Llywodraeth Cymru
Welsh Government

Soil Policy Evidence Programme 2020-21

Title: ALC Technical Review (Part 4) Grading of agricultural land with elevated PTE concentrations under the Agricultural Land Classification system

Date: 6 May 2020

Report code: SPEP2020-21/05

Welsh Government

Soil Policy Evidence Programme – Report SPEP2020-21/05
ALC Technical Review (Part 4)

Grading of agricultural land with elevated PTE concentrations under the Agricultural Land Classification system

Submitted to:

Soil Policy & Agricultural Land Use Planning Unit

Land, Nature and Forestry Division

Department for Rural Affairs

Welsh Government

Prepared by:

Dr Fiona Nicholson

ADAS Gleadthorpe

Netherfield Lane

Meden Vale

Nottinghamshire

NG20 9PD

John Williams and Kirk Hill

ADAS Boxworth

Battlegate Road

Boxworth

Cambridgeshire

CB23 4NN

ADAS

Date: 6 May 2020

EXECUTIVE SUMMARY

This note provides advice on potentially toxic element (PTE) limit values to be used to inform the grading of agricultural land under the Agricultural Land Classification (ALC) system.

PTEs (or heavy metals) are often associated with pollution and toxicity, although some are essential for living organisms at low concentrations. PTEs are present in soils as a result of natural soil formation processes but may be elevated above background levels due to pollution. PTEs may also be added to agricultural soils with sewage sludge, livestock manures, composts, digestates, fertilisers, plant protection products etc. The behaviour of PTEs in soils is influenced by a number of soil properties including the clay and organic matter contents, redox conditions and soil pH. Some PTEs (e.g. cadmium and zinc) tend to be more bioavailable than others (e.g. lead). Because PTEs can be toxic to humans, animals and plants, legislation is in place to control concentrations in soils used for certain purposes.

Agricultural land, in England and Wales, is graded based on the ALC system (MAFF 1988). There are no specific limit values for soil PTE concentrations included in ALC guidance, although an assessment is required of whether the land is "unsuitable for growing crops for direct human consumption". Additional guidance is therefore required on how to assess whether the soil PTE concentrations are at a level where they are unlikely to be suitable for this purpose.

In the UK, PTE concentrations in agricultural soils receiving sewage sludge are controlled by The Sewage Sludge (Use in Agriculture) Regulations and The Code of Practice for Agriculture Use of Sewage Sludge, which have been underpinned by numerous previous research studies and risk assessments. Controls on PTEs entering agricultural soils from livestock manures, composts, digestates, 'wastes' and other sources often refer to the limits specified for sewage sludge. In contrast, where development of potentially contaminated sites is proposed, the planning system requires that PTE concentrations are assessed against Category 4 Screening Values (C4SVs). These 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.

It is not appropriate to use C4SLs for ALC grading because these values were derived for non-agricultural land uses. It is therefore recommended that the soil PTE limit values included in the Code of Practice for Agricultural Use of Sewage Sludge are used as 'trigger values' to initiate further investigation before deciding on a final classification under the ALC system.

CONTENTS

EXECUTIVE SUMMARY II

1 BACKGROUND 4

2 PTEs IN SOILS 5

3 REVIEW OF LIMITS FOR PTEs IN SOILS 7

3.1 Controls on PTEs in agricultural soils 7

3.1.1 The Sewage Sludge (Use in Agriculture) Regulations 7

3.1.2 Controls on other materials applied to agricultural land 9

3.2 PTE limits and contaminated land. 11

3.2.1 Soil Guideline Values 11

3.2.2 Category 4 Screening Levels 12

3.3 Summary 13

4 PTEs AND AGRICULTURAL LAND CLASSIFICATION 15

5 SUMMARY AND CONCLUSIONS 16

6 REFERENCES 17

BACKGROUND

This Advice Note was produced in response to a request from the Welsh Government to advise on the grading of agricultural land with elevated potentially toxic element (PTE) concentrations under the Agricultural Land Classification (ALC) system.

In this Advice Note, the limits for PTE concentrations in agricultural and non-agricultural soils are reviewed, and a recommendation is made on the most appropriate values for informing the grading of agricultural land. In addition, guidelines are provided on the sampling and analysis methods to be used for measuring soil PTE concentrations.

