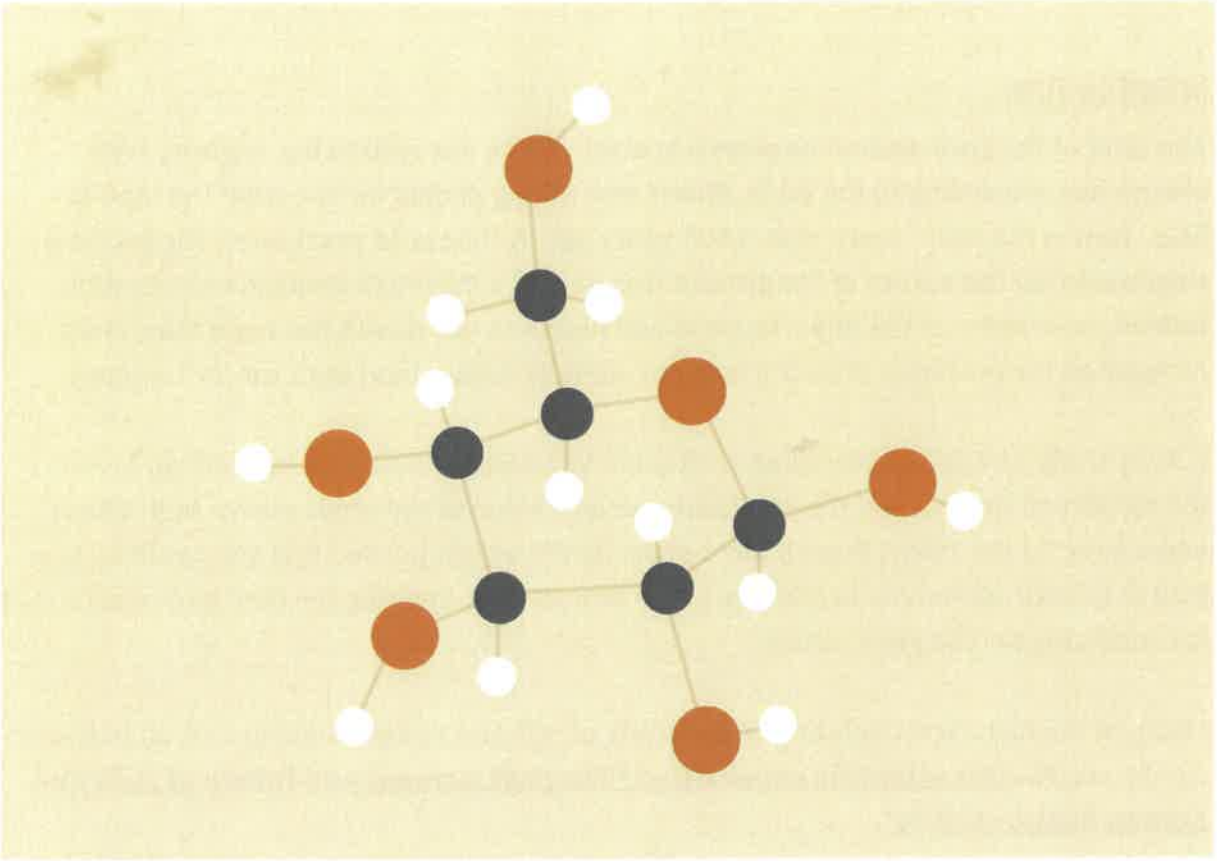
STANDARD CONTAMINATION TEST SUITE REPORT

Linda Symons - 7A Coppetts Rd, London, N10 1NN (Samples taken by hand)



Prepared by Safe Soil UK

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LONDON, UK

SUMMARY

Please find below the results of your sample soil testing. We include a table with a summary of your resulting values and use a colour code whereby green is below standard guideline values, orange signifies at or near some or all of the guidelines and red suggests a reading that is above guide thresholds. An explanation behind the rationale for various screening guidelines and an in-depth look at the elements included in your testing suite follow.

INTRODUCTION

The state of the land around us plays a crucial part in our well-being, it pretty well always has. According to the Bible, Moses was telling people to "see what the land is like…how is the soil?" more than 3,000 years ago. A thousand years later, Hippocrates suggested that the nature of the ground was part of a thorough medical examination. Indeed, awareness of the importance of soil health to our health has been inherently recognised for centuries even if it was not actually understood until the 20th century.

A 1921 study by English physician Sir Robert McCarrison made the connection between the fertility of the soil and the resultant nutrient value of the crops grown in it. Thirty years later, in the 1950s, French biochemist Andre Voisin posited that soil could be the source of toxic amounts of elements to the human diet, opening the door to research that is continuing to take place today.

More on the historical evolution of the study of soil and its relationship to human health can be read in **this scientific paper titled "The past, present and future of soils and human health studies".**

Our understanding of this process continues to evolve but we know that there are three ways in which humans can be exposed to elements in the soil: ingestion, absorption via the skin and inhalation. All three are considered when government agencies and scientists try to determine how much of something is harmful.

Understanding which soil elements pose the greatest risk to our health is also the subject of ongoing study and research. There's no disputing that the UK's industrial heritage has left behind a legacy of contaminated land. We are descendants of a people who were at

the sharp end of the industrial revolution and while this played an important part in establishing the living standards that we now enjoy, there was a darker downside as the very industrial processes and activities that made Britain one of the wealthiest nations on earth also released substances and waste products into the environment that have the potential to damage our health.

As a society we have come to generally accept that water and air pollution are damaging to our health, but we have been much slower in coming to understand – and accept – that soil contamination can have a similarly damaging impact. This is changing.

A European Commission report into the impacts on human health of soil contamination sums up some of the common risks:

"Health problems from cancers (arsenic, asbestos, dioxins), to neurological damage and lower IQ (lead, arsenic), kidney disease (lead, mercury, cadmium), and skeletal and bone diseases (lead, fluoride, cadmium) are serious issues, that in many cases we have yet to address. Heavy metals and persistent organic chemicals are of particular concern. Human activity introduces heavy metals (such as cadmium, arsenic and mercury) to our soils through mining, smelting, industry, agriculture and burning fossil fuels. Our disposal of materials containing heavy metals – a long list which includes paint, electronic waste, and sewage – also contributes to the burden of heavy metal contamination. Organic chemicals are also part of our industrial legacy, and many are still widely used today."

That report in full can be read here.

RESULTS IN BRIEF

Please find below a summary of results for Order No. 11016A&B (Pls note samples were collected by SSUK team on 23/07/26 with A for area to right of driveway [north] and B corresponding to opposite side):

LEGEND

Green - Indicates result is below standard guideline values.
Orange - Signifies result at or near some or all of the guidelines.
Red - Suggests a reading that is above guide thresholds.

TEST	METHOD	UNITS	RESULT A	RESULT B
Arsenic (total)	CM127M	mg/kg As	14.1	38.0
Cadmium (total)	CM127M	mg/kg Cd	2.3	<1.1
Calcium (total)	CM119	mg/kg Ca	15300	18100
Chromium (total)	CM127M	mg/kg Cr	22.7	20.2
Chromium (III)	CE208	mg/kg CrIII	22.7	20.2
Chromium (VI)	CE146	mg/kg CrVI	<0.04	<0.04
Copper (total)	CM127M	mg/kg Cu	183	64.4
Iron (total)	CM127	mg/kg Fe	7410	4860
Lead (total)	CM127M	mg/kg Pb	1260	396
Mercury (total)	CM127M	mg/kg Hg	<0.6	<0.6
Nickel (total)	CM127M	mg/kg Ni	16.5	12.7
Selenium (total)	CM127M	mg/kg Se	<3.0	<3.0
Zinc (total)	CM127M	mg/kg Zn	405	227
Ammonia	CE144	mg/kg N	13.4	14.9
Cyanide (total)	CE077	mg/kg CN	<1.0	<1.0
Phenols (total)	CE078	mg/kg PhOH	1.05	<0.50

PAHS				
Naphthalene	CE087M	mg/kg	0.096	0.147
Acenaphthylene	CE087M	mg/kg	0.128	0.175
Acenaphthene	CE087M	mg/kg	0.221	0.151
Fluorene	CE087U	mg/kg	0.179	0.134
Phenanthrene	CE087M	mg/kg	2.96	2.91
Anthracene	CE087U	mg/kg	0.783	0.776
Fluoranthene	CE087M	mg/kg	7.39	9.08
Pyrene	CE087M	mg/kg	6.24	7.67
Benzo(a)anthracene	CE087U	mg/kg	3.51	4.40
Chrysene	CE087M	mg/kg	3.07	4.11
Benzo(b)fluoranthene	CE087M	mg/kg	4.45	5.97
Benzo(k)fluoranthene	CE087M	mg/kg	1.83	2.21
Benzo(a)pyrene	CE087U	mg/kg	3.88	4.77
Indeno(123cd)pyrene	CE087M	mg/kg	3.72	4.93
Dibenz(ah)anthracene	CE087M	mg/kg	0.691	0.901
Benzo(ghi)perylene	CE087M	mg/kg	2.48	3.36

PAH (total of USEPA 16)	CE087	mg/kg	41.6	51.7
BTEX and TPH				
Benzene	CE192U	mg/kg	<0.01	<0.01
Toluene	CE192U	mg/kg	<0.01	<0.01
Ethylbenzene	CE192U	mg/kg	<0.01	<0.01
m & p-Xylene	CE192U	mg/kg	<0.02	<0.02
o-Xylene	CE192U	mg/kg	<0.01	<0.01
TPH (>C10-C40)	CE033M	mg/kg	581	637
Asbestos (qualitative)	-	-	No Asbestos Detected	No Asbestos Detected

METHODOLOGY BEHIND THE VALUES

The following from the Environment Agency and Defra provides some of the background and methodology behind the UK values we use.

England has a considerable legacy of historical land contamination from a wide range of substances. Nearly all soils have some small presence of substances that could be called 'contaminants' (for example, as a result of underlying geology or diffused air pollution). However, the sites most likely to pose an unacceptable risk almost always result from site-specific industrial pollution and waste disposal activities (for example, from the oil, gas, steel, mining and chemicals manufacturing industries, landfills and illegal chemical dumps).

More from Defra's Development of Category 4 Screening Levels for Assessment of Land

Affected by Contamination – Policy Companion Document **can be read here**.
In November 2006, the Department for Environment, Food and Rural Affairs (Defra) issued a discussion paper entitled Soil Guideline Values: The Way Forward (Defra, 2006a). The paper sought views from key organisations and groups on various ideas for how non-statutory technical guidance might be amended to make it more useful to assessors carrying out risk assessments, and to make clearer when land qualifies as contaminated land under Part 2A of the Environmental Protection Act 1990 in England and Wales. This exercise culminated in the publication by Defra of:

- Improvements to contaminated land guidance. Outcome of the "Way Forward" exercise on Soil Guideline Values (Defra, 2008a);
- Guidance on the legal definition of contaminated land (Defra, 2008b).

"We have produced framework documents that provide a methodology to help risk assessors develop generic assessment criteria to evaluate whether a child or adult might be exposed to harmful or potentially harmful levels of a chemical on a given site over a long period of exposure.

"In addition to the framework reports we are publishing Soil Guideline Values (SGV) reports for a selection of common contaminants relevant to the assessment of land contamination. We have selected these chemicals, in consultation with industry and the former Soil Guideline Value Task Force, because they are likely to be found on a large number of contaminated sites in the UK and have the potential to affect human health."

The SGV technical notes explain how the framework documents and individual chemical toxicology (TOX) reports have been used to derive SGVs.

Soil Guideline Values (SGVs) and the framework documents provide relevant, appropriate, authoritative and scientifically based information and advice on the assessment of risks to human health from land contamination. They provide non-statutory technical guidance to regulators and their advisors in support of the statutory regimes addressing land contamination, particularly Part 2A of the Environmental Protection Act 1990 and the consideration of land affected by contamination under the Town and Country Planning Acts (Defra 2008a, 2008b).

