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 cadmium 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).*

CADMIUM (Cd)

January 2013.

Cadmium (Cd) is a metallic element naturally occurring in trace amounts at the Earth's surface. It is toxic to humans, animals and plants, and known to be a human carcinogen. The metal associates with sulphide ores, mainly the mineral sphalerite (ZnS), and its cycling can be highly influenced by accumulation in plants and organic debris. Its abundance in igneous and sedimentary rocks is generally low, not exceeding 0.3 mg/kg, although Cd can concentrate in metalliferous ore deposits, in argillaceous (fine grained) rocks and in coal.

A contributing factor in determining the Cd content of soil is the chemical composition of the parent material. Areas in which soils are enriched in Cd are those with high naturally occurring Cd concentrations, usually associated with sulphide mineralisation, in the underlying rocks. Cadmium is an element associated with many of the mineralised areas and the accompanying mining and processing activities such as ore smelting. Zinc smelters may cause large emissions of fumes enriched in CdO. Phosphate fertilisers and sewage sludges are also sources of Cd in soil. The presence of Cd in car tyres and motor oil often accounts for the relative accumulation of Cd in roadside soils. Other important anthropogenic sources are Ni-Cd batteries and coal burning.

Cadmium has adverse effects on soil biological activity and plant metabolism. The occurrence of Cd in cultivated soils is of major concern since human health might be indirectly affected through vegetable or grain consumption. Cadmium can accumulate in relatively large amounts in plants without affecting them, leading to concentrations in crops that may possibly be harmful for human health.

The most important factors controlling soil Cd mobility and plant uptake are pH, oxidation potential and soil solution composition. Generally, Cd is most mobile in acidic soils and less mobile in alkaline soils. Cadmium goes readily into solution, as divalent free ion (Cd^{2+}) or forming aqueous complexes with chloride, carbonate and hydroxide and organic chelates. Soil microbial activity is known also to influence Cd behaviour in soils.

NORMAL BACKGROUND CONCENTRATIONS (NBCs)

Domain	Area (km^2)	Area (%)	NBC (mg/kg	n
Principal	18,700	88	**1.4**	681
Mineralisation 1	200	1	**nd**	15
Mineralisation 2	1,100	5	**2.2**	57
Urban 1	1,200	6	**6.2**	45

Table 1: NBCs for the cadmium domains (cited to 2 significant figures, n is number of samples used in the calculation). Cadmium is determined by laboratory-based X-ray fluorescence spectrometry (XRFS), *i.e.* total Cd 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. nd = not determined (because n<30).

Methods

NBCs are calculated using Cd data from soils systematically collected from a variety of land uses, analysed using certified methods, and with demonstrably high levels of quality assurance. For this purpose the primary data set used is the National Soil Inventory (NSI) from the Soil Survey of England and Wales (now the National Soil Resources Institute (NSRI), Cranfield University, UK) which were reanalysed at the British Geological Survey's laboratories by XRFS in 2010 (see Figure 1). All results used are for total concentrations of Cd measured by X-ray fluorescence spectrometry (XRFS). The British Geological Survey's G-BASE samples collected from the Cardiff and Swansea urban areas were analysed in the mid-1990s and the lower limit of detection for the XRFS at that time was such that a high percentage of results are recorded as being below detection. The 877 G-BASE urban samples have therefore not been used in the NBC calculations though have been used in the data exploration described in Ander *et al.* (2013) and clearly demonstrate elevated levels of Cd in the soils from Swansea. Soils used to calculate NBCs are from a consistent depth (0 – 15 cm) and are based on aggregating sub-samples collected from within a 20-m square. Wales has far fewer, and significantly less densely sampled, soil sites compared to England, so the contaminant NBCs for Wales are associated with a much greater level of uncertainty than the NBCs previously calculated for England.

Welsh soils have developed on a diverse range of parent materials, including those hosting metalliferous mineralisation, and therefore are inherently variable in their chemical composition (Figure 2). These soils have also been subjected to a long history of diffuse pollution, particularly around the South Wales Coalfield.

Results for Cd in all topsoils (NSI and G-BASE) range from <1 – 82 mg/kg with a mean of 1.35 mg/kg and a median of <1 mg/kg. In order to establish meaningful NBCs, soils are grouped in domains, defined by the most significant controls on a contaminant's high concentrations and distribution.