PTEs IN SOILS

Potentially toxic elements (PTE's) - 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, with the highest soil concentrations often occurring close to areas of historic mining and smelting activity. High concentrations can also be associated with urban areas as a result of industrial activity and the use of Pb in petrol (Rawlins *et al.*, 2012). On agricultural land, PTEs may be added to 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 soil PTE concentration data for soil samples (0-15 cm depth) collected for the National Soil Inventory (NSI) between 1978 and 1982 as described in McGrath & Loveland (1992). More recently Normal Background Concentrations (NBCs) were derived as part of a Defra-funded project (Defra, 2012b; Ander *et al*. 2013); these were based on the NSI data together with data from the BGS Geochemical Baseline Survey of the Environment (G-BASE) for rural and urban topsoils. Topsoil concentrations for selected PTEs from both sources are shown in Table 1.

Table 1. Topsoil PTE concentrations for England and Wales (mg/kg).

	Soil Geochemical Atlas of England and Wales[1]			Normal Background Concentration (principal domain)[2]	
PTE	**Mean**	**Median**	**Range**	**England**	**Wales**
Zinc	91	76	5.8 - 3359	-	-
Copper	24	19	0.76 - 1321	62	43
Nickel	23	21	0.26 - 469	42	40
Cadmium	0.52	0.33	0.14 – 48	1.0	1.4
Lead	81	49	13 – 10,000	180	230
Chromium	68	68	5.1 – 1141	-	-
Arsenic	20	15	0 - 820	32	36
Mercury	-	-	-	0.5	0.25

[1]Data from the National Soils Inventory (NSI); Rawlins *et al*. (2012).
[2]Data from the NSI and the BGS Geochemical Baseline Survey of the Environment (G-BASE); Defra (2012b), Ander *et al*. (2013). The principal domain refers to areas not associated with elevated PTE concentrations (e.g. urban).

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. Cadmium and Zn tend to be more mobile in soils and therefore more bioavailable than some other PTEs; as the soil pH decreases, so their adsorption to the soil matrix decreases and they become more available for plant uptake. In contrast, 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 (Davies, 1990; Zhao *et al*., 2004).

REVIEW OF LIMITS FOR PTEs IN SOILS

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 section provides an overview of the different regulations, controls and PTE limits for agricultural soils and contaminated land.

Controls on PTEs in agricultural soils

The Sewage Sludge (Use in Agriculture) Regulations

The only UK 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, 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 (Zn and Cd), and in addition provides recommendations on maximum permissible loading rates for chromium (Cr), molybdenum (Mo), arsenic (As), selenium (Se) and fluoride (F).

The soil MPCs are shown in Tables 2 and 3 for arable and grassland, respectively; biosolids must not be applied if it will cause PTE concentrations in the receiving soil to exceed these values. The MPCs have also 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 (MAFF/DoE, 1993a) and an Independent Scientific Committee (MAFF/DoE, 1993b) and concluded that PTE uptake by

Table 2. 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 3. 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

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, although 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 and to 300 mg/kg for soils of pH >7.0; Tables 2 and 3).

However, questions still remained about the risks to soil fertility. 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).

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 2):

- 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.

- 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 the Sludge Code of Practice.

- 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 detailed in the Sludge Code of Practice. The receiving soil should also be analysed for PTEs (Pb, Cd, Cr, Hg, Cu, Zn, Ni) to ensure that the MPCs given in 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).

Table 4. 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.

The SSVs (Table 4) 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, vanadium 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.

SSVs do not apply to biosolids recycled to land via the Sludge (Use in Agriculture) Regulations (SI, 1989) (see Section 2.2.1) or to quality compost and digestates; these are not considered to be 'wastes' and are controlled as described previously.

PTE limits and contaminated land.

Soil Guideline Values

The Environment Agency has 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.

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 5). 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.

Table 5. 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)

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 6). 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 6. 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 (Table 7). 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 7). 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 7. Normal background concentrations (NBCs) of selected PTEs (mg/kg) in England and Wales (Defra, 2014b)

PTE	Country	Principal domain	Urban domain	Mineral-isation domain 1	Mineral-isation domain 2	Iron-stone	Chalk
Arsenic	England	32		290		220	
	Wales	36	250	67			
Cadmium	England	1.0	2.1	17	2.9		2.5
	Wales	1.4	6.2		2.2		
Lead	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; d; e) and Wales (Defra, 2013a;b;c) are also available.

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 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.

Soil Guideline Values (SGVs) and 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.

