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WELSH GOVERNMENT

Assessment of Agricultural Land at Pwll-Glas, Mold

A brief evidence review to determine whether it is appropriate to use Category 4 Screening Values for contaminated land to inform the grading of agricultural land under the Agricultural Land Classification (ALC) system.

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ADAS

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Author: Dr Fiona Nicholson **Technical reviewer** Leila Froud *(CSci)*

Project manager: Kirk Hill *(MISoilSci)*

EXECUTIVE SUMMARY

A brief evidence review was conducted to determine if it is appropriate to use contaminated land Category 4 Screening Values (C4SVs) for potentially toxic elements (PTEs) to inform the grading of agricultural land under the Agricultural Land Classification (ALC) system.

In UK agricultural soils receiving sewage sludge, PTE concentrations are controlled by The Sewage Sludge (Use in Agriculture) Regulations and The Code of Practice for Agriculture Use of Sewage Sludge. Controls on PTEs entering agricultural soils from livestock manures, composts, digestates, 'wastes' and other sources often refer to the limits specified for sewage sludge. On potentially contaminated sites, PTE concentrations are assessed against Soil Guideline Values (SGVs) or C4SVs, which are based on modelled exposure pathways pertaining to residential, allotment, commercial and public open space land uses. They are not intended to be used for agricultural land use situations.

Agricultural land is graded based on the ALC scheme. There are no specific limit values for soil PTE concentrations in ALC guidance, although an assessment is required of whether the land is "unsuitable for growing crops for direct human consumption". It is not appropriate to use C4SLs for ALC grading because these values were derived for non-agricultural land uses. However, it would be pragmatic to use soil PTE limit values included in the Code of Practice for Agricultural Use of Sewage Sludge as 'trigger values' to initiate further investigation before deciding on the ALC classification.

Downgrading land at Gwernaffield Road, Pwll-Glas based on exceedance of the C4SL value for lead (Pb) is not justified, because this limit refers to residential soils with home-grown produce and is not intended to be used for agricultural land. The reported soil Pb concentrations were very similar to normal background concentrations for non-urban areas in Wales, thus the land is unlikely to be classified as contaminated under Part 2A of the Environmental Protection Act. At the Denbigh Road site, Pb concentrations were considerably higher than background levels indicating that this area is likely to be classified as contaminated. In addition, many soil samples exceeded the limits for Pb, zinc and cadmium specified in The Code of Practice for Agriculture Use of Sewage Sludge suggesting that there may be grounds for downgrading the ALC in this part of the development site.

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1 INTRODUCTION AND OBJECTIVE

ADAS have been requested by the Welsh Government to provide a brief evidence review to determine whether it is appropriate to use Category 4 Screening Values for contaminated land to inform the grading of agricultural land under the Agricultural Land Classification (ALC) system. The request has arisen as the result of a planning application, whereby the applicant's consultant downgraded two areas of agricultural land at Pwll-Glas, Mold, North Wales from an ALC grade of 3a to 3b based on their chemical characteristics, following the detection of elevated soil lead concentrations.

2 REVIEW OF LIMITS FOR POTENTIALLY TOXIC ELEMENTS IN SOILS

2.1 Potentially toxic elements in soils

Potentially toxic elements (PTEs) - also sometimes referred to as toxic metals or heavy metals – include arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni) and zinc (Zn). They are often associated with pollution and toxicity, although some, such as Cu and Zn, are essential for living organisms at low concentrations.

PTEs are present in soils as a result of soil formation processes from the weathering of bedrock, and natural (background) concentrations will vary widely depending on the composition of the underlying parent material. Soil PTE concentrations may be elevated above background levels due to pollution or contamination. For lead, the highest soil concentrations are usually close to areas of historic mining and smelting activity, or are associated with urban areas as a result of industrial activity and the use of lead in petrol (Rawlins *et al.*, 2012). PTEs, including Pb, may also be added to agricultural soils by the application of sewage sludge (biosolids), livestock manures, composts, digestates, fertilisers, plant protection products etc. (Nicholson *et al*., 2003).

The Advanced Soil Geochemical Atlas of England and Wales (Rawlins *et al*., 2012) presents data for soil samples (0-15 cm) collected for the National Soil Inventory (NSI) as described in McGrath & Loveland (1992). This reports that Pb concentrations in topsoil range from 13-10,000 mg/kg, with a mean of 81 mg/kg and a median of 49 mg/kg. More recently Normal Background Concentrations (NBCs) based on data from the NSI together with data from the BGS Geochemical Baseline Survey of the Environment (G-BASE) rural and urban topsoils were derived and indicate an NBC (principal domain) for Wales of 230 mg Pb/kg (see Table 6).

The fate and behaviour of PTEs in soils is influenced by a number of soil properties including the clay and organic matter content, redox conditions and soil pH. In general, the solubility and mobility of Pb are low, and only a small proportion of Pb in the soil is available for uptake by plants. At normal agricultural soil pH levels (pH 5-8), there is little modifying effect of pH on plant Pb uptake (e.g. Davies, 1990; Zhao et al., 2004).

Because PTEs can be toxic to humans, animals and plants, legislation is in place to measure and control concentrations in soils used for certain purposes. The following sections provide an overview of the different regulations, controls and PTE limits for agricultural soils and contaminated land.

