Soil contamination in China: current priorities, defining background levels and standards for heavy metals

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Abstract

The Chinese Government is working to establish an effective framework in managing soil contamination. Heavy metal contamination is key to the discussion about soil quality, health and remediation in China. Soil heavy metal contamination in China is briefly reviewed and the concepts of background values and standards discussed. The importance of contaminated land and its management for China food security and urbanization are discussed. Priorities for China's next steps in developing an effective research and management regime are presented. We propose that critically important to the science-based risk assessment of contaminants in soils is the incorporation of speciation and bioavailability into the measurement and evaluation criteria. Consideration of soil biology/ecological endpoints will be necessary to protect ecosystem health. National and regional/local scenarios of land use type/usage will address residential/urban re-use of industrial land as well as varying agricultural scenarios.

Keywords: Soil contamination, soil sampling, risk assessment, land use, China, United Kingdom

1. Introduction

Soil pollution refers to the occurrence of some substances in soil caused by human activities, which can change soil quality and function, lead to soil degradation, damage basic soil structures and has the potential to harm human and environmental health. Soil pollution has been identified as a key national priority in China, with an increase of reports on agricultural land and human health affected by soil pollution (Luo et al., 2015). With economic growth and industrial restructuring in China, soil pollution from abandoned sites in urban areas has also drawn attention and concern regarding the safety of human settlements and human health in industrial and brownfield sites (Cao and Guan, 2007; Luo et al., 2015). According to the National Investigation Bulletin of Soil Pollution Status (NIBSPS) issued by the Ministry of Environmental Protection of the People's Republic of China (MEP-PRC), investment in soil remediation will reach up to RMB 4,633,000 million (£526,000 million). This is a huge financial commitment, so it is critical that sound science and knowledge are applied to the decisions that determine how this money will be spent. There is still work to be done in China to improve information to define soil background conditions and pollution status, the relevant science and policies needed to set soil quality standards, the assessment system for site evaluation and soil remediation strategies and technologies (State Council, 2016). The importance of soil pollution and degradation in China has now been recognized at the highest level, with specific requirements included in China 13th Five-Year National Development Plan and the Fifth Plenum of the 19th Central Committee of the Communist Party of China (MEP-PRC, 2016).

This paper focusses on an assessment of some of the priorities relating to heavy metals in Chinese soils. Soil heavy metal pollution has become a widespread and serious problem globally. Heavy metals are present naturally in soils, but elevated levels may be derived from agricultural activities, urbanization, industrialization and other human activities. To define and resolve pollution problems, it is therefore necessary to be able to define what constitutes ‘clean’, ‘background’ and ‘contaminated’ and ‘polluted’ soils. Following surveys and analysis of heavy metals in soils, many countries such as the United Kingdom, the United States and the Netherlands have developed such values. Depending on the national environmental management and regulatory processes, different countries have different approaches. Examples include the *Soil Guideline Values (2009)* in the UK, the US *Soil Screening Levels (2002)*, the *Intervention Values (2009)* in the Netherlands, and *Environmental Quality Standards (EQS) (1991 and 1994)* in Japan.

China first developed its own Soil Environmental Quality Standards (SEQS) in 1995 (GB15618-1995) (Xia, 1996). So far, there are 63 current standards related to soil environmental protection in China and the number of standards released by the MEP-PRC has increased, especially in the last 5 years (Li et al., 2016). Following China previous focus on air and water quality, the Government has now turned a focus onto soils and groundwater, publishing a landmark ‘10-Measures for Soil Pollution Action Plan’ in 2016 (State Council, 2016). Its purpose is to manage, control and prevent soil pollution, to gradually improve soil quality in China. The Plan’s first action recommends conducting surveys on soil pollution to better define the status of China’s soil resources. GB15618-1995 first defined SEQS values for 8 heavy metals in China to apply to the whole country. Later, relevant soil quality standards in China were developed by referring to GB15618-1995 as a basic standard (Li et al., 2016). For example, the MEP-PRC issued a series of standards, such as ones for ‘Green food-technical conditions for environmental areas’ (NY/T391-2000), but these are rarely applied in practice. In contrast, European countries conduct soil pollution control mainly through a series of systematic assessment methods. These are based on different land use type, soil specificity or local environmental factors for understanding the risks either to the environment or human health. In China over the past 20 years, a general soil standard value (GB15618-1995) was applied to the whole country, without considering soil specificity and integrated environmental factors. During this period, in order to meet development needs, some regional standards for soil risk assessment were also set; for example, Beijing issued screening levels for soil environmental risk assessment of sites (DB11/T 811) in 2011.