PTEs AND 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 SGVs or 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 the ALC of an area of land. Clearly, considerations such as soil pH, texture and organic matter content still need to be taken into account when making an ALC assessment. For example, soil pH affects how plants take up PTEs from the soil; in acidic soil (i.e. a soil with low pH) some PTEs (e.g. Cd and Zn) are more likely to be taken up by plants. It is therefore recommended that the MPCs are used as 'trigger values' for further investigation rather than as a rigid cut-off point for grading soils.

It is also important that assessments of soil PTE concentrations for ALC should adhere to established sampling methodologies and analytical methods. For this reason, the guidance provided in the Appendix is based on (but is not identical to) the methodology for taking representative soil samples published in the Nutrient Management Guide (RB209), AHDB (2019). In addition, a soil sampling depth of 25 cm is recommended in line with the requirements of the Sludge (Use in Agriculture) Regulations (SI, 1989) and the Sewage Sludge Code of Practice (Defra, 2018), Tables 2 and 3.

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.
- 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.
- The soil MPCs for PTEs specified in the Code of Practice for Agricultural Use of Sewage Sludge were developed specifically to protect agricultural soils, and have been reviewed and deemed appropriate to protect plants, animals and humans.
- It is recommended that these MPCs should be used as 'trigger values' when assessing PTEs during ALC. If the MPCs are exceeded this should initiate further investigation before deciding on the final classification under the ALC system.
- Assessment of soil PTE concentrations for ALC should adhere to established sampling methodologies and analytical methods.

REFERENCES

AHDB (2019). *Nutrient Management Guide (RB209)*. Sections 1-7. https://ahdb.org.uk/nutrient-management-guide-rb209.

Ander, EL, Johnson CC, Cave, MR, Palumbo-Roe, B, Nathanail, P & Lark, RM. (2013). Methodology for the determination of normal background concentrations of contaminants in English soil. *Science of the Total Environment*, 454–455, 604-618.

BAS (2017). *Biosolids Assurance Scheme. The Scheme Standard*. Issue number 4. Assured Biosolids Limited, 13 November 2017. https://assuredbiosolids.co.uk/wp-content/uploads/2018/04/BAS-STANDARD-Issue-4-Online-version.pdf

Charlton A, Sakrabani R, Tyrrel S, Casado MR, McGrath S, Crooks B, Cooper P & Campbell C (2016a). Long-term impact of sewage sludge application on soil microbial biomass: An evaluation using meta-analysis. *Environmental Pollution*, 219, 1021-1035.

Charlton A, Sakrabani R, McGrath S & Campbell C (2016b). Long-term impact of sewage sludge application on *Rhizobium leguminisorum* biovar *trifolii* – an Evaluation using Meta-Analysis. *Journal of Environmental Quality*, doi:10.2134/jeq2015.12.0590

Davies, B. E. (1993). Lead. In: *Heavy Metals in Soils* (Ed. B. J. Alloway). London, Blackie.

Defra (2009). *Protecting our Water, Soil and Air. A Code of Good Agricultural Practice for farmers, growers and land managers*. TSO, Norwich. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/268691/pb13558-cogap-131223.pdf

Defra (2012a). *Environmental Protection Act 1990: Part 2A. Contaminated Land Statutory Guidance*. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/223705/pb13735cont-land-guidance.pdf

Defra (2012b). *Establishing data on background levels of contamination - SP1008*. Final Report. Department for Environment Food and Rural Affairs (Defra), Soils R&D Project SP1008. http://sciencesearch.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=17768

Defra (2012c). *Technical Guidance Sheet on normal levels of contaminants in English soils: Arsenic*. Technical Guidance Sheet No. TGS01, July 2012. Department for Environment Food and Rural Affairs (Defra), Soils R&D Project SP1008. Available on-line from Defra project SP1008 web page.

Defra (2012d). *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.

Defra (2012e). *Technical Guidance Sheet on normal levels of contaminants in English soils: Lead*. Technical Guidance Sheet No. TGS02, July 2012. Department for Environment Food and Rural Affairs (Defra), Soils R&D Project SP1008. Available on-line from Defra project SP1008 web page.