2.2 Controls on PTEs in agricultural soils

2.2.1 The Sewage Sludge (Use in Agriculture) Regulations

The only legislation controlling PTE inputs to agricultural soils are The Sludge (Use in Agriculture) Regulations (SI, 1989) which aim to control the recycling of sewage sludge (biosolids) to agricultural land. The Regulations implement The Sludge Directive (Council Directive No. 86/278/EEC on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture; EEC, 1986) and restrict the quantities of PTEs that can be applied to land from biosolids. The Regulations place legally binding limits on the amounts of Zn, Cd, Pb, Cu, Cr, Hg and Ni in biosolids that can be applied annually and also provide maximum soil metal concentrations above which biosolids cannot be applied (maximum permissible concentrations –MPCs). The Regulations are complemented by the Code of Practice for the Agriculture Use of Sewage Sludge (referred to hereafter as The Sludge Code of Practice; DoE, 1996) which sets lower MPCs for some PTEs (zinc and cadmium), and in addition provides recommendations on maximum loading rates for molybdenum (Mo), arsenic (As), selenium (Se) and fluoride (F).

The soil MPC for Pb is 300 mg/kg of dry soil i.e. sludge must not be applied to the soil if it will cause the Pb concentration to exceed this limit. Similar limits are in place for other PTEs (Tables 1 and 2 for arable and grassland, respectively) and have recently been incorporated in the requirements of the Biosolids Assurance Scheme (BAS, 2017).

Following implementation of the Sludge Regulations, two independent scientific reviews were conducted to determine possible risks to food safety, assess the potential long-term impact of repeated sludge application to agricultural land, and to confirm that the legislation put in place was sufficient to protect soil quality. These reviews were undertaken by the Steering Group on Chemical Aspects of Food Surveillance and an independent scientific committee (MAFF/DoE, 1993) and concluded that PTE uptake by plants was unlikely to pose a significant risk to food safety. The limits proposed by the Sludge Regulations were deemed sufficient to protect plants, animals, and humans from PTE toxicity. However, the reviews informed the decision to introduce lower soil MPCs in The Sludge Code of Practice for Zn (reduced to 200 mg/kg for soils of pH <7.0).

Table 1. Maximum permissible concentrations of PTEs in biosolids amended arable soils (0-15cm)[1] and average annual addition rates over a 10 year period (DoE, 1996; Defra, 2018; BAS, 2017)

	Maximum permissible concentration in soil (mg/kg dry solids)				Maximum permissible average annual rate of addition over 10 years (kg/ha)
	pH 5.0<5.5	pH 5.5<6.0	pH 6.0-7.0	pH >7.0	
Zinc	200	200	200	300	15
Copper	80	100	135	200	7.5
Nickel	50	60	75	110	3
	For pH 5.0 and above				
Cadmium	3				0.15
Lead	300				15
Mercury	1				0.1
Chromium[2]	400				15
Molybdenum[2]	4				0.2
Selenium[2]	3				0.15
Arsenic[2]	50				0.7
Fluoride[2]	500				20

[1]In order to comply with SI (1989) samples must be taken to a depth of 25 cm (or to the depth of the soil if less) before the first use of sludge and at least every twentieth year while sludge is being used on the site. For operational purposes, monitoring samples subsequent to the first statutory sample are taken to a depth of 15 cm to be consistent with agricultural practice.

[2]Values are advisory limits and not subject to the provisions of Directive 86/278/EEC

Table 2. Maximum permissible concentrations of PTEs in biosolids amended grassland soils (0-7.5cm)[1] and average annual addition rates over a 10 year period (DoE, 1996; Defra, 2018; BAS, 2017)

	Maximum permissible concentration in soil (mg/kg dry solids)				Maximum permissible average annual rate of addition over 10 years (kg/ha)
	pH 5.0<5.5	pH 5.5<6.0	pH 6.0-7.0	pH >7.0	
Zinc	200	200	200	300	15
Copper	130	170	225	330	7.5
Nickel	80	100	125	180	3
	For pH 5.0 and above				
Cadmium	3				0.15
Lead	300				15
Mercury	1.5				0.1
Chromium[2]	600				15
Molybdenum[2]	4				0.2
Selenium[2]	5				0.15
Arsenic[2]	50				0.7
Fluoride[2]	500				20

[1]In order to comply with SI (1989) samples must be taken to a depth of 25 cm (or to the depth of the soil if less) before the first use of sludge and at least every twentieth year while sludge is being used on the site. For operational purposes, monitoring samples subsequent to the first statutory sample are taken to a depth of 7.5 cm to be consistent with agricultural practice.

[2]Values are advisory limits and not subject to the provisions of Directive 86/278/EEC

However, questions remained about the risks to soil microorganisms. As a consequence, the Long-term Sludge Experiments (LtSE) were established in 1994 to determine the effects on soil fertility and microbial activity of PTEs in biosolids applied to agricultural soils (Gibbs *et al*., 2006 a,b). Overall, there was no evidence that the PTE applications were damaging to soil microbial activity in the short term after the cessation of sludge cake addition. However, a recent meta-analysis using data from the LtSE found that there had been significant decreases in biomass carbon (C) in soils where the total concentrations of Zn and Cu were below the current UK statutory limits (Charlton *et al*., 2016a). In a parallel study, Charlton *et al*. (2016b) reported a decrease in Rhizobium MPN (most probable number) in treatments with Zn, whilst no significant effect was noted with Cu. In contrast, application of biosolids predominantly contaminated with Cd appeared to have no effect on biomass C and Rhizobium MPN at concentrations below the current UK statutory limit (3 mg/kg).