A particular challenge for China is the country size and hence the range of soil types and conditions. Heavy metal concentrations vary naturally in soils, as a function of the geology, climate, land use etc. Hence, the Soil Environment Background Value (SEBV) will vary across the country. SEQS values were originally set nationally, so now there is an important discussion about whether different SEQS are needed regionally/locally. When managing contaminated sites, SEQS and SEBV will affect the selection, formulation and cost of remediation strategies.

Internationally, different countries have prioritized soil pollution and management in different ways. China has been eager to learn from this (Luo et al., 2015; Wang et al., 2005; Wen et al., 2010; Xia and Luo, 2007) and – given the Government's stated aim to manage its soil pollution problems effectively - has the opportunity to put in place sound, strong policies and management structures. An interesting comparison is with the UK, which has a long history and legacy of contaminated land problems and a mature environmental regulatory system (Luo et al., 2009; Wu, 2007). The 10-Measures Soil Pollution Action Plan strongly recommended that: surveys of the soil pollution situation be conducted; regulations and laws of soil pollution prevention be amended; soil pollution control and remediation be promoted; and a control system to prevent soil pollution be introduced (State Council, 2016).

Given the highly topical nature of soil contamination issues in China, in this paper we focus on the following questions: 1. What is the situation of soil heavy metal contamination in China? 2. What factors affect the background value of heavy metals in soils? 3. What are the background values of selected heavy metals and how do they compare between China and the UK? 4. What can we learn from the UK about soil survey methodologies and soil environmental standard assessment? 5. What are future priorities and next steps for China in its management of soil pollution?

2. Heavy metal soil pollution in China

As in other countries, key sources of heavy metals to Chinese soils include: metal mining and smelting; industrial activities, power generation; agricultural activities, including fertilizer and animal manure amendments; waste disposal activities; urbanization, transportation. In some regions, high contamination of the soil occurs around point sources, for example, mines and smelters – giving high but generally localized problems. In other situations, for example, agricultural soils, contamination may be lower, but important as a direct route of food contamination (Fu et al., 2016; Zhou et al., 2014; Zhu et al., 2008). In some countries, inventories have been published which estimate the relative importance of these different sources to the national soil resource. This approach would be very helpful in China, because it provides a scientific basis to prioritize source reductions; we are not aware that this exercise has been performed in China yet. The distinction between 'high level hotspots' of contaminated land (e.g. brownfield sites; mines) and diffusive agricultural sources may also be important in management. For example, should there be different standards for agricultural land? Can brownfield sites be cleaned by simply excavating and removing dirty soils from important areas of re-development? (Cao and Guan, 2007; Li et al., 2015; Wang et al., 2014; Wei and Yang, 2010).

Over the past decades, heavy metal contamination has increased worldwide, following large-scale mining and industrial releases (Li et al., 2014). Ultimately much of the metal from such activities reaches the soil, via wastes, disposal and atmospheric deposition. China has undergone huge and rapid urbanization and industrial expansion over the past thirty years, which will have resulted in increased release of heavy metals to the environment, and the burden of metals held in surface soils (Chen, 1991). It has been estimated that nearly 20 million hectares of arable land has been polluted by heavy metals, such as Cd, Pb, Cu, and Zn in China, accounting for approximately 20% of the total arable land area (Lin, 2004; Zhao et al., 2007). Although information is not available on a site-specific basis, national soil surveys conducted by the MEP-PRC and the Ministry of Land and Resources of the People's Republic of China (MLR-PRC) (2005 to 2013) concluded that 16.1% of national land (based on sampling points, including arable land, some woodland, grassland, unused land, construction land) was contaminated (i.e. exceeded background values), of which >80% were exceeded by inorganic contaminants. Contamination may have been with heavy metals and other inorganic contaminants, and/or with organic chemicals. Cd was responsible for most exceedances, accounting for 7% of national land. It should be noted that there was a sampling bias, because soils were not sampled in proportion to the national land coverage. Nonetheless, the Ministries concluded that "The overall situation looked not optimistic, of which, the situation of arable land and industrial abandoned land are the most severe". In addition, in recent years, many reports in China have highlighted contamination and poisoning of animal and human health through the food chain. Prominent cases include Cd in rice, Pb and As poisoning incidents (Song et al., 2013). Hu et al. (2014) concluded that Pb, Cr, As, Cd and Hg constituted the five most important heavy metal contaminants in Chinese soils.