Defra (2013a). Technical Guidance on normal levels of contaminants in Welsh soil: Arsenic. British Geological Survey (Keyworth, Nottingham) and Defra (London). R & D Project SP1008, January 2013. Available on-line from Defra project SP1008

Defra (2013b). Technical Guidance on normal levels of contaminants in Welsh soil: Cadmium. British Geological Survey (Keyworth, Nottingham) and Defra (London). R & D Project SP1008, January 2013. Available on-line from Defra project SP100

Defra (2013c). *Technical Guidance on normal levels of contaminants in Welsh soil: Lead*. British Geological Survey (Keyworth, Nottingham) and Defra (London). R & D Project SP1008, January 2013. Available on-line from Defra project SP1008 web page.

Defra (2014a). *SP1010 – Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination*. Final Project Report (Revision 2). http://randd.defra.gov.uk/Default.aspx?Module=More&Location=None&ProjectID=18341

Defra (2014b). *SP1010 – Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination. Policy Companion Document*. http://randd.defra.gov.uk/Default.aspx?Module=More&Location=None&ProjectID=18341

Defra (2018). *Sewage Sludge in Agriculture: Code of Practice*. https://www.gov.uk/government/publications/sewage-sludge-in-agriculture-code-of-practice

DoE (1996). *Code of Practice for Agricultural Use of Sewage Sludge*. Available from: http://webarchive.nationalarchives.gov.uk/20130402151656/http://archive.defra.gov.uk/environment/quality/water/waterquality/sewage/documents/sludge-cop.pdf

EA (2004). *Model Procedures for the Management of Land Contamination*. Contaminated Land Report 11. https://webarchive.nationalarchives.gov.uk/20140328160926/http:/cdn.environment-agency.gov.uk/scho0804bibr-e-e.pdf

EA (2009a). *Using Soil Guideline Values*. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/297676/scho0309bpqm-e-e.pdf

EA (2009b). *Human Health Toxicological Assessment of Contaminants in Soil.* Science Report – Final SC050021/SR2. https://webarchive.nationalarchives.gov.uk/20140328160926/http:/cdn.environment-agency.gov.uk/scho0804bibr-e-e.pdf

EA (2009c). *Updated Technical Background to the CLEA Model*. Science Report – Final SC050021/SR3. https://webarchive.nationalarchives.gov.uk/20140328153908/http://www.environment-agency.gov.uk/static/documents/Research/CLEA_Report_-_final.pdf

EA (2013). *How to comply with your landspreading permit*. TGN EPR 8.01. Bristol. Environment Agency.

EA (2017). *Derivation and Use of Soil Screening Values for Assessing Ecological Risks*. Report – ShARE id26. Bristol. Environment Agency.

EC (2012). *Occurrence and Levels of Selected Compounds in Europe Sewage Sludge Samples*. Results of a Pan-European Screening Experience (FATE SEES). Available at http://ec.europa.eu/dgs/jrc/downloads/jrc76111_lb_na_25598_en_n.pdf

EEC (1986). *Council Directive No. 86/278/EEC (OJ No. L181/6) on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture*. https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:31986L0278

Gibbs, P.A., Chambers, B.J., Chaudri, A.M., McGrath, S,P. & Carlton-Smith, C.H. (2006a). Initial results from long-term field studies at three sites on the effects of heavy metal-amended liquid sludges on soil microbial activity. *Soil Use and Management* 22, 180-187

Gibbs, P.A., Chambers, B.J., Chaudri, A.M., McGrath, S.P., Carlton-Smith, C.H., Bacon, J.R., Campbell, C.D. & Aitken, M.N. (2006b). Initial results from a long-term, multi-site field study of the effects on soil fertility and microbial activity of sludge cakes containing heavy metals. *Soil Use and Management* 22, 11-21.

MAFF (1988). *Agricultural Land Classification of England and Wales. Revised guidelines and criteria for grading the quality of agricultural land.* http://publications.naturalengland.org.uk/publication/6257050620264448

MAFF/DoE (1993a). *Review of the Rules for Sewage Sludge Application to Agricultural Land: Food Safety and Relevant Animal Health Aspects of Potentially Toxic Elements: Report of the Steering Group on Chemical Aspects of Food Surveillance*. PB 1562. MAFF Publications, London.

MAFF/DoE (1993b). *Review of the Rules for Sludge Application to Agricultural Land: Soil Fertility Aspects of Potentially Toxic Element*s. *Report of the Independent Scientific Committee*. MAFF/DoE, November 1993, 91pp.