NBCs are determined for each domain using robust statistical analysis that investigates the distribution of results and, by a process of iteration, takes into account the concentrations that may be associated with point source contamination. "Normal" levels of contaminants are referred to in the Statutory Guidance (Wales) (Sections 3.21-3.26 and 4.21(b)). They are represented here by the 95% confidence limit of the 95th percentile, *i.e.* the NBC value is the upper limit at or below which contaminant levels can be considered to be normal for the defined domain. Levels at or below the NBC may not be naturally occurring.

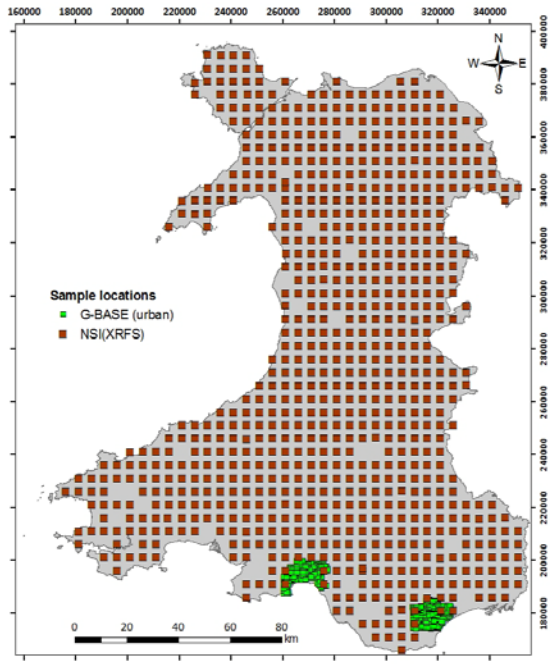


Figure 1: Map showing the distribution of samples available for use in the Cd NBC determination for Wales. NSI (XRFS) covers the whole country at a sample density of 1:25 km^2. G-BASE sampling densities for the urban areas of Swansea and Cardiff are 4:1 km^2. The 877 G-BASE samples were not used in the NBC calculations because the XRFS detection limit at the time of analysis meant that many Cd results are below the limit of lower detection.

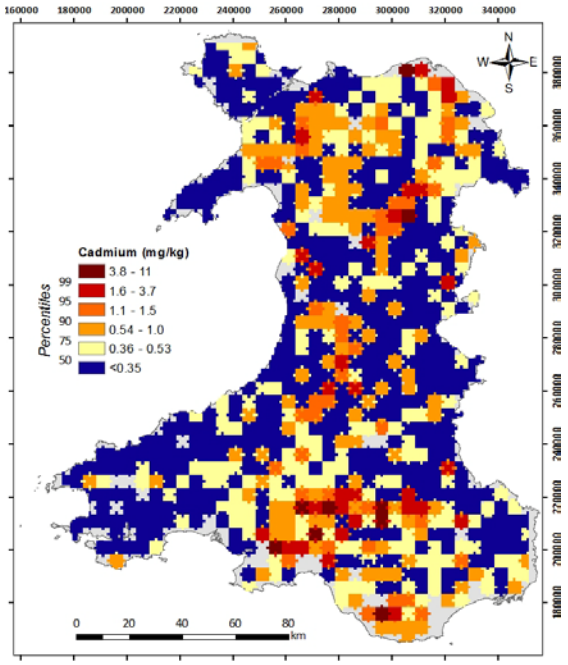


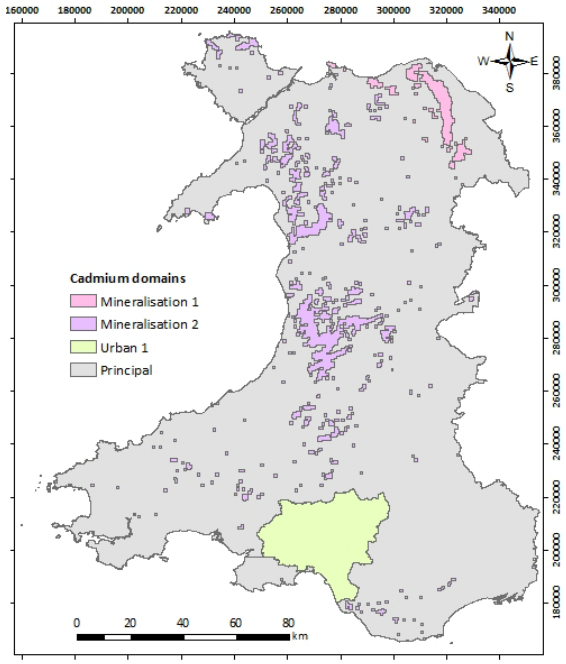
Figure 2: Map showing Cd in topsoil as a percentile classified interpolated image using NSI(XRFS) data only. All data are total concentrations by XRFS and colour thresholds designed for highly skewed data.