When we refer in this report to terms that are subject to legal definitions under Part 2A, we will use italics (for example, contaminated land).

What are Soil Guideline Values?

SGVs are scientifically based generic assessment criteria that can be used to simplify the assessment of human health risks arising from long-term and on-site exposure to chemical contamination in soil. They do not, however, consider risks to construction workers or risks from occupational exposure arising from activities in the workplace.

SGVs are a screening tool for the generic quantitative risk assessment of land contamination (Defra and Environment Agency, 2004). They are not (unless clearly stated otherwise) relevant for assessing risks to human health from short-term exposure to chemicals in soil including injury arising from direct bodily contact and do not take account of other types of risks to humans such as explosion or suffocation risks (associated with the build-up of gases such as methane and carbon dioxide) or aesthetic issues such as odour or colour.

SGVs do not take account of other non soil based sources of contamination such as contamination in groundwater, surface waters or drinking waters. They cannot be used to evaluate risks to non-human receptors such as controlled waters, ecosystems, buildings and services, domestic pets or garden plants. Where, for example, phytotoxic effects are an important consideration in the current or future intended land use further investigation should be undertaken.

SGVs are guidelines on the level of long-term human exposure to individual chemicals in soil that, unless stated otherwise, are tolerable or pose a minimal risk to human health. They represent "trigger values" – indicators to a risk assessor that soil concentrations above this level may pose a possibility of significant harm to human health (Defra, 2008b). Significance is linked to:

- the margin of exceedance;
- the duration and frequency of exposure;
- other site-specific factors that the enforcing authority may wish to take into account.

SGVs do not of themselves represent the threshold at which there is a significant possibility of significant harm (SPOSH). Nor do they automatically represent an unacceptable intake in the context of Part 2A of the Environmental Protection Act 1990.

However, they can be a useful starting point for such an assessment.

Science alone cannot answer the question of whether or not a given possibility of significant harm is significant, since what is either "significant" or "unacceptable" is a matter of socio-political judgement. The law entrusts decisions on this to the enforcing authorities (Defra, 2008b).

SGVs are not derived explicitly to be used as remediation standards. The process for setting remedial objectives and standards for remediation is outlined in CLR 11 (Defra and Environment Agency, 2004). Further guidance is also available on required remediation standards under Part 2A (Defra 2006b) and planning (ODPM 2004b).

SGVs can be used as a starting point for evaluating long-term risks to human health from chemicals in soil. SGVs can be used as an indication of chemical contamination in soil below which the long-term human health risks are considered to be tolerable or minimal.

SGVs do not represent the "trigger" for an unacceptable intake. Unless specifically stated, SGVs do not cover other types of risk to humans such as fire, suffocation or explosion, or short term and acute exposures.

SGVs cannot be used to evaluate risks to construction workers or non-human receptors. SGVs are not explicitly derived to define remediation standards.

Representative site soil concentrations at or below an SGV indicate that it is unlikely that a significant possibility of significant harm exists.

Representative site soil concentrations above an SGV might represent a significant possibility of significant harm. Further investigation and/or more detailed evaluation of human health risks will usually need to be conducted.

These have since been partially replaced by the Category 4 Screening Levels (C4SLs) introduced in March 2014 for some elements. These consist of estimates of contaminant concentrations in soil that are considered to present an "acceptable" level of risk. Its aim is described as follows: "The new statutory guidance will bring about a situation where the current SGV/GACs are replaced with more pragmatic (but still strongly precautionary) Category 4 screening levels (C4SLs) which will provide a higher simple test for deciding that land is suitable for use and definitely not contaminated land."

More on this, much more, is available here.
In 2014, the Chartered Institute of Environmental Health (CIEH) Generic Assessment Criteria for Human Health Risk Assessment adopted the Environment Agency's CLEA UK Model and Category 4 Screening Levels and in conjunction with Land Quality Management Ltd (LQM) derived guideline values that are compatible with current UK legislation, policy and technical guidance in the form of LQM/CIEH S4ULs (Suitable 4 Use Levels).

The methodology for deriving both the Soil Guideline Values and the new S4ULs is based on the Environment Agency's Contaminated Land Exposure Assessment (CLEA) methodology.

S4ULs are based on "minimal or tolerable risk" that are intended to be protective of human health for individual or mixtures of substances. Please note that this does NOT necessarily mean that the risk is unacceptable because "many conservative assumptions are included in the derivation of the S4ULs".

S4ULs are in place for some heavy metals, BTEX substances, Petroleum Hydrocarbons and Polycyclic Aromatic Hydrocarbons as well as a number of selected organic compounds. The S4ULs for residential use with home grown produce are used where they are available.

Where there is no official guidance from UK authorities on trigger values, we have looked further afield, including the European Union, the United States Environmental Protection Agency, the World Health Organization, Canada and Australia. Where these values are used, we identify the source material.

TEST SUITE ELEMENTS IN DETAIL

ARSENIC
Symbol: As
Atomic number: 33

Arsenic is a naturally occurring element that is also used in some man-made products,

for photography, photocopying, dyeing, calico printing, vacuum tube manufacture, galvanoplasty, lubricants, ice-nucleation agents, and in the manufacture of special mirrors.

- Following long-term exposure to cadmium, the main health concerns are its toxicity to the kidney and bones, arising via ingestion and inhalation, and its lung carcinogenicity seen in exposed workers following inhalation.

- Cadmium build-up also affects vitamin D metabolism, disturbing the calcium balance within the body, which may lead to a decrease in the mineral content within the bones, resulting in osteoporosis and Osteomalacia.

- Cadmium occurs naturally in soils as a result of the weathering of the parent rock.

- Anthropogenic (human) sources of cadmium are much more significant than natural emissions and account for its ubiquitous presence in soil.
- Cadmium is a trace element in phosphatic fertilisers, which have been applied extensively to arable and pasture land in the UK for decades.
- Atmospheric deposition is also an important source of cadmium pollution. The major sources of atmospheric emissions are non-ferrous metal production, fossil fuel combustion, waste incineration, and iron and steel production.
- Other sources of cadmium contamination include the application of sewage sludge, and metalliferous mining and smelting of zinc and sulphide ores.

- Although these are relatively small contributors to global cadmium pollution, these sources can be regionally and locally highly significant. For example, the soils of a village in southwest England were found to be highly contaminated with zinc, lead and cadmium as a result of the local mining of zinc during the 18th and 19th centuries.

- Adsorption of cadmium by soil depends strongly on pH, with its mobility decreasing with increasing alkalinity.

- Plant species and cultivars differ widely in their ability to uptake, accumulate and tolerate heavy metals including cadmium. Lettuce, spinach, celery and cabbage are reported to accumulate cadmium while potatoes, french beans and peas take up only small amounts.

- Several studies have concluded that soil pH is the most important factor controlling plant uptake and that this is linked to the concentration of cadmium in soil solution. Liming soil to increase pH to 7 and above has been shown to reduce the mobility and plant availability of cadmium in different soils.

- Plants have no metabolic requirement for cadmium and the symptoms of its toxicity include stunted growth and chlorosis (loss of normal green colouration). The phytotoxicity of cadmium is due to its interference with the normal metabolism of some micronutrients, its inhibitory effect on photosynthesis, its ability to disturb the transpiration and fixation of carbon dioxide, and its effect on the permeability of cell membranes.

- Several recent studies have recognised the potential importance of house dust as a route for exposure to cadmium.

Did you know?

Itai-Itai Disease (in Japanese "It hurts-It hurts" disease or "ouch-ouch" disease) was coined by residents of Toyama Prefecture who were affected by mass cadmium poisoning starting in the early 20th century and resulting from mining in the area. Those affected developed severe pain of the joints and spine as their bones became softer and increasingly brittle. A local mine had released cadmium in substantial quantities into a nearby river, which was used to irrigate rice fields. The cadmium was absorbed by the rice and accumulated in the people who ate it.

Soil Guideline Values

Cadmium concentrations in soil are measured in parts per million or milligrams per kilogram (mg kg).

The SGVs apply only to cadmium and its inorganic compounds. For residential and

including pesticides and ammunition. Low levels of it are found in soil, water and air. Arsenic is taken up by plants as they grow, which means it can make its way into our food. Although it is commonly described as a heavy metal, arsenic is a metalloid with a complex chemistry.

It is also a carcinogen.

Selected excerpts from the Environment Agency's technical notes on Arsenic in soil follow:

- Due to its known toxicity, use of arsenic in many applications has either been banned or phased out. Most arsenic is currently used to produce copper chrome arsenate (CCA), a wood preservative and pesticide.

- In 2003, the UK was reported to be the largest consumer of CCA in the European Union at 15,000 tonnes per year and the location of three of the four manufacturing plants.

- Historically, inorganic arsenic compounds including calcium arsenate, lead arsenate and sodium arsenite have been used as pesticides. In particular, lead arsenate has been used for pest control in fruit orchards.

- Long-term exposure produces lung tumors via inhalation and a range of cancers via the oral route (most clearly cancer of the skin, bladder and lung). Absorption through the inhalation route depends primarily on the particle size and solubility.

- Arsenic occurs naturally in soils as a result of the weathering of the parent rock. Although it occurs in igneous rocks, the greatest concentrations tend to be found in argillaceous sedimentary rocks (e.g. shales and mudstones) and in heavily sulphidic mineralised areas.

- Anthropogenic (human) activity has resulted in the widespread atmospheric deposition of arsenic from the burning of coal and the smelting of non-ferrous metals including copper.

- Agricultural practice including the historical use of arsenic-based pesticides and ongoing application of fertilisers, sludges and manures containing arsenic has resulted in the accumulation of arsenic in topsoils.

- In parts of Devon and Cornwall, a long history of mining tin, copper and arsenic has resulted in soil and water pollution arising from mine tailings and other wastes.

- The Soil and Herbage Survey (UK SHS) is a comprehensive survey of the concentrations of major contaminants in soils and herbage across the UK. The UK SHS found total arsenic concentrations in the range of 0.5 to 143 mg kg–1 dry weight (DW) for rural soils, with a mean of 10.9 mg kg–1 DW.

- There was considerable geographical variation across the UK, with higher mean concentrations in England and Wales (13.9 and 14.7 mg kg–1 DW respectively) than in Scotland and Northern Ireland.

- Although the UK SHS reported a mean arsenic concentration for urban soils (11 mg kg–1) similar to rural levels, the reported range from 1.75 to 32 mg kg–1 was much narrower.

- Natural geology and the impact of extensive mining activity have resulted in elevated arsenic levels in several regions of the UK. A median arsenic concentration in garden soils in the town of Camborne, Cornwall, of 320 mg kg–1 DW, the result of extensive regional mining activity. In Northamptonshire and Lincolnshire, elevated soil concentrations of total arsenic are associated with the underlying ironstone lithology.

Did you know?

As a result of its use by the ruling class to murder one another as well as its potency and discreetness, arsenic has been called the "poison of kings" and the "king of poisons," writes John Eric Holmyard in his book *Makers of Chemistry*.

During the Victorian era, British women maintained their prized pale complexions with the "help" of Rose's Arsenic Complexion Wafers, white chalk wafers filled with arsenic.

allotment land uses, SGVs are based on estimates representative of lifetime exposure.

Values (mg kg–1 Dry Weight):
Residential 10

Allotment 1.8

Commercial 230

Full EA guidance note is here.

These have since been replaced by the so-called Category 4 Screening Levels (C4SLs), which are as follows for cadmium:

Residential with homegrown produce: 26
Residential without homegrown produce: 149
Allotment: 4.9
Commercial: 10

The LQM/CIEH S4ULs for cadmium in soils with 6% organic matter are as follows:
Residential with homegrown produce: 11
Residential without homegrown produce: 85
Allotment: 1.9
Commercial: 190

CALCIUM
Symbol: Ca
Atomic number: 20

A grey silver alkaline earth metal, Calcium is the fifth most-abundant element in the earth's crust and after iron and aluminum the third most-common metal.