3. Soil background values and factors that affect them

'Soil environment background values' (SEBV) are the concentration of elements or components in soil with little influence from human activities (Connor and Shacklette, 1975; Wang and Yang, 1990). They reflect the underlying geology and soil formation processes; hence they vary between locations and are commonly expressed as a range of values for a particular country or region. The background value could change over time, if environmental processes (including background human activities) affect the burden in the soil. So, absolute uncontaminated or pristine soils may be difficult to identify, since industrial activities have emitted heavy metals and other contaminants into the atmosphere. In general, the SEBV is a relative concept (Xia and Luo, 2006). The geochemical background refers to the normal abundance of an element in barren earth material or the normal range of an element in certain areas. The concept of geochemical background aims to distinguish the normal and abnormal concentration of elements. In the exploration geochemistry field, it may be an indicator of an ore occurrence, while for environmental geochemistry, it may be an indicator of a contaminated or insufficient element (Cheng et al., 2014; Hawkes and Webb, 1963). It is assumed that the range of SEBVs give 'clean' soils where there are no adverse 'pollution' effects. Hence, contaminated soils are defined with levels of heavy metals (and other constituents) above the SEBV (Xia and Luo, 2006). This is why it is so important to conduct carefully designed surveys of contaminants in soils, because precise definition of the SEBV will determine whether the soil is contaminated and to what degree.

As just noted, the SEBV is affected by various abiotic and biotic factors that change in space and time. For example, parent materials, soil chemical properties, topographic factors, hydrological factors, human activities, geological factors, weathering and leaching conditions of parent material driven by climatic factors etc. (Chen and Wang, 1987; China National Environmental Monitoring Centre, 1990; Fu and He, 1992, Liang and Zhang, 1988). Parent materials are a direct and main factor influencing the SEBV in many studies (Chen and Wang, 1987; Nair and Cottenie, 1971; Oertel, 1961). Climatic factors indirectly affect the SEBV by controlling weathering and leaching processes. Chen and Wang (1987) found soil types and parent materials to be the main drivers that led to a decline from south to north in Shanxi province and from southeast to northwest, based on a survey of distribution trends and factors affecting the SEBV. Deng et al. (1986) showed that the main factors affecting background values are different from region to region in Beijing; topographical characteristics are the main driver in plain regions, while in mountain regions it is parent materials. Hydrological and topographical factors directly influence soil formation factors, soil surface runoff, soil surface temperature, the degree of surface erosion etc., and then influence soil parent materials and soil elemental composition. For example, fine clays which are richer in heavy metals than sands and silts, will accumulate in floodplains and result in higher concentrations than in hillslope soils. Thus, the determination of SEBVs needs to be based on statistical analyses, with careful consideration given to sampling design and soil sample collecting, statistical tests of sample frequency distribution, data distribution patterns and eigenvalues, to show the range of background values with a given confidence interval (China National Environmental Monitoring Centre, 1990). Further details on these issues are given later in the paper.