Although the regulatory limits set in the EU Sludge Directive and the UK Sewage Sludge Regulations, and the guidelines in The Sludge Code of Practice, have been underpinned by numerous previous research studies and risk assessments, research is still being funded and published on this topic. A study by the Joint Research Council (JRC; the European Commission's science and knowledge service) published in 2012 reviewed the evidence base for 114 chemicals including 21 metals in biosolids samples originating from 15 different countries including the UK. The study found that all regulated metal concentrations were well below the legislative limits and concluded that the introduction of new (lower) threshold limits to the Sludge Directive was not justified (EC, 2012).

The Sludge Code of Practice contained a footnote commenting that "*The permitted concentrations of zinc, copper, cadmium and lead are provisional and will be reviewed when current research into their effects on soil fertility and livestock is completed. The pH qualification of limits will also be reviewed with the aim of setting one limit value for copper and one for nickel across pH range 5.0<7.0 and therefore ensuring consistency with the approach adopted for zinc in response to the recommendations from the Independent Scientific Committee (MAFF/DOE 1993)*". Although the Sludge Code of Practice has recently been reissued and is now available online (Defra, 2018), the soil MPCs for PTEs remain unchanged.

2.2.2 Controls on other materials applied to agricultural land

Whilst there is no other UK legislation governing PTE applications to agricultural soils, a number of other provisions exist that will control the amount of PTEs entering soils from manures, organic materials and other sources. These often either refer to or are based on the limits specified in the Sludge Code of Practice (Table 1):

- The Nutrient Management Guide (RB209) (AHDB, 2019) points out that "*certain materials spread on land can also contain low concentrations of pollutants, especially heavy metals which, following repeated applications, can accumulate in the soil. This could pose a risk to human health and the environment. Remediating soils which contain pollutants is difficult and costly, so it is important to prevent unacceptable levels of pollutants getting into the soil*". It refers users to the statutory requirement to analyse topsoil for PTEs before spreading biosolids and to the limits in the Sludge Code of Practice (Defra, 2018).

- The Code of Good Practice for Soil, Water and Air (Defra, 2009) refers to soil contamination by PTEs or persistent organic chemicals. On fields which receive regular applications of pig and poultry manures, the advice is to monitor Zn and Cu concentrations in the manure and soil. Trigger values are given for when to seek advice when applying manures (or pesticides) namely 200 mg/kg for Zn and 80 – 100 mg/kg for Cu, i.e. based on DoE (1996).

- Quality Protocols (QPs) developed by WRAP and the Environment Agency set out criteria for the production of quality anaerobic digestate (WRAP/EA, 2009) and compost (WRAP/EA, 2012). If these criteria are met, the outputs from anaerobic digestion and composting are no longer considered to be wastes and can be applied to agricultural land without requiring an environmental permit from the Environment Agency (see below). The QPs contains good practice guidance for the application and use of quality materials. This includes the requirement to adhere to the maximum permissible annual rate of PTE addition over a 10 year period as per The Sludge Code of Practice (DoE, 1996). The receiving soil should also be analysed for PTEs (Pb, Cd, Cr, Hg, Cu, Zn, Ni) to ensure that the MPCs given by the Sludge Code of Practice are not exceeded.

- Natural Resources Wales and the Environment Agency (in England) regulate the spreading of waste-derived materials on farmland by issuing a landspreading permit under the Environmental Permitting Regulations (SI, 2016). These regulations ensure that the potential agronomic and economic benefits from waste recovery are balanced against the broader health and environmental risks. Guidance on how to comply with a landspreading permit (EA, 2013) states that "*in most cases it is important not to exceed the specified limits of concentration of PTE's in soil as set out in the Code of Practice for Agricultural Use of Sewage Sludge following treatment of the soil with a waste*".

- A set of Soil Screening Values (SSVs) for assessing ecological risk have been developed and updated based on the available research evidence, to specify soil concentrations of chemical substances below which there are not expected to be any adverse effects on wildlife such as birds, mammals, plants and soil invertebrates, or on the function of soil microbes (EA, 2017). The SSVs are intended to help the regulators to better review the technical suitability of landspreading proposals submitted by an operator for a wider range of chemicals (EA, 2017).

The SSVs (Table 3) are used to determine whether waste-derived materials can be spread to land for agricultural and horticultural benefit, and site restoration. They are primarily derived from soil ecotoxicity data which uses soil dose-response data for a range of key soil organisms. In Environmental Permitting risk assessments, the EA compare the SSVs (referred to as 'safe levels' in soils) with the amount of PTEs and organic pollutants added as a result of landspreading, in order to screen out low risk activities and focus on high risk ones (EA, 2017). It is not intended that SSVs alone are used to assess the acceptability of any landspreading activity; the benefits of waste recovery and other factors (e.g. background soil concentrations) as well as receptors that may be affected (e.g. human health) should also be considered.

The SSVs for PTEs differ from the soil limits in the Sludge Code of Practice in that site-specific soil properties (i.e. pH, organic matter content, clay content and cation exchange capacity), which may influence PTE bioavailability and toxicity, can be taken into account to adjust the generic SSV. In addition, for vanadium (V) and Zn, representative soil background concentrations can be added to the SSV for comparison with the measured total PTE concentration in the soil (the added risk approach).

There are SSVs for cobalt, silver, V and antimony which are not covered by the Sludge Code of Practice because these are elements for which ecotoxicity data has only started to become available relatively recently. Conversely, SSVs have not been set for Pb, Hg, Se, As and F.