Results

Exploration of the available topsoil data, supplemented with information from the high density G-BASE stream sediment survey of Wales, shows two significant controls on the distribution of higher Cd concentrations in Wales. These are areas of metalliferous mineralisation and historical mining activity and have resulted in elevated levels of Cd in the soil environment; and those regions associated with urbanisation and industrialisation, particularly associated with zinc ore smelting. Sphalerite was extensively mined as an ore of zinc in many areas of Wales most notably in the Central Wales and Halkyn-Minera Orefields. In the latter area, yellow cadmium-tinted smithsonite is recorded, derived from the weathering of sphalerite. From the data exploration two distinctly different areas of metalliferous mineralisation are identified – Mineralisation 1 Domain (Halkyn) and Mineralisation 2 Domain (Anglesey, north, central and south Wales). Both mineralisation domains are poorly represented by the low density NSI sampling though it is seen that the soils from the Halkyn area are generally much higher in Cd. In urban areas the dominant area of high Cd results is associated with the catchments of the rivers Loughor (Afon Llwchwr), Tawe (Afon Tawe and more commonly referred to as the Swansea Valley), and Neath (Afon Nedd), collectively referred here as the Urban 1 Domain. This is not surprising considering from the mid-nineteenth century until the 1920s Britain's most important group of zinc smelting works were established in Swansea. Therefore, including the Principal Domain, four Domain areas are identified (Figure 3 and Table 1).

A higher density more systematic sampling in the areas of sulphide mineralisation would be expected to result in higher concentrations of Cd than those currently recorded for the two Mineralisation Domains. The NBC for the

Mineralisation1 Domain (Halkyn) is not calculated as there are only 15 results available from this area using the NSI data. Topsoils results for the Mineralisation 1 Domain range from <0.25 – 11.5 mg/kg with a mean of 1.62 mg/kg. The NBC for the Mineralisation 2 Domain is not significantly higher than that of the Principal Domain, though the high density G-BASE stream sediment results clearly identify the Mineralisation 2 Domain as an area with significantly elevated levels of Cd.



In the NBC attribution, only the most significant areas at the national scale with the highest concentration range are classified as domains. Although four domains have been distinguished, further spatial variability will occur within these domains. Urban areas outside the Urban 1 Domain, for example, may be associated with a particular land use that has led to diffuse contamination giving rise to soils with locally elevated levels of Cd.

Figure 3: Cadmium domain map.

USING NORMAL BACKGROUND CONCENTRATIONS

The NBCs are produced to support the Part 2A contaminated land Statutory Guidance (SG) (Wales) and help inform as to what are normal levels of contaminants. Using this guidance, along with the further information and resources provided, a NBC test can be carried out:

1. A soil sample under investigation for Cd concentration should be spatially located in one of the four domains described. This should be part of a preliminary step in which the scenario and conceptual site model are considered.
2. If the Cd concentration is at or below the NBC for the specified domain then the result *"should not be considered to cause the land to qualify as contaminated land, unless there is a particular reason to consider otherwise*" (SG, Section 3.22). If the latter applies, then proceed to the use of other screening tools or further site investigation as necessary and appropriate.
3. If there is no reason "*to consider otherwise*" then the decision can be made that there is no evidence that the land is contaminated under Part 2A with respect to Cd (SG, Sections 5.2 – 5.4), that is, the land lies outside Categories 1 or 2.
4. If the Cd concentration is above the domain NBC then using the additional resources, including those provided with this technical guidance, a more detailed investigation at a local scale should be carried out or the use of other screening tools considered as appropriate. This is to determine whether the concentrations reflect "*levels of contaminants in the soil that are commonplace and widespread....and for which....there is no reason to*

consider that there is an unacceptable risk" (SG, Section 3.21). If this is so, then step 3 applies. In the case of Cd, for example, this may be an urban area within the Principal Domain where a particular land use has resulted in elevated levels of Cd in the soil.