Deriving soil background values in China and the UK

The UK has a widely varying geology for a comparatively small country, areas of heavy metal mineralization, a long history of mining and industrial activity, a legacy of soil contamination, and a lot of experience in the management and regulation of soil contamination. The development planning process has been used to deal with contaminated sites since the creation of the current UK land use planning system in 1947 (Luo et al., 2009). Soil remediation of contaminated sites has been carried out since the 1960s, often with low cost and pragmatic solutions (Ferguson, 1999). In 1976, the Inter-departmental Committee on the Redevelopment of Contaminated Land (ICRCL) was established as the first central institutional mechanism to clearly address this issue. In the Environmental Protection Act of 1990, the provision for registers of potentially contaminated sites was included. The current system of regulation was created in the 1995 Environment Act. In 2005, the Contaminated Land Exposure Assessment (CLEA) model was published with a series of soil guideline values and toxicological reports on key soil contaminants. Hence, the UK has developed a relatively effective management system from longstanding practice. China is experiencing a situation like the UK had several decades ago, although on different scales. As noted earlier, mining and industrial activities have become extensive in parts of China, whilst urban areas have expanded and re-developed on sites with a legacy of contamination. In rural areas, there are several examples where agricultural land and community areas have become contaminated too (Liu et al., 2013; Shi et al., 2008; Zhuang, 2015).

The UK approach to contaminated land management is underpinned by a series of comprehensive surveys of soil contaminants, which allow a clear definition of the typical levels, ranges and distributions of elements. It is therefore useful to compare the situation with China, which has undertaken national surveys too and is planning further work of this kind.

4. **Experience from surveying UK soils**

In the UK, there have been different national soil surveys in past decades. In the late 1970s, soil information in England and Wales was incomplete, knowledge of regional soil geochemistry was limited, available soil maps only covered ~25% of the area, and the existing information was not based on a representative and unbiased sampling strategy. Thus, between 1978 and 1983, the National Soil Inventory (NSI) carried out a survey of soil background metal concentrations in England and Wales (McGrath and Loveland, 1992).

In 1996, the Royal Commission on Environmental Pollution (RCEP) published the nineteenth report on the Sustainable Use of Soil, which stressed the need for the assessment and monitoring of soil quality, including certain chemical and physical attributes, and some biological parameters. A second survey – the so-called Countryside Survey – therefore began in 1998. The purpose has been to assess and monitor soil quality over time, by returning to the same locations over several years (Barr et al, 2003).

A third survey was conducted in 2011/12, to give guidance on normal levels of contaminants - to support revision of the Part 2A Contaminated Land Statutory Guidance. This was conducted by the British Geological Survey (BGS) in England and Wales (Johnson et al., 2012). A summary comparison of the survey designs and methodologies is presented in Table 1.

Table 1. Comparison of sampling methods across three national soil surveys in the UK.

	NSI	CS 2000	BGS
Study area	England, Wales	England, Wales, Scotland	England, Wales
Time	1978-1983	1998-2000	2011-2012
Sampling density	5 km x 5 km	1 km x 1 km	G-based: Urban: 1 km x 1 km; rural: 2 km^2; NSI (XRFS): 5 km x 5 km
Quadrat size	20 m x 20 m	14 m x 14 m	20 m x 20 m
Sample number (per quadrat)	1	3	5
Sampling depth	0-15 cm deep topsoil	15 cm deep x 8 cm dia.	topsoil: 0-15 cm; surface soil: 0-2 cm; deeper soil: >30 cm
Investigated elements	Al, Ba, Cd, Cr, Co, Cu, Fe, Pb, Mg, Mn, Ni, P, K, Na, Sr, Zn	Cd, Cr, Cu, Pb, Ni, V and Zn	As, Cd, Cu, Hg, Ni and Pb
Number of soil samples	5691	1081	42133
Analytical value	Range, mean, median, maximum, minimum	Mean, standard deviation, median, maximum value and minimum value	Mean, range, minimum, maximum

Notes: NSI: National Soil Inventory; CS2000: Countryside Survey 2000; BGS: British Geographical Survey.

As Table 1 shows, ~50,000 UK surface (0-15 cm) soil samples have been taken and analyzed, albeit with slightly different purposes and with a focus on different land use types. A comparison of a selection of heavy metals from these surveys is given in Table 2.

Table 2. Comparison of range, mean and median of four comparative heavy metals (Cd, Cu, Ni, Pb) from the results of NSI, CS2000 and BGS surveys (all concentrations in mg/kg).