Table 3. Generic and normalised (site specific) SSVs (EA, 2017)

PTE	Generic SSV (mg/kg dw)	Normalised SSV (mg/kg dw)[1]
Antimony	37.0	-
Cadmium	0.6	-
Cobalt	4.2	17.2
Copper	35.1	67.6
Molybdenum	5.1	62.1
Nickel	28.2	44.6
Silver	0.3	0.9
Vanadium	19.0	19.0
Zinc	59.7	103.4

[1]SSV adjusted based on the following default soil properties: pH=5.5; organic matter content = 3.4 wt%; clay content =10 wt%
Note: the soil sampling depth is recommended to be 7.5 cm for grassland and 15 cm for arable land.

SSVs do not apply to biosolids recycled to land via the Sludge (Use in Agriculture) Regulations (SI, 1989) (see Section 7.1.1) or to quality compost and digestates; these are not considered to be 'wastes' and are controlled as previously described.

2.3 PTE limits and contaminated land.

2.3.1 Soil Guideline Values

The Environment Agency issued Soil Guidance Values (SGVs) in line with UK guidance provided in Contaminated Land Report 11 (EA, 2004). The SGVs were derived using the CLEA software; full details of the principles and methods used are described in two science reports (EA, 2009a; b).

The SGVs and supporting technical guidance (EA, 2009a; b) are intended to assist with the assessment of long-term risk to health from human exposure to chemical contamination in soil. There are different SGVs according to land-use (residential, allotments, commercial) because this affects the number and type of people who may be exposed to soil contamination, and the exposure pathways. Note that SGVs are not specified for agricultural land use.

Table 4. Soil Guideline Values for PTEs (mg/kg dry weight) for the assessment of potentially contaminated land (EA, 2009b).

PTE	Residential	Allotment	Commercial
Arsenic (inorganic)	32	43	640
Nickel	130	230	1800
Mercury: -elemental -inorganic -methyl	 1.0 170 11	 26 80 8	 26 3600 410
Selenium	350	120	13000
Cadmium	10	1.8	230

Notes: the SGV for lead (450 mg/kg) has now been withdrawn; the SGVs for arsenic and cadmium have been superseded by C4SLs.

Soil sampling methodology and sampling depth not specified, however the soil data, including soil depth, should be representative of the exposure scenario being considered. The samples are assumed to be representative of the contaminant concentration throughout the soil volume (EA, 2009a)

SGVs are 'trigger values' for screening-out low risk areas of land contamination. They give an indication of representative average levels of chemicals in soil below which the long-term health risks are likely to be minimal. Exceeding an SGV does not mean that remediation is always necessary, although in many cases further investigation and risk evaluation will be undertaken. SGVs are only available for a limited number of chemical substances including some PTEs (Table 4). However, the framework reports and software provide a starting point for the assessment of a much wider range of chemicals. Professionals and regulators assessing risks to health from land contamination are not required to use SGVs and the supporting technical guidance; alternative approaches can be used provided that they satisfy the legislative requirements.

2.3.2 Category 4 Screening Levels

A revised Statutory Guidance to support Part 2A of the Environmental Protection Act 1990 (which is the legislative framework for dealing with contaminated land) was published in 2012. This introduced a new four-category system for classifying land in terms of 'Significant Possibility of Significant Harm to human health' (Defra, 2012a), where Category 1 includes land where the level of risk is clearly unacceptable and Category 4 includes land where the level of risk posed is acceptably low.

Category 4 Screening Levels (C4SLs) are generic screening values to show whether land is within Category 4, i.e. where there is 'no risk or the level of risk is low'. Where they exist, they replace the previous SGVs and provide a higher simple test for deciding whether land is suitable for use and not contaminated. The C4SLs were developed as part of Defra project SP1010 (Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination; Defra, 2014a) using a modified version of the CLEA framework. They are currently available for 6 substances, including As, Cd, Cr and Pb, and four generic land uses i.e. residential, allotments, commercial and public open space (Table 5). Because they are based on exposure modelling assessments for the specified land uses, they cannot be assumed to be applicable to agricultural land, where the exposure pathways may be very different. For example, the CLEA model includes indoor exposure pathways such as dermal contact and dust inhalation, which are not applicable to an agricultural soil environment.

Table 5. Final Category 4 Screening Levels for PTEs (mg/kg dry weight) for the assessment of potentially contaminated land (Defra, 2014b).

PTE	Residential (with home grown produce)	Residential (without home grown produce)	Allot-ments	Comm-ercial	Public Open Space 1	Public Open Space 2
Arsenic	37	40	49	640	79	170
Cadmium	22	150	3.9	410	220	880
Chromium VI	21	21	170	49	21	250
Lead	200	310	80	2300	630	1300

Note: soil sampling methodology and sampling depth not specified

Clear guidance on using C4SLs is given in a Defra policy document (Defra, 2014b). Before using C4SLs, it is important to understand their derivation and limitations, and that they are applicable to most, but not all sites. Even if levels of the substances exceed C4SLs, this does not automatically mean the land should be designated as contaminated. C4SLs are intended as an initial screen; where concentrations exceed the C4SL they should be compared with normal background concentrations for that area. If concentrations are higher than the C4SL but within normal background concentrations for that area, the site would not normally be considered to be contaminated under Part 2A of the Environmental Protection Act unless there was reason to consider otherwise.