It should be noted that calcium is never found in this isolated state in nature. Instead, it exists in compounds, which can be found in a variety of materials including fluorite (calcium fluoride), limestone (calcium carbonate) and gypsum (calcium sulfate).

However, calcium is not included here for any potential toxicity or health risk to humans - or even for its importance to soil health (too much calcium can make soils more alkaline, eventually limiting plants' ability to take up other nutrients while a calcium deficiency can result in physiological disorders such as necrosis around the tips of young leaves and fruit and bulb abnormalities).

Rather, it is its potential relationship with a heavy metal on this list, namely cadmium.

According to a scientific paper published in 2015, calcium (Ca) and cadmium (Cd) are "antagonistic ions competing for uptake in plants when they co-occur in soil solutions, and high Ca concentrations can reduce the uptake of Cd in plants."

The abstract is here.

Soil values

Calcium concentrations in soil are measured in parts per million or milligrams per kilogram (mg kg).

There is a wide variety of ranges for Calcium soil values but it is likely that when pH is within an optimal range, calcium is probably present in adequate amounts. A University of Arkansas circular sums it up rather nicely as follows:

"Most sandy soils have calcium concentrations below 400 to 500 parts per million, while clay soils usually test above 2,500 ppm. Normally, the higher the calcium level, the greater the soil clay content.

"Recent limestone applications may result in higher calcium levels. If the soil pH is maintained in the recommended range for the crop grown, calcium deficiency is very unlikely. In general, the higher the clay content, the more lime will be required to raise soil pH to the desired level."

That **circular in full can be found here.**

CHROMIUM
Symbol: Cr
Atomic number: 24

A hard silver-blue transition metal. Chromium is primarily used to harden steel and also to make stainless steel. It is also used in the process of tanning leather. When combined with other elements, it can produce a variety of vibrant colours making it useful in the production of dyes.

It is an essential trace mineral, however, hexavalent chromium Cr (VI) is toxic and carcinogenic. Consuming high levels of chromium in polluted drinking water or inhaling fumes of the heated element can cause ulcers, cancer and other health problems.

Selected excerpts from Defra's technical notes on Chromium in soil follow:

- Chromium is a transition metal of Group VIB of the periodic table that occurs naturally in the environment in the form of chromite ore, which contains other metals such as iron. Naturally occurring chromium exists predominantly in its chromic (chromium III) form, while the chromate (chromium VI) state is rarely found in nature and is produced mainly from commercial and industrial processes.

- Large amounts of chromium (VI) are produced through a range of activities, including the production of chromates and bichromates, stainless steel, welding, chromium plating, ferrochrome alloys and chrome pigment production, material tanning, the combustion of coal and oil, cement works, and waste incineration.

- Expert group consensus recommends that lung cancer is the most sensitive health effect following inhalation of Cr(VI).

- Note that for consumption of homegrown produce CLEA predicts the greatest exposure to chromium (VI) from tuber vegetables and tree fruit for both the residential and allotments scenarios (via ingestion of soil attached to produce).

- The principle (sic) exposure pathway for chromium (VI) for the residential and allotments land-use is direct ingestion of soil and soil-derived dust. However, the inhalation of indoor dust makes a very small contribution to total exposure but is the most significant risk driver for the residential and commercial land use scenarios because of the lower Low Level of Toxicological Concern (LLTC) for inhalation health effects. For the allotments land–use there is also a significant contribution from ingestion of soil attached to food; consumption of homegrown produce itself is not considered as chromium (VI) is reduced to chromium (III) within plants.

Did you know?

Chromium is named after the Greek word for colour, chroma, because it can be used to form numerous coloured compounds.

Rubies are red because of chromium.

Julia Roberts played Erin Brockovich in the 2000 film of the same name. Brockovich was an environmental activist and legal clerk who led a case against a utility company for contaminating drinking water with chromium(VI), the toxic compound **known to cause cancer**, according to the U.S. Occupational Safety and Health Administration (OSHA).

Soil Guideline Values

Chromium concentrations in soil are measured in parts per million or milligrams per kilogram (mg kg).

A CL:AIRE technical bulletin on chromium states that "The overall toxicity of trivalent Cr is relatively low. Indeed, Cr(III) is an essential element in human metabolism and health benefits from supplementation of diets of subjects with Cr deficiencies have been observed."

That bulletin can be read here.

Consequently the focus is on the considerably more toxic chromium (VI).

Defra guidance here is less specific than other toxic compounds in this report. It

They may have done wonders for their complexions but this fillip was short-lived, as indeed were many of them.

Soil Guideline Values

Arsenic concentrations in soil are measured in parts per million or milligrams per kilogram (mg kg).

For residential and allotment land uses, SGVs are based on estimates representative of exposure of young children because they are generally more likely to have higher exposures to soil contaminants.

Values (mg kg–Dry Weight)

Residential 32
Allotment 43
Commercial 640

Full EA guidance note is here.

These have since been replaced by the so-called Category 4 Screening Levels (C4SLs), which are as follows for arsenic:

Residential with homegrown produce: 37
Residential without homegrown produce: 40
Allotment: 49
Commercial: 640

The LQM/CIEH S4ULs for arsenic in soils with 6% organic matter are as follows:
Residential with homegrown produce: 37
Residential without homegrown produce: 40
Allotment: 43
Commercial: 640

CADMIUM
Symbol: Cd
Atomic number: 48

A silver-white and lustrous metal, Cadmium is an excellent electrical conductor. This property made it a favourite in electroplating and batteries.

However, as the World Health Organization notes "cadmium exerts toxic effects on the kidneys as well as the skeletal and respiratory systems. It is classified as a human carcinogen".

Selected excerpts from the Environment Agency's technical notes on Cadmium in soil follow:

- The primary commercial source of cadmium is as a byproduct from the processing of zinc ores including sphalerite and smithsonite. Historically, cadmium metal was recovered from the smelting of zinc ores by fractional distillation under reducing conditions to increase its purity.

- Between 2000 and 2002, about 1,100 tonnes per year of cadmium was produced by European countries with a further 1,700 tonnes per year imported from outside the EU. A small but important proportion of cadmium, primarily from batteries, is recycled.

- Cadmium metal, its alloys and compounds have been used in a variety of different industrial and consumer products, although most uses are now declining due to concerns about its toxicity. Currently, most cadmium is used in the production of nickel–cadmium batteries for industrial and commercial use although alternative products such as lithium ion batteries have eroded their market share in recent years. It is also still used as a semi-conductor and a photo-conductor in solar cells and other electronic devices.

- Cadmium has also been used in pigments for plastics, glass and ceramics, as a fungicide, in stabilisers for plastics including PVC, and in corrosion-resistant coatings on steel and other non-ferrous metals; it has other minor applications

states that: "The probability that inhalation exposure to a random individual from the critical receptor group would exceed the Low Level of Toxicological Concern (LLTC) is 47% for a soil concentration of 52 mg kg, decreasing to 40% for a soil concentration of 49 mg kg. The probability of inhalation exposure exceeding the LLTC at a soil concentration of 82 mg.kg is 86%."

Full Defra guidance note is here.

These have since been replaced by the so-called Category 4 Screening Levels (C4SLs), which are as follows for chromium (VI):

Residential with homegrown produce: 21
Residential without homegrown produce: 21
Allotment: 170
Commercial: 49

The LQM/CIEH S4ULs for chromium (III) in soils with 6% organic matter are as follows:
Residential with homegrown produce: 910
Residential without homegrown produce: 910
Allotment: 18000
Commercial: 8600

The LQM/CIEH S4ULs for chromium (VI) in soils with 6% organic matter are as follows:
Residential with homegrown produce: 6
Residential without homegrown produce: 6
Allotment: 1.8
Commercial: 33

COPPER
Symbol: Cu
Atomic number: 29

A reddish metal found in its free state in nature, copper is an excellent conductor of electricity and heat, explaining its extensive use in cables.

Copper is an essential trace element in humans, plants and animals. Indeed because of its role in the body's absorption of iron, copper deficiency can produce anemic-like conditions.

However, although the body is able to excrete it, the US National Library of medicine states that consuming large quantities can cause symptoms including abdominal pain, diarrhea and vomiting. It adds that touching it may turn one's hair green while breathing in large quantities of copper dust and fumes can result in acute symptoms of metal fume fever, which appears to be as unpleasant as it sounds. **More on that here.**

In the UK, copper is not one of the elements for which Soil Guideline Values (SGVs) have been published by the government though there is no shortage of published and detailed guidance in the scientific community and indeed still more internationally.

We start closest to home with a Defra document on copper concentrations in Welsh soils. Highlights from the paper follow:

- Copper is often found enriched in the top horizons of a soil profile. Its accumulation in topsoils is seen in urban areas resulting from human activity. Anthropogenic sources of Cu include mining and smelting, coal burning, the electrical and metallurgical industries, agriculture, sewage sludge and steel works.

- Results for Cu in topsoils range from 2.7 – 2,131 mg/kg with a mean of 65.5 mg/kg and a median of 26.7 mg/kg. In order to establish meaningful Normal Background Concentrations, soils are grouped in domains, defined by the most significant controls on a contaminant's high concentrations and distribution.

More on safe limits below.

IRON
Symbol: Fe
Chemical number: 26

A transitional metal that is solid at room temperature, iron is useful, cheap and abundant.

Iron is a crucial part of a healthy diet because it is a key element in making red blood cells, which carry oxygen around the body. However, as ever, too much of a good thing is less than ideal.

The NHS states that the side effects of consuming more than 20 mg of iron include constipation, feeling sick, vomiting and stomach pain. It adds that very high doses "can be fatal, particularly if taken by children".

The Field Science consultancy, suggests that the reason the UK became the world's first industrialized nation – apart from producing world-class scientists in the 18th and 19th centuries – is the abundant presence of coal and iron.

"Large deposits of both were found all over England, Scotland and Wales. Even in areas with no commercial iron deposits, soils are still found to contain high levels of iron. One giveaway to the casual observer is the colour. The rich red soils common to many parts of the UK are all high in iron, but so are many of the dark brown clays and loams. The only soils of the UK that are low in iron are some of the chalks. Consequently, iron is rarely deficient; in fact most iron-related problems stem from excess, not deficiency."

Selected excerpts from US Environmental Protection Agency's excellent technical note on iron in soil follow:

- Iron is a commonly occurring metallic element, with typical soil concentrations ranging from 0.2% to 55% (20,000 to 550,000 ppm). Concentrations can vary significantly even within localized areas due to soil types and presence of other sources.

- Iron is essential for plant growth, and is generally considered to be a micronutrient. Iron is considered the key metal in energy transformations needed for syntheses and other life processes of the cells (Thompson and Troeh, 1973).

> Consequently, plants regulate its uptake. In well aerated soils between pH 5 and 8, the iron demand of plants is higher than the amount available (Römheld and Marschner, 1986). Because of this limitation, plants have evolved various mechanisms to enhance iron uptake (Marschner, 1986). Under these soil conditions, iron is not expected to be toxic to plants.

The full document can be accessed here.

Did you know?
Iron is used to make steel, which is an alloy of mostly iron and carbon. The addition of other elements can alter steel's properties – adding chromium makes it resistant to rust (stainless steel) while adding manganese increases its strength and makes it more resistant to wear.

The symbol for iron, Fe, comes from the Latin *ferrum* or "firmness".

Soil Guideline Values
Iron concentrations in soil are measured in parts per million or milligrams per kilogram (mg kg).

In the absence of published UK Soil Guideline Values (SGVs), we note the following limitations on soil test results for iron.

Soil tests for Fe are dominantly influenced by other factors such as soil pH and the moisture regime rather than soil test results per say.

Consequently, we are looking at levels that suggest a deficiency rather than a maximum threshold before human health is potentially negatively influenced.