Cd	**Range**	**Mean**	**Median**
NSI	<0.2-41	0.8	0.7
CS2000	0-11	0.49	0.3
BGS	0.3-20	0.5	0.3
Cu	**Range**	**Mean**	**Median**
NSI	1.2-1508	23	18
CS2000	0.3-448	18	14
BGS	<1-5326	27	20
Ni	**Range**	**Mean**	**Median**
NSI	0.8-440	25	22.6
CS2000	0-1890	24	16.3
BGS	1-506	25	23
Pb	**Range**	**Mean**	**Median**
NSI	3-16338	74	40
CS2000	1.3-20600	88	37
BGS	3-10000	72	41
pH	**Range**	**Mean**	**Median**
NSI			
CS2000	3.4-8.71	5.72	5.58
BGS			
Soil organic matter	**Range**	**Mean**	**Median**
NSI			
CS2000	2-98.02	29.11	12.57
BGS			

Notes: Median values are the most commonly reported values for background soils. They are more meaningful than mean values, which can be biased by a few extreme polluted values. See, for example Davies (1983) paper on soil Pb values.

Median values (Davies, 1983) provide a good way to compare the data: the 3 surveys gave the following values for the elements presented in Table 2: Cd – 0.7, 0.3 and 0.3; Cu – 14, 18 and 20; Ni, 23, 16 and 23; Pb – 40, 38 and 41. The main conclusions from Tables 1 and 2 are: i. despite different sampling and analytical methods, the general soil quality determined by the 3 surveys is very similar. ii. The sampling, preparation procedures and – crucially - the large number of samples taken provides a robust way to determine the typical range of heavy metal concentrations in soils.

5. Surveying Chinese soils

The earliest research on SEBVs in some selected city areas of China (Beijing, Nanjing, Guangzhou etc.) was in the mid-1970s. Subsequently, in 1978, SEBVs for 9 elements in agricultural soils and crops were surveyed in 13 provinces. In 1982, a background value survey was listed in the national key scientific and technological projects, which was carried out in a few of the main climate zones in northeast China, Yangzi River basin, Pearl River Basin etc. In 1990, a large-scope and systematic survey for SEBVs was carried out across the whole of China, covering all 29 provinces, cities and autonomous regions. These survey data were summarized in a book entitled China Soil Element Background Value (China National Environmental Monitoring Centre, 1990). From 2005, the MEP-PRC and the Ministry of Land Resources launched a national soil pollution survey to capture the distribution data and to look for changes in the 20 years since the 1990 survey. It covered all arable land and parts of the woodland, grassland, unused and construction land. In 2014, a national bulletin on site-specific soil pollution status was published, to summarize the pollution situation without detailed site-specific or soil survey data.

A comparison of Tables 2 and 4 shows close agreement for Chinese and UK Cu and Ni background values. The median value for Cd in UK soil is ~0.3 mg/kg, about 3 times higher than that of the Chinese 1990 survey. UK Pb median values were ~40 mg/kg, against a Chinese median of 24 mg/kg. This might be explained by the UK's long history and density of Pb mining and inefficient smelting operations (Davies, 1983).

Table 3. Sampling details for the 1990 national soil survey in China

Study area	Covered 29 provinces, cities and autonomous regions
Time	1990
Sampling density	East areas: 30 x 30 km^2 per study point; Central areas: 50x 50 km^2 per study point; west areas: study point from 80 x 80 km^2 per study point
Soil profile	1.5m x 0.8m x 1.2m (Length x width x depth)
Sample depth	A layer: 0-20cm, B layer: 50cm, C layer: 100cm
Investigated elements	As, Cd, Co, Cr, Cu, F, Hg, Mn, Ni, Pb, Se, V, Zn
Number of soil samples	4095
Analytical value	Maximum value, minimum value, arithmetic mean and geometric mean

Table 4. The range, mean and median of four comparative heavy metals from the 1990 China soil survey (all concentrations in mg/kg).