For lead, advances in the understanding of Pb toxicology have resulted in some C4SLs that are lower than the normal background concentration of lead (Table 6). Thus Defra (2014b) recommends that "*a pragmatic approach for lead would be to recommend the use of the 'normal' background concentration when the land use and domain permit (for example, providing other site and contaminant specific characteristics such as chemical form, bioavailability, soil depth, site use, etc. are comparable between the background and the site under investigation) so as not to disproportionately target land where there is widespread diffuse pollution of lead*".

Table 6. Normal background concentrations (NBCs) of lead (mg/kg) in England and Wales (Defra, 2014b)

	Principal domain	Urban domain	Mineralisation domain 1
England	180	820	2400
Wales	230	890-1300	280

Note: NBCs 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. Detailed information on the derivation of NBCs can be found in Defra project SP1008 (Defra, 2012b) and in Ander *et al*. (2013). Technical guidance sheets for England (Defra, 2012c) and Wales (Defra, 2013) are also available.

2.4 Summary

The controls and limit values for PTEs in soils in the UK have been developed over time to meet the different requirements and objectives of the various regulatory regimes.

The Sludge Code of Practice sets maximum permissible concentrations (MPCs) of PTEs in agricultural soils where biosolids are applied; biosolids cannot be spread on land if this means that the MPCs will be exceeded. These concentrations were set to ensure that "human, animal or plant health is not put at risk" (DoE, 1996). They were based on the best scientific evidence available at the time, although a more recent study has concluded that the introduction of new (lower) limits is not justified (EC, 2012). The limits have subsequently been used in the Quality Protocols for compost and anaerobic digestate, and in guidance pertaining to other organic material applications to agricultural land.

Soil Screening Values (SSVs) specify soil concentrations of chemical substances below which there are not expected to be any adverse effects on wildlife or on the function of soil microbes. They are intended to help the regulators to better review proposals for the landspreading of wastes - for agricultural and horticultural benefit, and site restoration - in order to screen out low risk activities and focus on high risk ones.

Category 4 Screening Levels (C4SLs) are precautionary screening values which are intended to indicate whether land is suitable for use as residential, allotments, commercial and public open space. They are based on human exposure modelling assessments and assume that people are living and/or working on land being used for the specified purposes. Unlike SSVs, they do not take into account any potential effects on wildlife or soil health.

3 ASSESSMENT OF AGRICULTURAL LAND AT PWLL-GLAS

In this section the findings and conclusions of the reports on which the decision to downgrade the two areas of agricultural land at Pwll-Glas was based are summarised.

3.1 Report by Reading Agricultural Consultants

In November 2017, a report on the Agricultural Land Classification (ALC) and soil resources for the land at Pwll-Glas, Mold, North Wales was issued in response to an instruction from Anwyl Homes Ltd by Reading Agricultural Consultants Ltd (RAC, 2017).

The report states that the guidance for assessing the quality of agricultural land in England and Wales published in 1998 by the Ministry of Agriculture Fisheries and Food (MAFF, 1988) has been followed, whereby agricultural land is graded based on the extent to which physical or chemical characteristics impose long-term limitations on agricultural use.

To assess the chemical characteristics of the site, Reading Agricultural Consultants draw on data provided in a Geo-Environmental Investigation Report prepared by Robert E Fry and Associates Ltd for the Gwernaffield Road site (REFA, 2018a). The Geo-Environmental Investigation Report identified 9 out of 20 soil samples containing Pb concentrations greater than 200 mg/kg, which exceeds the C4SL for the assessment of land affected by contamination. Based on this information, Reading Agricultural Consultants state that: "*The topsoil is considered unsuitable for reuse within the garden areas of the proposed development and is also unsuitable for growing crops for direct human consumption*".

Reading Agricultural Consultants then refer to Section 3.3 of the ALC guidelines (MAFF, 1988) which states that in relation to toxic elements which could adversely affect plant growth or are potentially harmful to animals or humans (i.e. Zn, Cu, Pb, Cd, Hg, As, Ni, Cr and F) *"Land will not be graded higher than Subgrade 3b if it is considered to be unsuitable for growing crops for direct human consumption."*

Because the Pb concentrations in some of the sampled soils exceeded the C4SL, the entire site was therefore considered to be unsuitable for growing crops for direct human consumption and could not, as a result, be classified higher than Subgrade 3b.

3.2 Supporting REFA report for Gwernaffield Road

The Geo-Environmental Investigation Report prepared by Robert E Fry and Associates Ltd (REFA, 2018a) for the Gwernaffield Road site reported on the analysis of soil samples for a suite of PTEs. The report methodology was based on the premise that the site will be developed on a private residential basis with large areas of private gardens. "*Accordingly the site usage has been considered on the basis of an end land use of residential as defined by EA Science Report SC050021/SR3 2009 in relation to the most recent soil guideline values*." The site has had a history of agricultural use.

The sampling methodology states that 30 samples of 'topsoil and 'natural strata' representative of shallow ground conditions, were retained for chemical analysis. A PTE analysis suite was undertaken on 20 topsoil samples (depth 0-10cm or 0-15cm) including As, Cd, Cr (total), Cu, Pb, Hg, Ni, Se and Zn. In addition, 10 samples of the 'natural strata' (depth 0-40cm or 0-50cm) were analysed for Pb only. This was because a 'Geo-Insight report', referred to in REFA (2018a) but not available for review here, included estimated geometric mean soil concentrations for various elements. This report suggested that whilst the majority of soil PTE concentrations were anticipated to be below tier 1 assessment criteria in relation to human health effects, elevated concentrations of Pb had been noted. It was therefore recommended that "*lead analysis should be carried out to the underlying natural strata to confirm that it does not contain elevated concentrations of lead that may be at a harmful concentrations to long term end users of the site*".