In Soil and Plant Testing for Iron: an Appraisal, Communications in Soil Science and Plant Analysis, Kanwar L. Sahrawat posited that:

"Nevertheless, the soil tests do provide indexes of nutrient availability, and help in judicious and efficient use of applied nutrient; however, there is always an element of uncertainty due to other factors (see above) that are also necessary for optimum growth and production of plants.

Did you know?
The huge Statue of Liberty in New York is made of copper, which turns green as it oxidizes, or loses electrons when it is exposed to water and air. It took the statue more than 30 years to complete its transformation to the green hue we know today.

Together with gold, copper is the only metal on the periodic table that is not naturally silver or grey.

Copper is biostatic, which means that bacteria and many other forms of life will not grow on it. As a result it was often used to line hulls of ships to stop barnacles from attaching to them.

Soil Guideline Values
Copper concentrations in soil are measured in parts per million or milligrams per kilogram (mg kg).

As stated earlier, in the absence of government published Soil Guideline Values, we look further afield for guidance.

A consultation document prepared for a Cardiff development proposal used the CLEA UK model to calculate a generic assessment criteria of 220 mg kg copper in soil for a "residential with plant uptake" exposure scenario.

That calculation in full can be seen here.
Meanwhile, a European directive breaks down the limits by soil pH as follows:
At pH 5.0-5.4 = 80
At pH 5.5-5.9 = 100
At pH 6.0-7.0 = 135
At pH 7.1 + = 200

A study of copper distribution in European topsoils published in 2018 summarizes copper levels as follows:

One of the most cited guidelines and threshold values for Cu are those proposed by the Finnish and Swedish legislations for soil contamination. According to the Government Decree on the Assessment of **Soil Contamination and Remediation** Needs 214/2007, the copper threshold value is 100 $mg\,kg^{-1}$ and the guideline value is 150 $mg\,kg^{-1}$.

The threshold is the value beyond that further assessment is needed in the area, while the guideline value is seen as denoting an ecological or health risk.

The copper threshold of 100 $mg\,kg^{-1}$ is also proposed by numerous scientific studies to denote unpolluted soils.

The report in full is here.

Finally, according to the Centers for Disease Control in the United States, the average concentration of copper in the earth's crust is about 50 parts copper per million parts soil.

Soil generally contains between 2 and 250 ppm copper, although concentrations close to 17,000 ppm have been found near copper and brass production facilities. High concentrations of copper may be found in soil because dust from these industries settles out of the air, or wastes from mining and other copper industries are disposed of on the soil.

Guidance for New Yorkers pegs the Guidance Value Protective of Public Health at 270 ppm.

More on that here.

The LQM/CIEH S4ULs for copper in soils with 6% organic matter are as follows:
Residential with homegrown produce: 2400
Residential without homegrown produce: 7100
Allotment: 520
Commercial: 68000

"The situation is even relatively more unreliable in the soil testing for nutrients such as iron (Fe) because the availability of applied or soil Fe is dominantly determined by factors other than Fe."

The paper can be viewed in full here.

LEAD
Symbol: Pb
Atomic number: 82

A lustrous silver-blue heavy metal, lead is solid at room temperature and occurs naturally in trace amounts on earth's surface environment.

Concentrations in rocks average about 15 mg kg. Most acid igneous rocks (such as granites) have higher lead concentrations than basic ones such as basalts. Concentrations in sedimentary rocks vary with up to 70 mg kg in some limestones.

Lead has a long history of use in human activities, dating back to Roman times when it was used in pipes to carry water. Indeed, there are suggestions that the fall of the Roman Empire is at least partially due to the long-running effects of prolonged lead poisoning.

In England there are a number of historical lead mining areas - the Derbyshire Peak District for one - where there is a legacy of lead contamination resulting from mining and related activities.

It is a non-essential element and toxic to humans as well as animals through the food chain and soil dust inhalation or ingestion.

It is corrosion resistant making it useful in lining tanks for corrosive materials like sulfuric acid.

Many instances of lead poisoning are due to ongoing low-dose exposure. Because its symptoms are predominantly emotional and mental in nature, lead poisoning is not easily spotted. Children are at greatest risk because lead can delay physical and mental development in babies and the young. It's also dangerous to adults with accumulations in the body resulting in kidney and nervous system damage, anaemia, stroke and cancer.

According to a Penn State University report: "Serious human health risks, particularly for children under 6 years of age, are associated with lead poisoning… Low-level, chronic exposure to lead in contaminated residential soil can cause several developmental and behavioral problems in children. Among these are reduced IQ and attention span, hyperactivity, impaired growth, learning disabilities, hearing loss, and insomnia. Once absorbed by the human body, lead is extremely difficult, if not impossible to remove. Therefore, not only is prevention of lead poisoning the best cure, but it may be the only cure."

More from the Penn State report can be viewed here.

Selected excerpts from the Environment Agency-Defra and Health Protection Agency technical notes on lead in soil follow:

- The soil is a significant sink for anthropogenic lead, and there are several well recognised major sources: mining and smelting activities; sewage sludge usage in agriculture; and aerial contamination from vehicle exhausts. It has been estimated that in Britain alone there has been in excess of 4000 km2 of land affected by lead as a result of mining activity dating from Roman times or earlier. Historically, lead arsenate may have been applied to orchard trees to control pests and such soils may contain small amounts of lead residues.

- Estimated anthropogenic emissions of lead to the urban UK atmosphere have fallen substantially since the mid-1980s primarily as a result of the phasing out of lead in petrol. Air quality measurements in the city of Birmingham show a decline in air lead concentrations of around 90% over the period 1975 to 1992.

- With the decline in combustion of leaded fuel and the phasing out of lead in pipes and paints, industrial emissions from mining, smelting, recycling or waste incineration are the major source of environmental lead.

- Human exposure to inorganic lead occurs primarily through food and drinking water, although exposure via soil, dust, air and paint chips significantly contribute.

The document in full can be accessed here.

The World Health Organization adds the following:

- Lead is a naturally occurring toxic metal found in the Earth's crust. Its widespread use has resulted in extensive environmental contamination, human exposure and significant public health problems in many parts of the world.

- Important sources of environmental contamination include mining, smelting, manufacturing and recycling activities, and, in some countries, the continued use of leaded paint, leaded gasoline, and leaded aviation fuel. More than three quarters of global lead consumption is for the manufacture of lead-acid batteries for motor vehicles.

- Lead is, however, also used in many other products, for example pigments, paints, solder, stained glass, lead crystal glassware, ammunition, ceramic glazes, jewellery, toys and in some cosmetics and traditional medicines.

- Young children are particularly vulnerable to lead poisoning because they absorb 4–5 times as much ingested lead as adults from a given source. Moreover, children's innate curiosity and their age-appropriate hand-to-mouth behaviour result in their mouthing and swallowing lead-containing or lead-coated objects, such as contaminated soil or dust and flakes from decaying lead-containing paint.

The WHO circular in full is here.

However, recent research in the UK suggests that the picture is perhaps more complicated.

A study published in Environment International found some crops are more suitable for growing at sites with elevated lead – these include shrub and tree fruit – while others like beetroot, parsnips and carrots are less so.

Newcastle City Council tested the soil in its allotments and found the average lead level to be around 550 mg kg. Rather than remediating or closing the sites, the council commissioned a study to look into whether elevated lead levels in soil were reflected in the levels of lead in the blood of gardeners, who were exposed to the lead in the ground and presumably consumed the produce they grew on it. No elevated blood levels were

found though the numbers participating in the study were in the dozens suggesting more research is necessary before the suggested limits for lead in soil are relaxed.

Northumbria University environmental geochemist Professor Jane Entwistle was co-lead on the study and said: "U.K. soil screening guidelines are overly cautious in the context of many of our urban allotments and our research has found that how the lead is held in the soil is more important than simply the presence of lead. While some metals are more readily taken up by plants, lead remains attached to the soil as it is not a mobile element. What we therefore need to do is look at the form of the lead and natural regional variances rather than using standard guidelines that don't recognize these differences." **The study in full is here.**

Did you know?
The chemical symbol for lead is Pb, based on the Latin word *plumbum*, or "waterworks," in reference to Roman times when lead was used for water pipes.

Lead was a popular ingredient in cosmetics in 16th and 17th century Europe because it helped produce the very pale complexion popular at the time. Its users included Queen Elizabeth I who would doubtless have been better off avoiding it.

Soil Guideline Values
Lead concentrations in soil are measured in parts per million or milligrams per kilogram (mg kg).
Category 4 Screening Levels for Lead
Residential (with consumption of homegrown produce) 200
Residential (without consumption of homegrown produce) 310
Allotments 80
Commercial: 2330

Background and methodology behind these can be explored in detail here.
And here.

The EPA in the US uses a threshold of 400 mg kg for residential soil while the SGVs replaced by the C4SLs was 450 for all residential uses, allotments / 750 for commercial.

The extensive methodology and calculation of soil screening values including the one above can be studied here.

MERCURY
Symbol: Hg
Atomic number: 80

A silvery heavy element, Mercury is the only one that is liquid at room temperature. It has a myriad of uses, including fluorescent lighting, thermometers, batteries, switches and other commercial applications.

Described as beautiful though deadly, it has long fascinated humans because of its rare ability to react with gold. About half of the mercury in the atmosphere comes from volcanic eruptions, the rest is due to human activity.

The burning of coal is a major source of mercury in the environment. Among other pollutants, coal contains mercury that is released when it is burned in coal power plants and heating stoves.

According to the World Health Organization, mercury poses an extremely serious risk to human health, including:

- Neurological and behavioural disorders may be observed after inhalation, ingestion or dermal exposure of different mercury compounds. Symptoms include tremors, insomnia, memory loss, neuromuscular effects, headaches and cognitive and motor dysfunction;

- Exposure to mercury – even small amounts – may cause serious health problems, and is a threat to the development of the child in utero and early in life;

- Mercury may have toxic effects on the nervous, digestive and immune systems, and on lungs, kidneys, skin and eyes.

More from the WHO is available here.

Selected excerpts from the Environment Agency's technical notes on mercury in soil follow (this guidance has now been withdrawn so we will take in values from other European countries to help establish safe limits):

- The principal target organs for the toxic effects of mercury are the central nervous system (CNS), the brain and the kidneys.

- Almost all commercial production of mercury comes from the sulphide ore, cinnabar, which results from hydrothermal mineralisation associated with volcanic activity.

- Anthropogenic activity is a major source of aerial emissions of mercury and a significant contributor to soil contamination.

- The main sources of contamination have been mining and smelting, burning of fossil fuels, industrial production of sodium hydroxide and chloride, and waste incineration although mercury also occurs in trace amounts in fertilisers used on farmland.

- Plants differ in their ability to take up mercury and can develop a tolerance to high concentrations on contaminated sites, with corresponding elevated concentrations in edible parts compared with natural soils.

- SGVs for the three chemical forms of mercury differ significantly from each other for two reasons: 1. Human toxicology differs for each of the three main forms, with elemental mercury and methylmercury the most toxic by the inhalation and oral routes respectively; and, 2.Elemental mercury and monomethylmercury forms are much more volatile than inorganic mercury and therefore vapour inhalation is more likely to contribute to exposure.

- Several studies have reported the accumulation of mercury in plant roots, although translocation within the plant to other parts including shoots and seeds will also occur.

The EA technical note can be seen in full here.

Did you know?

During the Second World War, Allied spies are said to have used mercury to sabotage the Luftwaffe, the German Air Force, by applying mercury paste to exposed aluminium on planes, which caused corrosion and, in turn, structural failures.

In the 18th and 19th centuries, felt hats were made using an orange mercury compound solution that separated the fur and pelt of animal skins and matted them together. The process was called "carroting" because of the solution's colour. Unfortunately, the solution and the vapours it produced were highly toxic, prompting the US to ban the process in the 1940s. The psychological symptoms of mercury poisoning gave rise to the expression "mad as a hatter".