China soil survey 1990	Range	Mean	Median
Cd	0.001-13.4	0.097	0.079
Cu	0.33-272	23	21
Ni	0.06-628	27	25
Pb	0.68-1143	26	24

6. Methodologies for determining background concentrations in soil

6.1 Statistical methods used for UK soils

6.1.1 Countryside Survey 2000

All elements were analyzed in different environments, classified according to Land Class and eighteen broad habitats and major soil groups and Countryside Vegetation System Aggregate Vegetation Class. Data are typically presented as figures (box-plots, scatterplots, frequency histograms etc.) to summarize the variation in different environmental factors. Mean values, standard deviations, median, maximum value and minimum values are commonly calculated to represent the primary analysis (Black et al., 2002).

6.1.2 National Soil Inventory

For all variables, the range, mean, median, maximum, minimum, skewness and kurtosis were calculated for both transformed and log10-transformed data (except for pH). Box plot analysis was performed for the data of Cd, Co, Cr, Cu, Ni, Pb and Zn. Correlation analysis was performed on soil element concentrations (log10-tranformed data). Principal component analysis (PCA) was performed on all datasets, including all elemental concentrations, organic carbon and pH to provide an overall view of the relations among variables. Simple or multiple linear regression analysis was used to exclude the outlier data (McGrath and Loveland 1992).

6.1.3 British Geological Survey

Values for contaminant domain normal background concentrations were calculated by a study of a contaminant's population distribution. Skewness coefficient and octile skew were used as statistical measures. Percentiles for the domain data sets for each contaminant were generated along with calculations of percentile confidence intervals. The upper limit for a normal background concentration has been as the upper confidence limit of the 95th percentile (Johnson et al. 2012).

6.2 Statistical methods used in Chinese soils

Relevant information (soil types, parent materials, topography, latitude, longitude, vegetation, land use types, administrative regions etc.) of 4,095 typical soil profiles, together with the chemical analytical data were stored in a database of Chinese soil background values. In summary, soil types were divided into 41 statistical units, parent materials were divided into 21 units, and administrative regions were divided into 34 units, so in total, every element has 97 statistical units. Frequency distribution graphs are available for different elements, with the maximum, minimum, arithmetic mean and geometric mean values were presented. For elements with a log-normal distribution, the geometric mean (M) was used to represent the data distribution, the geometric standard deviation (D) to represent the level of dispersion, and M/D^2-MD^2 for the range of 95% confidence interval. For the elements with a normal distribution, the arithmetic mean ($\bar{x}$) was used to represent the data distribution, the arithmetic standard deviation (s) for the level of dispersion and $\bar{x} \pm 2s$ for the range of 95% confidence interval (China National Environmental Monitoring Centre, 1990).

6. Soil standards

Environmental Quality Standards (EQSs) for soils (GB15618-1995) in China were officially released in 1995. They were derived based on several factors: data on the soil background in China; data from soil ecological tests; data from geographically anomalous areas in China and information on soil standards or guidelines from abroad (MEP-PRC, 1995; Wu and Zhou, 1991). These EQSs set the maximum acceptable concentration of pollutants and relevant monitoring methods in the soil based on different soil functions/uses, protection targets and soil properties.

Three types of standard were set: Type I is protective of soils in national nature reserves, centralized drinking water resources, tea plantations, pasture and other protected areas, and the goal is to basically maintain the natural background level. Type II is applicable to the soil in general farmland, land for growing vegetables, tea plantations, orchards, pasture etc., where the goal is to not cause harm and pollution to plants and the environment. Type III is applicable to woodland soil, and farmland soils near to high background soils of more pollutant capacity and mineral fields, where the goal is basically to not cause harm and pollution to plants and the environment. Chinese EQSs take account of the soil pH value, cropping pattern and soil cation exchange capacity (see Table 5 for details) (MEP-PRC, 1995).

Table 5. Soil environment quality standards adopted in China for general farmland (mg/kg). See text for definition of Type I, II and III.