Appendix K of the report details the test results from Exova Jones Environmental and Table 8 of the report, reproduced below, shows the summary data for the 20 'topsoil' samples.

The report compared the soil Pb concentrations to the C4SLs published by Defra (2014b) using the C4SL value of 200 mg/kg which relates to residential soils with home grown produce. Table 8 reproduced below shows that of the 20 'topsoil' (0-10 or 15cm depth) samples tested, 9 exceeded the C4SL, although none were higher than 300 mg/kg (mean 200 mg/kg; see Table 7).

Table 8: Summary of Contamination Analysis: Metals & Inorganics - Topsoil					
	No. of Samples	Range of Values (mg/kg)	Assessment Criteria (mg/kg)	No. of Samples Failing	Locations
Arsenic	20	9.3 – 19.2	37[3]	0	-
Cadmium	20	0.3 – 1.0	11.0[3]	0	-
Chromium (total)	20	39.8 – 68.4	910[3]	0	-
Copper	20	20.0 – 40.0	2400[3]	0	-
Lead	20	17.0 – 293.0	200[1]	9	TP01-0.1, TP03-0.1, TP04-0.1, TP04-0.15, TP15-0.15, TP17-0.1, TP18-0.1, TP20-0.1, TP28-0.15
Mercury	20	<0.1	40[3]	0	-
Nickel	20	19.6 – 37.9	180[3]	0	-
Selenium	20	<1.0	250[3]	0	-
Zinc	20	120 – 200	3700[3]	0	-
Total Cyanide	20	0.6 – 1.1	34.2[3]	0	-
Phenol	20	<0.15 – 0.71	120[3]	0	-
pH	20	5.92 – 7.36	-	0	-
SOM	20	3.85 – 12.55	-	0	-
SO_4 (2:1)	20	<0.001 – 0.009	0.5[4]	0	-

1 DEFRA : SP1010 : Category 4 Screening Levels
2 Atkins Atrisk SSV residential without home grown produce (1% SOM)
3 LQM and CIEH S4UL's for Human Health Risk Assessment (Registration No. S4UL 3265) residential with home grown produce (1% SOM)
4 BRE Special Digest 1:2005 DS-1 (units in g/l) ND – None Detected

Note: there is an error in the above table. The range of Pb concentrations should be 105 – 293 mg/kg and not 17 – 293 mg/kg (see Table 1)

The majority of topsoil samples were taken from a depth of 0-10 cm. The standard recommended depth for sampling agricultural soils for PTE analysis is 15 cm for arable and 7.5 cm for grassland soils (AHDB, 2018) and it is not clear from the report why a non-standard sampling depth was chosen. SGV guidelines (EA, 2009a) state that for residential or allotment land use "*the critical soil volume is the area of an individual garden, communal play area or working plot from the surface to a depth of between 0.5m and 1.0m.*" The results for the samples taken to a depth of 40 or 50 cm were not mentioned in the report, however the laboratory analysis results show that these had much lower Pb concentrations with none exceeding 70 mg/kg (mean 36 mg/kg; see Table 7).

Table 7. Lead concentrations at each sampling point and depth. Laboratory analysis data from Exova Jones taken from Appendix1 of REFA (2018a).

Sample depth 0-10cm			Sample depth 0-50cm		
Sample No	Sample id	Pb (mg/kg)	Sample No	Sample id	Pb (mg/kg)
1	TP01	*272*	2	TP02	65
3	TP03	*234*	5	TP05	49
4	TP04	*203*	9	TP09	29
6	TP07	177	13	TP12	26
7	TP08	128	17	TP15	54
8	TP09	193	19	TP16	32
10	TP10	163	24**	TP19	22
11	TP11	181	26**	TP21	17
12	TP12	105	28	TP25	27
14*	TP13	192			
15*	TP14	*293*			
16*	TP15	*218*			
18*	TP16	181			
20	TP17	*292*			
22	TP18	*239*			
23	TP19	140			
25	TP20	*229*			
27	TP22	175			
29*	TP28	*220*			
30*	TP29	156			
	Mean	**200**		**Mean**	**36**

*Sample depth 0-15cm
**Sample depth 0-40cm

The report concluded that *"Chemical analysis has identified numerous elevated concentrations of lead within the topsoil material and therefore the topsoil is considered unsuitable for reuse within the garden areas of the proposed development"*. However, it does not appear that the soil Pb concentrations were compared with normal background Pb concentrations in the area as recommended in the Policy Companion Document for using C4SLs (Defra, 2014b). Taking the values in Table 6 for Wales, this would indicate that normal background Pb concentrations for non-urban areas are likely to be in the range 230-280 mg/kg, which is very similar to those reported in Table 7 (mean 200 mg/kg). Thus according to Defra (2014b), "*it is not envisaged that [the] site would be determined as contaminated under Part 2A (unless there was a reason to consider otherwise)*."

3.3 REFA report for Denbigh Road

As with the Gwernaffield Road site, the Geo-Environmental Investigation Report prepared by Robert E Fry and Associates Ltd for Denbigh Road was based on the assumption that the site would be developed on a private residential basis with large areas of private gardens (REFA, 2018b). The site previously contained a factory pond and a sand and gravel quarry; it is currently being used as agricultural grazing land.