Soil Guideline Values
Mercury concentrations in soil are measured in parts per million or milligrams per kilogram (mg kg).

Please note that the values below relate to elemental mercury, where the most toxic pathway is via inhalation.
Residential 1.0 mg/kg
Allotment 26 mg/kg
Commercial 26 mg/kg

Note: Soil adsorption of mercury may decrease above pH 5 and therefore there is the potential that more mercury will be available for plant uptake.

The EA has withdrawn the guidance note containing the above values so we look further afield for additional guidance. For contrast, note that the values in Germany for mercury are 20 for residential use and 10 for playing fields but just 1 for residential use in Italy while the values are between 1 and 7, depending on use, in Sweden.

More on European values can be found here.
The full EA briefing is here.

The LQM/CIEH S4ULs for mercury in soils with 6% organic matter are as follows for elemental mercury / inorganic mercury / methylmercury:
Residential with homegrown produce: 1.2 / 40 / 11
Residential without homegrown produce: 1.2 / 56 / 15
Allotment: 21 / 19 / 6
Commercial: 25.8 / 1100 / 320

Note: We are unable to speciate mercury so the figure in these results is for total Hg, which is below each of the individual values above.

NICKEL
Symbol: Ni
Atomic number: 28

A gold-tinged silvery white transition metal, nickel is the fifth most-common element on earth. It is hard and is most commonly combined with other metals to produce more durable alloy materials.

Its sturdiness and resistance to corrosion makes it a common ingredient in the manufacture of coins, often as an alloy with copper.

However, and as ever, exposure to too much - as with many elements on this list - is no good thing. The World Health Organization states that nickel appears to be an essential trace element to some animal species, human and plant life.

According to the scientific paper Nickel in soils: A review of its distribution and impacts by Yahaya Ahmed Iyaka:

"The toxic effects of nickel result from its ability to replace other metal ions in enzymes, proteins or bind to cellular compounds and among animals, micro-organisms and plants, nickel is reported to interact with at least 13 essential elements namely calcium, chromium, cobalt, copper, iodine, iron, magnesium, manganese, molybdenum, phosphorus, potassium, sodium and zinc. Therefore, prolonged exposure to oxides and sulphides of nickel is associated with possible risk to lung and nasal tumours, while systematic effects whose initial symptoms are mild nausea, headache, dyspnoea, and chest pain could be ascribed to nickel carbonyl; these symptoms may disappear or consequently results in severe pulmonary insufficiency."

It concludes that: "Although nickel is ubiquitous in the environment, its functional role as a trace element for animals and humans is not yet recognized. Therefore, it becomes trace metal of concern because of its major route of exposure which is either through the dietary intake or ingestion through the food chain which may arise principally from the nickel accumulation in crops, fruits and vegetables grown on contaminated soils and their consequent consumption by animals or man."

The full summary can be seen here.

Selected excerpts from the Environment Agency's technical notes on nickel in soil follow (this guidance has now been withdrawn so we will take in values from other European countries to help establish safe limits):

- The primary uses of nickel metal are in the production of alloys including stainless steel, in nickel plating, in the manufacture of nickel containing products such as batteries and welding electrodes.

- Nickel metal alloys and nickel plated items have been used extensively in the transport, consumer, industrial and construction sectors including the production of motor vehicles, consumer white goods and bathroom fittings, kitchen and tableware, electronics, food processing, textiles, fasteners, wires, and cables.

- Nickel is a potent skin sensitiser (that is, able to cause allergic reaction in humans) and as many as 1 – 4 percent of men and 8 – 20 percent of women in the general population may be nickel-sensitive.

- Ingestion of nickel can cause skin reactions in previously sensitised individuals. The other main concern for oral exposure to nickel is its developmental toxicity potential, which has been observed in experimental animal studies.

- Soluble nickel salts and the mixture of nickel sulphides and oxides present in refinery dust are carcinogenic to the lung and nasal tissues in humans. Other toxic effects of nickel observed following inhalation exposure include chronic bronchitis, emphysema, reduced vital capacity and asthma.

- Nickel occurs naturally in soils as a result of the weathering of the parent rock. The highest concentrations are found in basic igneous rocks with much lower levels found in sedimentary rocks including shales, clays, limestones, and sandstones.

- The underlying geology and soil-forming processes strongly influence the amount of nickel in soils with higher median concentrations reported in clays, silts, and fine grained loams relative to coarser grained loams, sandy and peaty soils.

- Anthropogenic (human) activity has resulted in the widespread atmospheric deposition of nickel from the burning of oil and coal. Localised nickel contamination may also occur near to a smelter or plating works or be associated with mining activity such as around Clydach in South Wales.

- Agricultural fertilisers, especially phosphates, are also a significant source of nickel in soil but it is unlikely to build-up in soil in the long term from their use. More important is the application of wastes to land including sewage sludge and pulverised fuel ash, for example coal can contain up to 70 mg kg-1 nickel which can become highly concentrated in ash residues.

- Plant species also differ in their tolerance and ability to take up nickel from soil. Plant families that have been reported for their tolerance to, and hyperaccumulation of, nickel include Cruciferae (e.g. cabbage, cauliflower and turnip) and Leguminosae (e.g. pea and bean).

The EA technical note can be seen in full here.

Please note: Soil pH is the most important factor controlling nickel solubility, sorption and mobility with the clay, ironmanganese mineral, and soil organic matter content being of secondary importance

Did you know?
The nickel alloy Nitinol remembers its previous shape. Heat the wire of this nickel and titanium mixture to about 500 C (932 F) and bend it into any shape. Once it has cooled, shape it into something else.

If you reheat the wire, the original shape will reappear.

Soil Guideline Values
Nickel concentrations in soil are measured in parts per million or milligrams per kilogram (mg kg).

The SGVs apply only to nickel and its inorganic compounds. For residential and allotment land uses, SGVs are based on estimates representative of exposure of young children because they are generally more likely to have higher exposures to soil contaminants.

Soil Guideline Values
(mg kg–1 Dry Weight)
Residential 130
Allotment 230
Commercial 1,800

Full EA guidance is here.

Since the above had been published, the EA withdrew the document. For context, guidance elsewhere around Europe tends to be somewhat lower with screening values for negligible risk ranging from 24 mg/kg in Belgium to 60 mg/kg in the Czech Republic.

More on European values can be found here.

The LQM/CIEH S4ULs for nickel in soils with 6% organic matter are as follows:
Residential with homegrown produce: 180
Residential without homegrown produce: 180
Allotment: 230
Commercial: 980

SELENIUM
Symbol: Se
Atomic number: 34

Solid at room temperature, selenium was discovered in the 19th century by a Swedish chemist. It is named after the Greek word for moon, Selene.

It has a number of commercial uses, including solar cells, glass and pigments and as an additive to stainless steel while selenium sulfide is used in anti-dandruff shampoos.

Selenium is an essential trace element or micronutrient for humans and animals, playing an essential role in the immune and reproductive systems as well as DNA synthesis. While also playing a pivotal role in fighting cancer and some other diseases it is also toxic when humans consume too much of it.

Indeed it is a very fine balance, making selenium supplements risky with symptoms of

overdoing selenium consumption including irritability, fatigue, weight loss, skin rashes and even loss of fingernails.

Selected excerpts from the Environment Agency's technical notes on selenium in soil follow:

- Elemental selenium (CAS No. 7782-49-2) can exist in several allotropic states. The grey or hexagonal form is stable at ordinary room temperature. The other important allotropes are red (monoclinic) selenium and amorphous selenium – the latter existing in red and black forms.

- Adverse effects on human health occur from both too much and from too little exposure to selenium.

- Elemental selenium occurs rarely in rocks and soils. Usually selenium is found combined with other substances.

- Major sources of selenium compounds added to the environment include the burning of fossil fuels (particularly coal) and the mining and refining of copper and other metals.

- There is a wide variation in uptake between different types of plants. Selenium can be phytotoxic and causes interveinal chlorosis and black spots in crop plants (Environment Agency, 2009e). At high tissue concentrations, complete bleaching or yellowing of younger leaves may occur and pinkish spotting may be observed on the roots.

- Some selenium tolerant plants (such as cruciferous plant species, for example; cabbage, broccoli and cauliflower) are capable of concentrating selenium up to extremely high tissue levels of over 1,000 mg kg-1; food crops generally have a low selenium tolerance.

- The pH, is the most important of the soil properties affecting plant uptake resulting in greater availability of selenium at increasingly alkaline conditions.

The EA technical note can be seen in full here.

Did you know?
In 2019, 21 polo ponies perished ahead of a match at the US Polo Open. A few days later, a pharmacy said the animals had received an overdose of one of the elements in their vitamin supplement. Blood analysis suggested selenium concentrations in the horses were 10-15 times higher than normal and indeed selenium was later confirmed to have been responsible for their deaths.

Soil Guideline Values
Selenium concentrations in soil are measured in parts per million or milligrams per kilogram (mg kg).

Residential 350
Allotment 120
Commercial 13,000

More on the EA's methodology behind these values can be read here.

The LQM/CIEH S4ULs for selenium in soils with 6% organic matter are as follows:
Residential with homegrown produce: 250
Residential without homegrown produce: 430
Allotment: 88
Commercial: 12000

ZINC
Symbol: Zn
Atomic number: 30

A blue-silver brittle metal at room temperature, zinc is the 25th most available element in the earth's crust. It has a number of commercial uses, chief among them utilising its anti-corrosive properties to galvanize steel or iron. It is also a key ingredient of brass, the alloy of zinc and copper.

Selected excerpts from a Defra technical note on heavy metal contamination in UK soils follow:

- Zinc and copper are essential trace elements for humans, animals and higher

plants, although both elements have been assigned a provisional maximum TDI by the WHO… both Zn and Cu can be phytotoxic at high soil concentrations and have been shown to have adverse effects on soil microorganisms & microbial processes.

- Zinc was the metal deposited on soil in the largest amounts from the atmosphere in England and Wales, followed by Cu and Pb. The rate of Zn deposition was relatively consistent across all the monitoring stations (126 - 356 g/ha/yr), indicating that this element was probably emitted to the atmosphere from many different sources and may also be subject to long-range, trans-boundary transport.

The Defra technical note can be seen in full here.

A New York State public health circular titled *Healthy Soils, Healthy Communities* makes the following points about zinc in soil:

- In nature: Zinc is present in low concentrations in many types of rock. It is concentrated in sulfide ore minerals such as sphalerite, which are mined for this metal.

- Man-made sources - Zinc is used in galvanized steel (used in roofing, pipes, and gutters), wire fences and rubber (tires). It is used in some metal alloys, batteries, and pigments. Other sources include electroplating waste, mine spoils, emissions from coal burning, smelting and incinerators, some fertilizers, manure and sewage sludge composts.

- Zinc is generally adsorbed on clays and organic matter above pH 6.0 but is relatively easily released to the soluble and plant-available form. It is quite soluble and plant-available if soil pH is low (less than 5.5).

- Human health: Small amounts of zinc in the diet are essential for good health. Too little zinc can cause a wide variety of serious adverse effects; too much zinc can alter the copper content of red blood cells and reduce the level of an important enzyme in red blood cells.

- Plant health: Zinc is an essential micronutrient for plants, but it can be toxic to plants at higher soil levels, even below those that are a concern for human health.

Zinc levels above 150-200 ppm may cause toxicity and stunted growth in some crops. Nevertheless, because of the near-neutral pH (6.5 - 7.5) of most urban garden soils, zinc is usually not soluble enough to be toxic to plants.

The circular can be read in full here.

Meanwhile the US Department of Health and Human Services has the following to say about zinc in its memorandum:

- Zinc enters the air, water, and soil as a result of both natural processes and human activities. Most zinc enters the environment as the result of mining, purifying of zinc, lead, and cadmium ores, steel production, coal burning, and burning of wastes.