McGrath, S. P. & Loveland, P. J. (1992). *The Soil Geochemical Atlas of England and Wales*. London: Blackie

Nicholson F. A., Smith, S. R., Alloway B. J., Carlton-Smith, C. & Chambers, B. J. (2003). An inventory of heavy metals inputs to agricultural soils in England and Wales. *Science of the Total Environment* 311, 205-219.

Rawlins, B G, McGrath, S P, Scheib, A J, Breward, N, Cave, M, Lister, T R, Ingham, M, Gowing, C and Carter, S. (2012). *The Advanced Soil Geochemical Atlas of England and Wales*. Keyworth, Nottingham: British Geological Survey.

SI (1989). *The Sludge (Use in Agriculture) Regulations*. No. 1263. http://www.legislation.gov.uk/uksi/1989/1263/contents/made

SI (2016). *The Environmental Permitting (England and Wales) Regulations 2016*. No. 1154. http://www.legislation.gov.uk/uksi/2016/1154/contents/made

WRAP/EA (2009). *Quality Protocol. Anaerobic Digestate*. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/292473/426765_EA_QP_Anaerobic_Digestate_web.pdf

WRAP/EA (2012). *Quality Protocol. Compost*. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/297215/geho0812bwpl-e-e.pdfUse Appendix Body Text style for references so that it is not indented.

Zhao, F. J., Adams, M. L., Dumont, C., McGrath, S. P., Chaudri, A. M, Nicholson, F. A. Chambers, B. J. & Sinclair, A. H. (2004). Factors affecting the concentration of lead in British wheat and grain. *Environmental Pollution* 131, 461-468.

APPENDIX: Guidance for using soil PTE concentrations to inform Agricultural Land Classification grading.

These Guidelines provide a brief summary of the processes that should be followed when grading land using the Agricultural Land Classification (ALC) system which may contain 'elevated' soil potentially toxic element (PTE) concentrations.

Soil sampling for PTE determination is not required in all cases, but only where there are strong grounds for believing that PTE concentrations may be elevated above normal background levels e.g. there is a history of mining or industrial activity in the area.

1. Soil sampling for PTE determination

Soil samples should be taken in accordance with established protocols for sampling agricultural soils as detailed below:

- The timing of soil sampling is not critical (as it is with nutrients) because soil PTE concentrations generally do not change rapidly. However, it is advisable not to sample within six weeks of an organic material (e.g. livestock manure, sewage sludge, compost) application.
- Avoid sampling when the soil is very dry or very wet.
- Do not take samples where muck heaps or feeders have been, in headlands, or in the immediate vicinity of hedges, trees or other unusual features.
- The soil sample must be representative of the area sampled. Areas of land known to differ in some important respects (e.g. soil type) should be sampled separately.
- Ideally, the sampled area should be no larger than 5 hectares. If the area being graded is larger than this, then additional samples will be required. For example, if an area of 20 ha is being assessed then 4 samples will be required.
- Clean tools before starting and before sampling a new area.
- Walk a 'W' pattern across the sampling area, stopping at least 25 times.
- At each point, collect a subsample (core) using a gouge corer or screw auger to a depth of 25 cm or the depth of the soil, whichever is less.
- The subsamples should be bulked to form a representative sample of around 0.5 - 1.0 kg.
- The samples should be sent to the laboratory for analysis of pH and the following PTEs : zinc (Zn), cadmium (Cd), lead (Pb), copper (Cu), mercury (Hg), nickel (Ni), chromium (Cr), molybdenum (Mo), arsenic (As), selenium (Se) and fluoride (F).
- Ensure that a suitably accredited laboratory is used for the analysis. Note that not all laboratories offering routine soil analysis for pH and nutrients will provide PTE analysis.
- Use appropriate packaging (normally available from the laboratory) and label samples clearly, providing as much information as possible about the area from which each sample was taken.

2. Interpreting and acting on laboratory results

The PTE concentrations found in the soil samples need to be assessed against the maximum permissible concentrations (MPCs). If the sampled soils approach or exceed the MPCs, then further action is required before an ALC grade can be assigned.

- Ensure that the soil PTE concentrations provided by the laboratory are reported in the correct units (i.e. mg/kg dry soil) to allow comparison with the MPCs.
- Compare the laboratory results for soil PTE concentrations with the MPCs detailed in the tables below. Table 1 should be used for soil samples taken from arable fields, and Table 2 for soil samples taken from grassland fields. The soil pH values reported by the laboratory should be used to determine the appropriate MPC to be used for comparing the Zn, Cu and Ni concentrations.