The sampling methodology states that 11 samples (at a range of depths from 0-10 cm to 0-70 cm) were taken of topsoil and made ground from soil bunds, which may be retained within the proposed residential development. The natural strata at this site were not considered to contain elevated concentrations of contaminants and hence were not sampled. All samples were analysed for PTEs (As, Cd, Cr (total), Cu, Pb, Hg, Ni, Se and Zn).

Appendix K of the report details the test results from Exova Jones Environmental and Table 8 of the report, reproduced below, shows the summary data for the 11 samples. All of the samples tested exceeded the C4SL for Pb of 200 mg/kg, and most were higher than the 300 mg Pb/kg Code of Practice limit for agricultural soils receiving sewage sludge (Table 8). In addition, many samples exceeded the sludge limit values for Zn (200 mg/kg) and Cd (3 mg/kg). However, it should be noted that the depth at which the samples were taken varied greatly and none were taken to 15cm or 7.5cm which is the standard for arable and grassland soils respectively (AHDB, 2018).

The report concluded that *"Chemical analysis has identified numerous elevated concentrations of lead within the topsoil material and therefore the topsoil and bund material is considered unsuitable for reuse within the proposed garden and landscaped areas of the development".*

The soil Pb concentrations have not been compared with normal background concentrations in the area as recommended in the Policy Companion Document for using C4SLs (Defra, 2014b). However, Table 6 indicates that normal background Pb concentrations in Wales for non-urban areas are in the range 230-280 mg/kg and in urban areas 890-1300 mg/kg. The values in Table 8 mostly exceed these background values by a large margin indicating that this site is likely to be considered as contaminated under Part 2A of the Environmental Protection Act.

Table 8: Summary of Contamination Analysis: Metals & Inorganics					
	No. of Samples	*Range of Values (mg/kg)*	*Assessment Criteria (mg/kg)*	*No. of Samples Failing*	*Locations*
Arsenic	11	6.4 – 25.1	37[3]	0	-
Cadmium	11	0.6 – 36.4	11.0[3]	2	TP01 – 0.1m, TP02 – 0.2m
Chromium (total)	11	35.4 – 77.9	910[3]	0	-
Copper	11	20.0 – 97.0	2400[3]	0	-
Lead	11	288 – 13,380	200[1]	11	All samples
Mercury	11	<0.1 – 0.4	40[3]	0	-
Nickel	11	23.5 – 47.2	180[3]	0	-
Selenium	11	<1.0 – 2.0	250[3]	0	-
Zinc	11	146.0 – 5,192	3700[3]	1	TP01 – 0.1m
Total Cyanide	11	<0.5 – 0.8	34.2[2]	0	-
Phenol	11	<0.15 – 0.24	120[3]	0	-
pH	11	4.87 – 8.37	-	0	-
SOM	11	0.46 – 8.63	-	0	-
SO_4 (2:1)	11	<0.0015 – 0.02	0.5[5]	0	-
Asbestos	2	ND	Present/Absent	0	-

[1] DEFRA : SP1010 : Category 4 Screening Levels
[2] Atkins Atrisk SSV residential without home grown produce (1% SOM)
[3] LQM and CIEH S4UL's for Human Health Risk Assessment (Registration No. S4UL 3265) residential with home grown produce (1% SOM)
[4] BRE Special Digest 1:2005 DS-1 *ND – None Detected*

Table 8. Lead, cadmium and zinc concentrations at each sampling point. Laboratory analysis data from Exova Jones taken from Appendix1 of REFA (2018b).

Sample No	Sample id	Depth (cm)	Pb (mg/kg)	Cd (mg/kg)	Zn (mg/kg)
1	TP01	10	13380	36.4	5192
2	TP02	20	12040	13.5	2265
3	TP04	30	498	1.3	285
4	TP05	20	8777	10.1	2088
5	TP04	70	9171	8.0	1565
6	TP08	10	1167	1.3	263
7	TP10	20	5261	2.9	755
8	TP11	10	288	0.6	146
9	TP13	10	3503	2.3	516
10	S1	-	2666	11.3	2263
11	S2	-	2666	4.1	668

4 AGRICULTURAL LAND CLASSIFICATION

Guidelines and criteria have been published for grading the quality of agricultural land using the Agricultural Land Classification (ALC) of England and Wales (MAFF, 1988). The ALC provides a framework for classifying land according to the extent to which it's physical or chemical (e.g. high levels of PTE's) characteristics impose long- term limitations on agricultural use.

There is no indication as to which PTE limit values should be used in the ALC assessment process. The guidelines simply state that "*Toxic elements can occur at levels which adversely affect plant growth (phytotoxicity) or are potentially harmful to animals or man (zootoxicity). The most commonly occurring toxic elements are zinc, copper, lead and cadmium although others including mercury, arsenic, nickel, chromium and fluorine are also found. High concentrations of these elements are most likely to be associated with spoil heaps from metalliferous mining, industrial waste and sewage disposal. The level of toxicity depends on the type, form and concentration of elements present and on complex chemical interactions which may be influenced by soil pH, texture and organic matter content. It is therefore not practicable to indicate precise concentrations as limits for grades or subgrades*".