- These activities can increase zinc levels in the atmosphere. Waste streams from zinc and other metal manufacturing and zinc chemical industries, domestic waste water, and run-off from soil containing zinc can discharge zinc into waterways.

- The level of zinc in soil increases mainly from disposal of zinc wastes from metal manufacturing industries and coal ash from electric utilities.

- Sludge and fertilizer also contribute to increased levels of zinc in the soil.

- Zinc can enter the body through the digestive tract when you eat food or drink water containing it. Zinc can also enter through your lungs if you inhale zinc dust or fumes from zinc-smelting or zinc welding operations on your job. The amount of zinc that passes directly through the skin is relatively small.

- The levels of zinc that produce adverse health effects are much higher than the Recommended Dietary Allowances (RDAs) for zinc of 11 mg/day for men and 8 mg/day for women. If large doses of zinc (10–15 times higher than the RDA) are taken by mouth even for a short time, stomach cramps, nausea, and vomiting may occur. Ingesting high levels of zinc for several months may cause anemia, damage the pancreas, and decrease levels of high density lipoprotein (HDL) cholesterol.

The circular can be read in full here.

Did you know?
Zinc has a high density and is both malleable and cheap, making it an increasingly common replacement for lead in weight applications for everything from fishing weights to tyre balances.

Soil Guideline Values
Zinc concentrations in soil are measured in parts per million or milligrams per kilogram (mg kg).

The absence of published UK SGV or other limits for zinc in soil prompts us to look further afield for some guidance. In New York, the Guidance Value Protective of Public Health sets the level of zinc in soil at 2200 ppm.

Meanwhile the WHO adds the following:

- Among terrestrial invertebrates, earthworms (Eisenia andrei) and woodlice (Porcellio scaber) show adverse effects on reproduction starting at total zinc concentrations of 560 and 1600 mg/kg dw, respectively… The adverse effects of zinc must be balanced against its essentiality.

- The essential nature of zinc, together with its relatively low toxicity in humans and the limited sources of human exposure, suggests that normal, healthy individuals not exposed to zinc in the workplace are at potentially greater risk from the adverse effects associated with zinc deficiency than from those associated with normal environmental exposure to zinc.

More from the WHO is here.

The LQM/CIEH S4ULs for zinc in soils with 6% organic matter are as follows:
Residential with homegrown produce: 3700
Residential without homegrown produce: 40000
Allotment: 620
Commercial: 730000

PAHS / BENZO(A)PYRENE (BAP)

Polycyclic aromatic hydrocarbons (PAHs) is a group of several hundred chemically-related environmentally persistent organic compounds.

The U.S. Environmental Protection Agency identified 16 of these as "priority pollutants" based on their potential human and ecological health effects.

According to Public Health England, Benzo[a]pyrene (BaP) acts as an indicator species for PAH contamination.

A crystalline aromatic hydrocarbon, Benzo(a)pyrene is a known carcinogen.

Public Health England has published an overview of the health risks associated with PAHs. Excerpts include:

- The most well-known PAH is benzo[a]pyrene (BaP), the majority of the data on the health effects of PAHs comes from studies of this compound.

- PAHs may enter the environment from both human activities and natural processes that involve the burning of organic material. Burning of coal, wood and other solid fuels can release PAHs into the environment. PAHs may also be present in vehicle emissions and cigarette smoke. Natural sources of PAHs include forest fires and volcanoes.

- For the general public, food is the major source of exposure to PAHs. PAHs largely found in food that has been smoked or cooked using methods such as in charbroiling, grilling and frying.

- Tobacco smoke is a major source of exposure to PAHs for smokers. In a smoker's home, the majority of PAHs in the air may be from cigarette smoke.

- Indoor air sources of PAHs include cooking and heating with open fires. Exposure to PAHs from incense and candle burning can also occur, however, as exposure would be expected to be low, it is unlikely to pose a significant risk to health.

- Exposure to low levels of PAHs may also occur through contaminated soil or drinking water.

- Any effects that may occur following exposure to PAHs largely depend on how exposure occurs. There are few reports on the health effects of single doses of PAHs, but health effects are more likely following exposure over long periods of time.

- Some PAHs, including BaP, caused tumours in animals when they breathed, ate or had skin contact for long periods. Many studies on workers that have been exposed to PAHs for a long time suggest that breathing in PAHs may cause lung cancer, and skin contact with PAHs may cause skin cancer.

- Studies of women who were exposed to very high levels of PAHs and specifically BaP throughout pregnancy showed effects on the growth of the unborn child and post-natal development of the child's nervous system.

- A small number of studies observing the development of children whose mothers were exposed to high levels of PAHs throughout pregnancy showed attention, intelligence and movement problems.

- Chronic exposure to high levels such as those seen in these studies would not be expected in the UK.

The full PHE guidance can be read here.

Did you know?
In the 18th century, a London surgeon and writer, Sir Percivall Pott, diagnosed and named the chimney sweeps' carcinoma after he spotted the connection between this cancer of the skin of the scrotum and soot, which contains a number of PAHs. This became the first reported instance of occupational cancer.

Soil Guideline Values
BaP concentrations in soil are measured in parts per million or milligrams per kilogram (mg kg).
Category 4 Screening Levels (C4SLs) are as follows for Benzo(a)pyrene (as a surrogate marker for genotoxic PAHs):

Residential with Home Grown Produce: 5
Residential without Home Grown Produce: 5.3
Allotment: 5.7

More on how the above were formulated, including a detailed methodology, can be found here.

The Dutch National Institute for Public Health and the Environment published an extensive study into each of the 16 PAHs and outlined environmental risk limits for each.

The document collates two derived figures for concentrations of individual PAHs in soil: the Maximum Permissible Concentration and a Serious Risk concentration. These are listed below in that order (measures are, as ever, mg kg for soil containing 10% organic matter):
Naphthalene 0.69 / 14
Acenaphthylene 0.17 / 9.4
Acenaphthene 0.68 / 31
Fluorene 1.6 / 82
Phenanthrene 3.6 / 90
Anthracene 0.34 / 60
Fluoranthene 4.8 / 309
Pyrene 1.8 / 53
Benz[a]anthracene 0.19 / 91
Chrysene 1.6 / 38
Benzo[b]fluoranthene 0.79 / 62
Benzo[k]fluoranthene 0.79 / 44
Benzo[a]pyrene 0.16 / 76
Indeno[1,2,3-cd]pyrene 0.38 / 89
Dibenz[a,h]anthracene 0.18 / 18
Benzo[ghi]perylene 0.49 / 10

More on the individual Dutch values can be read here.

The LQM/CIEH S4ULs for PAHs for residential with home grown produce land-use are as follows for soils with organic matter content of 1% / 2.5% / 6%:
Naphthalene 2.3 / 5.6 / 13
Acenaphthylene 170 / 420 / 920

Acenaphthene 210 / 510 / 1100
Fluorene 170 / 400 / 860
Phenanthrene 95 / 220 / 440
Anthracene 2400 / 5400 / 11000
Fluoranthene 280 / 560 / 890
Pyrene 620 / 1200 / 2000
Benz[a]anthracene 7.2 / 11 / 13
Chrysene 15 / 22 / 27
Benzo[b]fluoranthene 2.6 / 3.3 / 3.7
Benzo[k]fluoranthene 77 / 93 / 100
Benzo[a]pyrene 2.2 / 2.7 / 3.0
Indeno[1,2,3-cd]pyrene 27 / 36 / 41
Dibenz[a,h]anthracene 0.24 / 0.28 / 0.3
Benzo[ghi]perylene 320 / 340 / 350

The LQM/CIEH S4ULs for PAHs for residential without homegrown produce land-use are as follows for soils with organic matter content of 1% / 2.5% / 6%:
Naphthalene 2.3 / 5.6 / 13
Acenaphthylene 2900 / 4600 / 6000
Acenaphthene 3000 / 4700 / 6000
Fluorene 2800 / 3800 / 4500
Phenanthrene 1300 / 1500 / 1500
Anthracene 31000 / 35000 / 37000
Fluoranthene 1500 / 1600 / 1600
Pyrene 3700 / 3800 / 3800
Benz[a]anthracene 11 / 14 / 15
Chrysene 30 / 31 / 32
Benzo[b]fluoranthene 3.9 / 4 / 4.0
Benzo[k]fluoranthene 110 / 110 / 110
Benzo[a]pyrene 3.2 / 3.2 / 3.2
Indeno[1,2,3-cd]pyrene 45 / 46 / 46
Dibenz[a,h]anthracene 0.31 / 0.32 / 0.32
Benzo[ghi]perylene 360 / 360 / 360

The LQM/CIEH S4ULs for PAHs for allotment land-use are as follows for soils with organic matter content of 1% / 2.5% / 6%:
Naphthalene 4.1 / 10 / 24
Acenaphthylene 28 / 69 / 160

Acenaphthene 34 / 85 / 200
Fluorene 27 / 67 / 160
Phenanthrene 15 / 38 / 90
Anthracene 380 / 950 / 2200
Fluoranthene 52 / 130 / 290
Pyrene 110 / 270 / 620
Benz[a]anthracene 2.9 / 6.5 / 13
Chrysene 4.1 / 9.4 / 19
Benzo[b]fluoranthene 0.99 / 2.1 / 3.9
Benzo[k]fluoranthene 37 / 75 / 130
Benzo[a]pyrene 0.97 / 2.0 / 3.5
Indeno[1,2,3-cd]pyrene 9.5 / 21 / 39
Dibenz[a,h]anthracene 0.14 / 0.27 / 0.43
Benzo[ghi]perylene 290 / 470 / 640

TOTAL PETROLEUM HYDROCARBONS (TPHS)

Total Petroleum Hydrocarbons or TPH is a term used to describe any mixture of several hundred compounds that are byproducts of crude oil - although they are all different, they are all mostly made from hydrogen and carbon (thus hydrocarbons). These products are divided into groups (called fractions) of those that tend to behave similarly in either water or soil and have similar boiling points. This is further complicated by the fact the type of analytical methods used to measure the substances impacts some of the terminology.

The TPH we look at are in the relatively broad C10-C40 fraction - it is also sometimes called the diesel/oil range or mineral oil. It should be noted that a TPH measure is not by itself a completely reliant basis for the evaluation of potential risks to people and the environment because relatively benign products such as, for example, baby oil or petroleum jelly will return levels on par with considerably more toxic elements - as both are byproducts of crude. However, we include it because it is one of the thresholds in use in England and Wales as part of landfill waste criteria.

As such, TPH (C10-C40) is included in the Standard suite as a broad indicator and the fact that we have that Landfill (England and Wales) Regulations 2004 waste acceptance criteria of 500 mg/kg as a general guide - a breakdown of the fractions is not offered here

because of the cost of such analysis. As mentioned previously, the total content approach is not by itself a completely reliant basis for the evaluation of potential risks to people and the environment because the total TPH measurement also does not give enough basis for the assessment of the risks for human health and the environment. The assessment of human toxicity and effects due to TPH exposure generally requires much more detailed information than what is provided by a single TPH value.

Another approach considers TPH division into fractions according to their physico-chemical and toxicological properties, performed in terms of the environmental behaviour (aliphatic and aromatic compounds) and the Equivalent Carbon number (EC). This approach lets us determine the associated risk for human health through the Human Risk Index.

More is available about the differentiation of the two approaches here.

Some chemicals that may be found in TPH are hexane, jet fuels, mineral oils, benzene, toluene, xylenes, naphthalene, and fluorene, as well as other petroleum products and gasoline components. However, it is likely that samples of TPH will contain only some, or a mixture, of these chemicals."

In addition to fuels, other things that may show up in TPH include cleaning products as well as lubricating and engine oils.

More on TPHs from the EPA can be found here.

And the comprehensive **Overview of Total Petroleum Hydrocarbons published in 2019 is here.**

Soil Guideline Values

TPH concentrations in soil are measured in parts per million or milligrams per kilogram (mg kg).