Table 1. Maximum permissible concentrations of PTEs in arable soils (mg/kg dry soil).

	Maximum permissible soil concentration			
	pH 5.0<5.5	pH 5.5<6.0	pH 6.0-7.0	pH >7.0
Zinc	200	200	200	300
Copper	80	100	135	200
Nickel	50	60	75	110
	For pH 5.0 and above			
Cadmium	3			
Lead	300			
Mercury	1			
Chromium	400			
Molybdenum	4			
Selenium	3			
Arsenic	50			
Fluoride	500			

Table 2. Maximum permissible concentrations of PTEs in grassland soils (mg/kg dry soil).

	Maximum permissible soil concentration			
	pH 5.0<5.5	pH 5.5<6.0	pH 6.0-7.0	pH >7.0
Zinc	200	200	200	300
Copper	130	170	225	330
Nickel	80	100	125	180
	For pH 5.0 and above			
Cadmium	3			
Lead	300			
Mercury	1.5			
Chromium	600			
Molybdenum	4			
Selenium	5			
Arsenic	50			
Fluoride	500			

- If any of the measured PTE concentrations in any of the soil samples is greater than or equal to the MPC, then a further investigation should be conducted to determine if there are other factors which need to be taken into consideration before assigning an ALC grade (see below).
- If the measured PTE concentrations in the soil samples are less than the MPC, then the ALC grade assigned will not be affected by the soil PTE concentrations.

3. Further investigation

The followings section provides guidance of what to do when further investigation is required because soil PTE concentrations are equal to or exceed the MPC value.

- The investigation should consider whether the measured PTE concentrations at the site are in line with ‘typical‘ or normal background concentrations in the surrounding area (see Table 3). More information and maps of soil PTE distribution can be found on the British Geological Society (BGS) website.

Table 3. Topsoil PTE concentrations for England and Wales (mg/kg dry soil).

	Soil Geochemical Atlas of England and Wales[1]			Normal Background Concentration (principal domain)[2]	
PTE	**Mean**	**Median**	**Range**	**England**	**Wales**
Zinc	91	76	5.8 - 3359	-	-
Copper	24	19	0.76 - 1321	62	43
Nickel	23	21	0.26 - 469	42	40
Cadmium	0.52	0.33	0.14 – 48	1.0	1.4
Lead	81	49	13 – 10,000	180	230
Chromium	68	68	5.1 – 1141	-	-
Arsenic	20	15	0 - 820	32	36
Mercury	-	-	-	0.5	0.25

[1]Data from the National Soils Inventory (NSI)

[2]Data from the NSI and the BGS Geochemical Baseline Survey of the Environment (G-BASE). The principal domain refers to areas not associated with elevated PTE concentrations (e.g. urban).

- The spatial distribution of the PTE concentrations should be considered, to determine whether the elevated levels are restricted to certain parts or if the whole area if affected. This may require further soil samples to be taken.
- The investigation should also take into account other soil properties such as pH, organic matter content and clay content which are known to affect the bioavailability (i.e. plant uptake) of some PTEs. This will therefore have a bearing on the suitability of the land for growing crops for direct human consumption and hence its ALC grade.
- Because the investigation requires in depth knowledge of PTE behaviour in soils and involves potentially complex soil-plant interactions, it is strongly recommended that a FACTS qualified soil scientist with appropriate expertise is consulted before reaching a final decision on grading.

Further information

Further information on soil sampling can be obtained from the following sources:

https://ahdb.org.uk/nutrient-management-guide-rb209.

http://www.nutrientmanagement.org/paag-sampling-guide-routine-samples-oct-2013/

A list of laboratories offering various services can be found here:

http://www.nutrientmanagement.org/what-we-do/support-and-advice/find-a-laboratory/

Information on maximum permissible concentrations of PTEs in agricultural soils where sewage sludge is applied can be found on the Biosolids Assurance Scheme or the Defra websites:

https://assuredbiosolids.co.uk/wp-content/uploads/2018/04/BAS-STANDARD-Issue-4-Online-version.pdf

https://www.gov.uk/government/publications/sewage-sludge-in-agriculture-code-of-practice

More information on soil PTE concentrations in England and Wales can be obtained from the British Geological Society (BGS):

https://www.bgs.ac.uk/gbase/advSoilAtlasEW.html

https://www.bgs.ac.uk/gbase/home.html