The guidelines go on to say that "*the effect of soil toxicity on grading is assessed in relation to the effects on plant growth and any limitations placed on the management or use of the land, such as restrictions on cultivation (which may bring contaminated material to the surface), stocking levels or grazing periods, or on the use made of produce obtained from it. Land will not be graded higher than Subgrade 3b if it is considered to be unsuitable for growing crops for direct human consumption. Land which is limited to grass production and on which there are significant restrictions on grassland management will be no better than Grade 4. Where only extensive grazing is possible the land will be Grade 5 and, where it is unfit for all forms of agricultural production, can be regarded as non-agricultural*".

The question is, therefore, how to assess whether the land is "unsuitable for growing crops for direct human consumption". It is not appropriate to use the C4SL values, as these have been derived for different (non-agricultural) land uses and are based on outputs from exposure modelling which are not necessarily applicable or appropriate in an agricultural soil context.

Given that the soil MPCs for PTEs in the Sewage Sludge Code of Practice were developed specifically to protect agricultural soils receiving sewage sludge applications, and that they have been widely adopted and incorporated into UK guidance for landspreading other organic materials and wastes, it would seem pragmatic that these limits should be adopted when assessing ALC. Clearly, considerations such as soil pH, texture and organic matter content still need to be taken into account when making an ALC assessment, but the MPCs could be used as 'trigger values' for further investigation rather than as a rigid cut-off point for grading soils.

It is also important that any guidelines on measuring soil PTE concentrations for ALC should consider sampling methodologies. Guidance for taking topsoil samples for the assessment of pH and nutrients states that the standard depth of sampling is 15cm for arable and field vegetables, and 7.5 cm for grassland (AHDB, 2018). This is important for PTEs which are relatively immobile in soils and hence tend to accumulate in the soil surface layers when there is little or no mixing of the topsoil. Taking soil samples to a lesser depth could result in over-estimation of topsoil PTE concentrations, and vice versa. Sampling depths of 15cm for arable and 7.5cm for grassland soils when measuring soil PTE concentrations are also specified in DoE (1996), Defra (2018) and BAS (2017), although the Sludge (Use in Agriculture) Regulations SI (1989) specify a sampling depth of 25cm prior to the first application of biosolids (see Tables 1 and 2). Furthermore, both the NSI/Soil Geochemical Atlas (McGrath & Loveland, 1992; Rawlins *et al*., 2012) and the more recent G-BASE data used to derive Normal Background Concentrations (see Table 6) use a sampling depth of 0-15 cm.

It is also important to take a representative soil sample or samples following published guidelines for agricultural soils (AHDB, 2018). Furthermore, any ALC assessment should consider the spatial distribution of any PTEs that exceed agreed thresholds across the site. For example, the Gwernaffield Road site at Pwll Glas has a large contiguous block with Pb levels that do not even exceed the C4SL, let alone the Sewage Sludge Code of Practice thresholds.

5 SUMMARY AND CONCLUSIONS

- PTE concentrations in agricultural soils receiving sewage sludge are controlled by the EU Sludge Directive and implemented in the UK in The Sewage Sludge (Use in Agriculture) Regulations and The Code of Practice for Agriculture Use of Sewage Sludge.

- Controls on the amount of PTEs entering agricultural soils from livestock manures, composts, digestates, 'wastes' and other sources are often based on or refer to the limits specified for sewage sludge.

- Research published in 2012 by the EC Joint Research Council concluded that the introduction of new (lower) threshold limits to the Sludge Directive was not justified.

- PTE concentrations in potentially contaminated site are assessed against SGVs or Category 4 Screening Level Values. These were developed using the CLEA model based on exposure pathways pertaining to residential, allotment, commercial and public open space land uses. They are not intended to be used for agricultural land use situations.

- Agricultural land is graded based on the ALC scheme, which provides a framework for classifying land according to the extent to which its physical or chemical characteristics (including PTE concentrations) may limit agricultural use.

- ALC guidelines do not place specific limit values for soil PTE concentrations, but require an assessment of whether the land is "unsuitable for growing crops for direct human consumption".

- It is not appropriate to use C4SL values for ALC as these were derived for non-agricultural land uses, based on outputs from exposure modelling which are not necessarily applicable for agricultural soils.

- It would seem pragmatic that soil MPCs for PTEs specified in the Code of Practice for Agricultural Use of Sewage Sludge should be used as 'trigger values' which would initiate further investigation before deciding on the ALC classification. These were developed specifically to protect agricultural soils, and have been reviewed and deemed appropriate to protect plants, animals and humans.

- We suggest that the downgrading of land at Gwernaffield Road, Pwll-Glas based on 9 out of 20 samples exceeding the C4SL value for Pb of 200 mg/kg was not justified, because this limit refers to residential soils with home-grown produce and is not intended to be used for agricultural land. No soil samples exceeded the limit of 300 mg/kg Pb for sewage sludge applications to agricultural land.

- In addition at Pwll-Glas, soil Pb concentrations were not compared with normal background Pb concentrations in the area as recommended in policy advice. The reported values at the Gwernaffield Road site were very similar to normal background Pb concentrations for non-urban areas in Wales, thus the land is unlikely to be classified as contaminated under Part 2A of the Environmental Protection Act.
- At the Denbigh Road site, Pb concentration were considerably higher than normal background levels indicating that this part of the development site is likely to be classified as contaminated. In addition, many samples exceeded the limits for Pb, Zn and Cd in the Sludge Code of Practice suggesting that there may be grounds for downgrading the ALC of this part of the development site.

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