As there are no specific guidance values for total petroleum hydrocarbons (TPH) in our range, we turn to the inert waste acceptance criteria of 500 mg/kg that is detailed within the Landfill (England and Wales) Regulations 2004 and also within the UK Water Industry Research (UKWIR) in soil. It is also worth noting that in 2018 the EU proposed

in industrial and petroleum products, and commonly occur together in the environment as a result of related pollution.

The US Environment Protection Agency published a factsheet on toluene. Excerpts include:

- Central nervous system dysfunction and narcosis have been frequently observed in humans acutely exposed to elevated airborne levels of toluene; symptoms include fatigue, sleepiness, headaches, and nausea.

- The highest concentrations of toluene usually occur in indoor air from the use of common household products (paints, paint thinners, adhesives, synthetic fragrances and nail polish) and cigarette smoke. The deliberate inhalation of paint or glue may result in high levels of exposure to toluene, as well as to other chemicals, in solvent abusers.

- Automobile emissions are the principal source of toluene to the ambient air. Toluene may also be released to the ambient air during the production, use, and disposal of industrial and consumer products that contain toluene.

The full EPA document can be read here.

The Environment Agency has published a technical review of toluene. Excerpts include:

- Toxicity to the central nervous system (CNS) is the main human health concern following medium- to long-term inhalation exposure. Although there is a lack of human studies of oral toxicity, nervous system toxicity has been observed in animal studies following ingestion.

- Although toluene occurs naturally as a result of forest fires and is found in low concentrations in crude oil, these sources are small compared with anthropogenic inputs into the environment (ECB, 2003). Most soils will contain very little, if any, toluene as a result of natural processes or diffuse pollution.

- Rapid initial rates of BTEX volatilisation from soil have been reported, but removal via volatilization from a sorbed or dissolved phase at depth can take

considerably longer. For example, 90 percent of toluene released to surface soils has been shown to volatilise within 24 hours, while the level of the same contaminant fell by less than 3 per cent in a year at depths of 1–1.3 metres below ground.

- Toluene in soil is also subject to microbial degradation under both aerobic and anaerobic conditions; the former is typically much more rapid, with toluene expected to degrade readily under most aerobic environmental conditions.

- Toluene can also be taken up from the atmosphere by plant leaves and other aboveground parts, although this is balanced to various extents.

- Uptake of gaseous toluene by leaves varies between plant species, depending on leaf morphology and chemical composition of the cuticle.

- Toluene concentrations of varying degrees have been found in apples, tomatoes, celery and cabbage among others. No presence was detected in root vegetables including potatoes.

The full EA document can be seen here.

Soil Guideline Values
Toluene concentrations in soil are measured in parts per million or milligrams per kilogram (mg kg).

Residential: 610*
Allotment: 120*

* Based on a sandy loam soil and 6% SOM. At a lower SOM, SGV may not be sufficiently protective.

The LQM/CIEH S4ULs for toluene in soils with 1% / 2.5% / 6% organic matter are as follows:
Residential with homegrown produce: 130 / 290 / 660
Residential without homegrown produce: 880 / 1900 / 3900
Allotment: 22 / 51 / 120
Commercial: 56000 / 110000 / 180000

ETHYLBENZENE
A colourless liquid, ethylbenzene smells like petrol. It is used in a variety of products including petrol, carpet glue, varnishes and paints.

An Environment Agency report states that: Benzene, toluene, ethylbenzene and xylene are often referred to collectively as BTEX because they have closely related chemical structures, and have similar fate and transport properties. They are often used together in industrial and petroleum products, and commonly occur together in the environment as a result of related pollution.

An extensive Danish study into the effects of ethylbenzene on the environment concluded: "The general human population is predominantly exposed to ethylbenzene via inhalation associated with the use of self service gasoline pumps or while driving a gasoline-powered motor vehicle especially in high traffic areas or in tunnels. In indoor air, tobacco smoke provides a general source of exposure to ethylbenzene. Exposure from food or drinking water is not expected to be a significant source of ethylbenzene."

The study in full can be read here.

Meanwhile, a German risk assessment of the chemical concludes that: "In humans, high concentrations of ethylbenzene vapours are irritating to mucous membranes of the eyes, nose and respiratory tract. Chemical burns of the eyes, mouth, face, and trunk after a leakage of a pipeline with ethylbenzene are reported."

That risk assessment can be seen in full here.

The Environment Agency published a technical note on ethylbenzene. Excerpts include:

- Ethylbenzene forms naturally in forest fires and is a constituent of crude oil.
- Ethylbenzene occurs in crude oil and is formed as a byproduct from the combustion of natural materials. These natural sources are considered to be small compared with anthropogenic sources.
- Upon release into soil, ethylbenzene will tend to sink through the unsaturated zone until it reaches the saturated zone. It has a low aqueous solubility and

will tend to collect at the water table as a light non-aqueous phase liquid (LNAPL) if present in sufficient concentrations.

The technical note can be seen in full here.

Soil Guideline Values
Ethylbenzene concentrations in soil are measured in parts per million or milligrams per kilogram (mg kg).
Residential: 350
Allotment: 90

Source for the above is here.

The LQM/CIEH S4ULs for ethylbenzene in soils with 1% / 2.5% / 6% organic matter are as follows:
Residential with homegrown produce: 47 / 110 / 260
Residential without homegrown produce: 83 / 190 / 440
Allotment: 16 / 39 / 91
Commercial: 5700 / 13000 / 27000

XYLENE
An aromatic hydrocarbon, xylene is a solvent with a sweet odor that is widely used in industry and medical technology.

An Environment Agency report states that: Benzene, toluene, ethylbenzene and xylene are often referred to collectively as BTEX because they have closely related chemical structures, and have similar fate and transport properties. They are often used together in industrial and petroleum products, and commonly occur together in the environment as a result of related pollution.

According to a UK Government circular on xylene:

- Xylene occurs naturally in petroleum products and crude oil.
- Exposure to xylene can occur from cigarette smoke and vehicle exhaust emissions.

- Breathing in xylene vapours in the air can cause irritation to the eyes, nose and throat.
- Ingesting xylene can severely irritate the stomach; nausea and vomiting may follow.
- Xylene can cause irritation, redness and swelling to the skin or eyes.
- Exposure to xylene can also cause headaches, dizziness, vertigo and drowsiness.

The circular in full can be read here.

Excerpts from the Environment Agency backgrounder on xylene include:

- Xylene has been detected in nuts, meat and fish, but was not generally detected in other food groups and its presence in water is low.

- Although individual xylene isomers occur naturally in the environment, their contribution to soil levels is considered smaller than anthropogenic sources.

- Mixed xylenes and xylene isomers are widely released into the environment due to their widespread use in petrol and as an industrial solvent.

- Highly elevated concentrations in soil can occur as a result of localised spills of petroleum and solvent products from historical and poor management practice (which can result in persistent contamination over a wide area). Xylene is often a component of complex and weathered mixtures of hydrocarbon compounds and may exist in soil as degradation by-products of more complex hydrocarbons.

- Most surface soils are likely to contain very little, if any, xylene. Xylene will volatilise readily from surface soil given its vapour pressure, air–water partition coefficients and Koc, but less rapidly than benzene and toluene.

- The inhalation of indoor vapour and the consumption of homegrown produce are the most significant exposure pathways at the SGV for the residential land use (both contributing similar amounts, approximately 45 per cent of total exposure, each). However, because the inhalation HCV is three times lower than that for oral exposure, the dominant exposure pathway driving the risk for the SGV for this land use is inhalation of indoor vapour.

- The consumption of homegrown produce is the most significant exposure pathway at the SGV for allotment land use.

Soil Guideline Values
Xylene concentrations in soil are measured in parts per million or milligrams per kilogram (mg kg).

O-xylene / m-xylene / p-xylene*
Residential: 250 / 240 / 230
Allotment: 160 / 180 / 160

*Exposure to all isomers of xylene should be considered together, because the HCV applied is based on the intake of total xylene, and not an individual isomer in isolation.

More on how the Environment Agency arrived at these values can be seen here.

The LQM/CIEH S4ULs for o-xylene in soils with 1% / 2.5% / 6% organic matter are as follows:
Residential with homegrown produce: 60 / 140 / 330
Residential without homegrown produce: 88 / 210 / 480
Allotment: 28 / 67 / 160
Commercial: 6600 / 15000 / 33000

The LQM/CIEH S4ULs for m-xylene in soils with 1% / 2.5% / 6% organic matter are as follows:
Residential with homegrown produce: 59 / 140 / 320
Residential without homegrown produce: 82 / 190 / 450
Allotment: 31 / 74 / 170
Commercial: 6200 / 14000 / 31000

The LQM/CIEH S4ULs for p-xylene in soils with 1% / 2.5% / 6% organic matter are as follows:
Residential with homegrown produce: 56 / 130 / 310
Residential without homegrown produce: 79 / 180 / 430
Allotment: 29 / 69 / 160
Commercial: 5900 / 14000 / 30000

PHENOL

Phenol, also known as carbolic acid, is an aromatic organic compound, usually in the form of colourless or white crystals. It has a sickly sweet smell and a sharp burning taste. Phenol is a part of coal tar and is formed during the natural decomposition of organic materials.

The Environment Agency describes Phenol as a colourless to pink crystalline solid that is water soluble and a weak acid. It occurs naturally in coal tar and is formed during the natural decomposition of organic materials; however, most of the phenol in the environment comes from anthropogenic (ie caused by human activities) sources. Among these are the production and use of phenol and its derivatives, waste incineration, motor vehicle exhausts, wood burning and cigarette smoking. However, it does persist in contaminated soils and coal tar wastes, suggesting that optimal degradation conditions are not always achieved.

Other excerpts from the EA circular on phenol include:

- Phenol has corrosive properties and is acknowledged to be a powerful skin irritant in humans.

- Phenol was widely used in the 19th century as an antiseptic and local anaesthetic, but its potential to cause tissue irritation led to a reduction in its use.

- Phenol has been shown to cause liver and kidney damage, neurotoxic effects and developmental toxicity in laboratory animals.

- Most soils will contain very little phenol from natural processes. Phenol is formed during the natural decomposition of organic matter and is a major metabolite of benzene. It has also been found in animal manures, which are a small but significant component of atmospheric emissions, and in human urine and faeces. Phenol is formed during combustion of organic materials including wood, and elevated levels have been detected as a result of forest fires.

- Anthropogenic activity is the main source of phenol in soil.

- The highest concentrations of phenol are expected to be found in soils contaminated with coal tars and other wastes from former gasworks.

The full Environment Agency report is here.

Soil Guideline Values
Phenol concentrations in soil are measured in parts per million or milligrams per kilogram (mg kg).
Residential: 420
Allotment: 280

The European Chemicals Bureau published a phenol risk assessment paper that states that in Denmark a health based limit value for phenol, cresols and xylenols in soil has been set at 70 mg phenols/kg soil.

ECB report is here.

The LQM/CIEH S4ULs for phenol in soils with 1% / 2.5% / 6% organic matter are as follows:
Residential with homegrown produce: 280 / 550 / 1100
Residential without homegrown produce: 750 / 1300 / 2300
Allotment: 66 / 140 / 280
Commercial: 760 / 1500 / 3200

ASBESTOS

Asbestos is the name used to describe several naturally occurring minerals that are made up of very thin microscopic fibers. These have been used to strengthen and fireproof materials right through much of the 20th century.

However, exposure to asbestos causes cancer and several other life-threatening diseases.

The British Lung Foundation adds:

- Before its dangers were known, asbestos was often used in buildings for

insulation, flooring and roofing and sprayed on ceilings and walls. It is now banned in the UK. Buildings constructed before the year 2000 may still have asbestos in them. If the asbestos-containing materials inside these buildings remain intact, they pose very little risk.

