	1100	5
	Urban 1	**1300**	342	1200	6
	Urban 2	**890**	291	500	2



Thank you for your attention.

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All resources are available to download:
http://www.bgs.ac.uk/gbase/NBCDefraProject.html