5. If the concentration of Cd in the soil is not considered to be commonplace and widespread then further testing is required (apply quantitative risk assessment (QRA)).

FURTHER RESOURCES

Additional resources on NBCs are available from the BGS project website. These resources include: project reports; a database of essential information about relevant soil data sets; technical guidance sheets for other contaminants; polygons defining domain boundaries in various GIS formats; and a project bibliography.

Because there are substantial information gaps relating to systematically collected soils across Wales, information on elevated contaminant levels in the surface environment are usefully informed by the BGS high density stream sediment survey (British Geological Survey. 2000. *Regional geochemistry of Wales and part of west-central England: stream sediment and soil*. Keyworth, Nottingham: British Geological Survey).

THIS GUIDANCE SHOULD BE READ IN CONJUNCTION WITH THE FOLLOWING:

Part 2 A documents:

Part 2A of the Environmental Protection Act 1990, as amended. The Contaminated Land (Wales) (Amendment) Regulations 2012 (Statutory Instrument 2012 No 263) (Amends Contaminated Land (Wales) Regulations 2006 ("the 2006 Regulations") (S.I. 2006/1380).)

Welsh Government. 2012. Contaminated Land Statutory Guidance -2012. Welsh Government, Document Number WG15450.

Project Reports:

Available from the Defra Project SP1008 web page and the British Geological Survey at: http://www.bgs.ac.uk/gbase/NBCDefraProject.html

Ander, E.L., Cave, M.R., Johnson, C.C. and Palumbo-Roe, B. 2011. Normal background concentrations of contaminants in the soils of England. Available data and data exploration. *British Geological Survey Commissioned Report*, CR/11/145. 124pp.

Ander, E.L., Cave, M.R. and Johnson, C.C. 2013. Normal background concentrations of contaminants in the soils of Wales. Exploratory data analysis and statistical methods. *British Geological Survey Commissioned Report*, CR/12/107.

Ander, E.L., Cave, M.R., Johnson, C.C. and Palumbo-Roe, B. 2012b. Normal background concentrations of contaminants in the soils of England. Results of the data exploration for Cu, Ni, Cd and Hg. *British Geological Survey Commissioned Report*, CR/12/041. 88pp.

Cave, M.R., Johnson, C.C., Ander, E.L. and Palumbo-Roe, B. 2012. Methodology for the determination of normal background contaminant concentrations in English soils. *British Geological Survey Commissioned Report*, CR/12/003. 56pp.

Johnson, C.C., Ander, E.L., Cave, M.R. and Palumbo-Roe, B. 2012. Normal Background Concentrations of contaminants in English soil: Final project report. *British Geological Survey Commissioned Report*, CR/12/035. 40pp.

Defra, 2012. Technical Guidance Sheet on normal levels of contaminants in English soils: Cadmium. Technical Guidance Sheet No. TGS06, July 2012. Department for Environment Food and Rural Affairs (Defra), Soils R&D Project SP1008. Available on-line from Defra project SP1008 web page.

ACKNOWLEDGEMENTS

The British Geological Survey has produced a series of Technical Guidance Sheets on NBCs for England as part of a project funded by Department for Environment Food and Rural Affairs (Defra) (Soils R&D Project SP1008, October 2011 – March 2012). The work was extended to apply the same methodology for determining NBCs in Wales. This guidance sheet was compiled by Chris Johnson, Louise Ander and Mark Cave. The project thanks the many people and projects that have assisted in the provision of data, in particular, the BGS G-BASE project and the NSRI NSI soil samples (reanalysed by BGS). These systematic national surveys have created unbiased data sets sampled and analysed to consistent and high standards of quality that have enabled the NBCs for many inorganic contaminants to be calculated with a high level of confidence.

Version 1.0

BIBLIOGRAPHIC REFERENCE

When referring to this document the following bibliographic reference should be made:

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