- It is only when these materials are damaged and/or disturbed that the tiny asbestos fibres can be released into the air and consequently breathed into your lungs.

- The symptoms of asbestos-related disease take many years – even decades – to appear after the original exposure to asbestos, so exposure a long time ago might only be showing up as a disease today.

More from the British Lung Foundation on asbestos can be found here.

The European Commission's in-depth report Soil Contamination: Impacts on Human Health states:

- Asbestos contamination in the soil is of concern in a number of locations, because it can be released to the air by the wind or by human disturbance. Asbestos has long-term health consequences if it is inhaled, with increased mortality from lung cancer and mesothelioma the most extreme outcomes. Disturbing contaminated soil can pose an inhalation risk.

- Researchers established links between asbestos exposure and lung malignancies, such as lung cancer and malignant mesothelioma (MM) several decades ago, and people living closest to mines or asbestos plants have been found to have an increased chance of contracting MM (in addition to workers at the plants, who have suffered occupational exposure). Clear cut cases have also been established where asbestos in soil causes health impacts for residents.

- Asbestos lies dormant in the lungs, typically only beginning to cause illness at least 20 years after exposure.

Excerpts from an industry guidance report issued by *Contaminated Land: Applications in Real Environments* (CL:AIRE) and titled Interpretation for

Managing and Working with Asbestos in Soil and Construction and Demolition Materials follow:

- Asbestos may also become entrained in soil and C&D materials on a brownfield site due to demolition activities, where asbestos has not been fully removed from site structures prior to demolition.

- Practitioners also should be aware of the possibility that asbestos contamination may be encountered on so-called 'greenfield' sites, or sites that do not appear to have been developed for potentially contaminating industrial uses.

The CL:AIRE document can be viewed in full here.

Soil Guideline Values

There does not appear to be a safe threshold for asbestos in growing spaces. It is a highly toxic element and poses grave health risks once airborne and inhaled so we recommend using an absolute measure here whereby the presence of any amount of asbestos poses a potential problem.

CYANIDE

A chemical compound, cyanides can exist in several forms including a colourless gas and crystals. They include any compound containing the monovalent combining group CN. Inorganic cyanides include the highly toxic sodium cyanide. Organic cyanides are usually called nitriles and include methyl cyanide or acetonitrile as well as the common hydrogen cyanide (HCN).

HCN is used in the preparation of acrylonitrile, which is used to produce acrylics, synthetic rubber and plastics.

Public Health England has published a factsheet on hydrogen cyanide. Excerpts include:

- Hydrogen cyanide is a colourless or light blue liquid or gas and is extremely flammable. It has a faint bitter almond odour, though not everyone is able to

detect this. Other names for hydrogen cyanide include prussic acid and hydrocyanic acid.

- Hydrogen cyanide is an important industrial chemical and over a million tonnes are produced globally each year. There are many uses for hydrogen cyanide, primarily in the manufacture of paints, plastics, synthetic fibres (for example nylon) and other chemicals.

- Hydrogen cyanide and other cyanide compounds have also been used as a fumigant to control pests. It also has uses in metal cleaning, gardening, ore-extraction, electroplating, dying, printing and photography. Sodium and potassium cyanide and other cyanide salts may be made from hydrogen cyanide.

- Hydrogen cyanide is released from a number of natural processes including by bacteria and fungi and from volcanic activity. Hydrogen cyanide may enter the environment from certain industrial processes, from release during combustion or from accidents involving its transport. A wide range of combustion processes produce hydrogen cyanide gas in the smoke or fumes; including building fires, cigarettes, vehicles exhausts and fires involving nitrogen-containing materials such as polyurethane foams.

- Hydrogen cyanide is very toxic, it prevents the body from using oxygen properly. Early signs of exposure to hydrogen cyanide include headache, a feeling of sickness, dizziness, confusion and drowsiness. Substantial exposure may rapidly lead to unconsciousness, fitting, coma and possibly death.

The full PHE circular can be read here.

Soil Guideline Limits

Cyanide concentrations in soil are measured in parts per million or milligrams per kilogram (mg kg).

The official assessment of the Grenfell fire implications on the surrounding environment concluded that "there are no UK SGVs, C4SLs or S4ULs for cyanide species", and instead relies on the following Dutch Intervention Values and USEPA RSLs based on 1% SOM (values in mg/kg):

Cyanide (free)

Dutch Intervention Values for
Residential with plant uptake: 20
Residential without plant uptake: 20
Allotment: 20

Cyanide (total)
USEPA RSL
Residential with plant uptake: 78
Residential without plant uptake: 78

The Grenfell report can be read here.

AMMONIA

A colourless gas with a distinct odor, ammonia is a common industrial chemical. It is composed of nitrogen and hydrogen. It is also the starting material for many nitrogen compounds.

Its most common use is as a fertilizer but it is also used in the manufacture of explosives – trinitrotoluene, also known as TNT, and nitroglycerine among others.

The International Programme on Chemical Safety has published an ammonia health and safety guide. Excerpts include:

- Ammonia is one of the most extensively used industrial chemicals, production in the USA alone being of the order of 20 million tonnes per year. Most of this is used in fertilizers, fibres and plastics, and explosives. It is also widely used as a cleaning and descaling agent and in food additives, applications that may result in general population exposure.

- Ammonia is present in the environment as a result of natural processes and industrial activity, including certain types of intensive farming.

- Industrial activity may cause local and regional elevations in emission and atmospheric concentrations. Surface waters receive ammonia from point

sources, such as effluent from sewage treatment and industrial plants, and also through atmospheric deposition, the breakdown of vegetation and animal wastes, applied artificial fertilizers, and urban run-off.

- Exposure of the skin and eyes or the respiratory tract may occur, but the chief effect of ammonia is local irritation due to its alkalinity when dissolved in body fluids.

- Occupational atmospheric exposure is usually regulated to a limit within the range of 18-40 mg/m^3, but exposures of up to 100 mg/m^3 are well tolerated for short periods in such situations as poultry houses. Ammonia is present in raw foods and is added to processed foods. It has been calculated that the daily human intake of ammonia and ammonium salts from this source is about 18 mg/day.

- Ammonia released into the atmosphere is deposited on the ground, chiefly as ammonium sulfate and ammonium nitrate. Ammonia applied to the ground as fertilizer and discharged from point sources, such as sewage treatment plants, is similarly converted, though high levels of ammonia may occur locally. Ammonia is a key compound in the nitrogen cycle. It is converted by soil bacteria to nitrate, which is then taken up by plants and incorporated into amino acids and other nitrogenous compounds. Plants cannot excrete ammonia and levels exceeding those that can be incorporated are toxic.

The Inchem guide can be read in full here.

In 2002, the Department for Environment, Food and Rural Affairs (Defra) published an extensive investigation titled Ammonia in the UK. Excerpts include:

- Ammonia is an air pollutant largely emitted from agriculture that threatens significant areas of valuable habitats in the UK.

- Ammonia is very soluble in water and readily reacts with other substances in the atmosphere to form ammonium (NH4 +) compounds such as ammonium sulphate and ammonium nitrate. Following the emission of ammonia gas to

the atmosphere, it may be deposited to land either as gas or as ammonium-N compounds in rainfall. This can have profound effects on natural ecosystems (e.g. heathland, moorland).

- Concentrations of ammonia in the air are greatest in those parts of the country with the most livestock farming, particularly where ammonia emissions are mainly from pig, poultry and cattle farming. High concentrations of ammonia are also found in some urban areas.
- Ammonia reacts in the atmosphere to form particles containing ammonium. Most of these particles are removed from the atmosphere by rain, while the gaseous ammonia is absorbed by land surfaces (such as soil, water and vegetation).
- There are several potential options to reduce ammonia emissions from non-agricultural sources. Given the large number of small sources a broad approach would be required to make significant reductions. Vehicles fitted with catalytic converters, sewage sludge processing and industrial processes are the sectors with the most potential to reduce non-agricultural emissions.

The Defra publication in full can be read here.

Soil Guideline Values

In the absence of preset UK amounts we rely on the above Inchem guide, which states that:

"Long-term contact with more dilute ammonia solutions that are not immediately irritant may produce damage to the skin as a result of alkaline saponification of protective fats. The vapour is irritant to the eyes and the respiratory tract at concentrations above about 50 mg/m^3 (70 ppm). Mild irritation can occur with short-term exposure to concentrations below about 150 mg/m^3 (210 ppm)."

As for soil levels, Inchem writes: "The ammonia present in soil is in dynamic equilibrium with nitrate and other substrates of the nitrogen cycle and is difficult to measure as its concentration is in constant flux."

And:

"The major groups of organisms at risk from elevated ammonia levels are aquatic

raising the maximum concentration of these in sewage sludge for agricultural use to 1000 mg/kg.

The regulations can be read here.

MONOCYCLIC AROMATIC HYDROCARBONS (MAHs or BTEX)

This is a group of four chemicals: benzene, toluene, ethylbenzene and xylene.

BENZENE
An organic chemical compound, benzene is a colourless flammable liquid. It is a natural component of crude oil and petrol. The World Health Organization describes exposure to benzene as a major public health concern.

Excerpts from a WHO circular on benzene include:

- Human exposure to benzene has been associated with a range of acute and long-term health effects and diseases, including cancer and aplastic anaemia.
- Exposure can occur occupationally and domestically as a result of the ubiquitous use of benzene-containing petroleum products, including motor fuels and solvents. Active and passive exposure to tobacco smoke is also a significant source of exposure.
- Benzene causes acute myeloid leukaemia (acute non-lymphocytic leukaemia), and there is limited evidence that benzene may also cause acute and chronic lymphocytic leukaemia, non-Hodgkin's lymphoma and multiple myeloma. Individuals who have experienced benzene poisoning requiring treatment show a substantially increased risk of mortality from leukaemia.

The full WHO document can be read here.

The EA has published a technical review of benzene. Excerpts include:

- Benzene can also be taken up from the atmosphere by plant leaves and other above ground parts.

- Surveys of benzene concentrations in plants have found that they tend to accumulate in oil-containing plant structures such as the wax layers of leaves and fruit.

The full EA document can be seen here.

Soil Guideline Values
Benzene concentrations in soil are measured in parts per million or milligrams per kilogram (mg kg).

Category 4 Screening Levels for Benzene
Residential with home grown produce: 0.87
Residential without home grown produce: 3.3
Allotments: 0.18
Commercial: 98

More on the Defra C4SL can be read here.

The LQM/CIEH S4ULs for benzene in soils with 1% / 2.5% / 6% organic matter are as follows:
Residential with homegrown produce: 0.087 / 0.17 / 0.37
Residential without homegrown produce: 0.38 / 0.70 / 1.4
Allotment: 0.017 / 0.034 / 0.075
Commercial: 27 / 47 / 90

TOLUENE
An aromatic hydrocarbon, toluene is a colourless liquid with a distinctive smell associated with paint thinners.

Toluene is used in making paints, paint thinners, fingernail polish, lacquers, adhesives and rubber. It is also used in some printing and leather tanning processes. It is added to petrol along with benzene and xylene to improve octane ratings.

An Environment Agency report states that: Benzene, toluene, ethylbenzene and xylene are often referred to collectively as BTEX because they have closely related chemical structures, and have similar fate and transport properties. They are often used together

animals and terrestrial plants. There appears to be little danger for terrestrial animals, including man, except from acute accidental exposure."

And conclude with a US Centers for Disease Control circular summary stating:

"A 4-year study on ammonia levels in the soil (0–10 cm deep) of an open field (samples obtained in early May of each year) showed that ammonia concentrations ranged from 1 to 5 ppm (Beauchamp et al. 1982). The day after application of a slurry of liquid cow manure, the soil concentration ranged from 2 to 3,349 ppm. Five days after application, the concentration of ammonium ranged from 2 to 848 ppm. The greatest ammonia concentration was in the uppermost 4 cm of soil."

The full CDC circular can be perused here.

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