Standard		Type I soil	Type II soil			Type III Soil
Soil pH		Natural background	<6.5	6.5~7.5	>7.5	>6.5
Cd		0.20	0.30	0.30	0.30	1.0
Hg		0.15	0.30	0.50	1.0	1.5
As	Paddy field	15	30	25	20	30
As	Non-irrigated farmland	15	40	30	25	40
Cu	Farmland	35	50	100	100	400
Cu	Orchard	--	150	200	200	400
Pb		35	250	300	350	500
Cr	Paddy field	90	250	300	350	400
Cr	Non-irrigated farmland	90	150	200	250	300
Zn		10	200	250	300	500
Ni		40	40	50	60	200

In order to protect agricultural soil, control agricultural soil contamination risk, safeguard agricultural product security, the normal growth of crops and soil ecological environment, China has been working on the development of new soil environmental quality standards. Twenty years after the release of GB15618-1995, the new soil quality guidance (Risk control standard for soil contamination of agricultural land GB15618-2018) was issued in 22nd June 2018, to replace GB15618-1995 and to take effect on 1st August 2018 (Table 6 & 7). This standard regulates the soil risk screening value and risk intervention value in agricultural land, and the requirements of monitoring, implementation and supervision. These values were derived from human health risk assessment procedures. In addition, a risk control standard for soil contamination of development land (GB36600-2018) was also issued, to come into force at the same time to protect human health and living environmental security.

Table 6 Screening values of soil pollution risk of agricultural land (basic items) (mg/kg).

Pollutant	Risk screening value				
		$pH \leq 5.5$	$5.5 < pH \leq 6.5$	$6.5 < pH \leq 7.5$	$pH > 7.5$
Cd	Paddy	0.3	0.4	0.6	0.8
Cd	other	0.3	0.3	0.3	0.6
Hg	Paddy	0.5	0.5	0.6	1
Hg	other	1.3	1.8	2.4	3.4
As	Paddy	30	30	25	20
As	other	40	40	30	25
Pb	Paddy	80	100	140	240
Pb	other	70	90	120	170
Cr	Paddy	250	250	300	350
Cr	other	150	150	200	200
Cu	Paddy	150	150	200	200
Cu	other	50	50	100	190
Ni		60	70	100	190
Zn		200	200	250	300

To quote the new guidance: ‘The value of the main pollutant content in the soil when the quality and safety of edible agricultural products, crop growth or the soil ecological environment are or may have adverse effects. If the content of pollutants in soil is lower than this value, the risk of soil pollution such as non-conformity of quality and safety standards in edible agricultural products, may generally be ignored. If there may be a risk of soil pollution, soil environmental monitoring and coordinated monitoring of agricultural products should be strengthened, and in principle, safe use measures should be taken. Agricultural land is classified into three types – arable land (paddy, irrigated land, dry land), garden (orchard, tea garden) and pasture (natural pasture and artificial pasture). In this standard, ‘others’ include all kinds of land except for paddy.’

Table 7 Intervention values of soil pollution risk of agricultural land (mg/kg).

Pollutant	Risk intervention value			
	pH≤5.5	5.5<pH≤6.5	6.5<pH≤7.5	pH>7.5
Cd	1.5	2.0	3.0	4.0
Hg	2.0	2.5	4.0	6.0
As	200	150	120	100
Pb	400	500	700	1000
Cr	800	850	1000	1300

Notes: Risk intervention value in this standard refers to the value of the main pollutant content in the soil when it causes or may cause serious effects on the quality and safety of edible agricultural products. If the content of pollutants in the soil exceeds this value, the risk of soil pollution, such as non-compliance with quality and safety standards, is high, and strict control measures shall be taken in principle.

A particular challenge for China at the present time is that specific areas are considering variants to the national standards, to reflect their particular challenges. For example, areas (jurisdictions at province or city level) with high background values, or particular soil/crop systems may wish to adopt more pre-cautionary limits. In other situations, standards may be considered as targets for remediation of contaminated sites. Although not published from the national survey of China, there are many studies which have reported geographical variations, with some provinces having high background values, for example (Cheng et al., 2014; Cheng and Tian, 1993; Dong et al., 2007; He et al., 2006; Pan and Yang, 1988). Hunan Province is an interesting example. It has a long history (~2,700 years) of non-ferrous metal mining and metal resources, which began to be extensively exploited in the 1980s. With industrial development, many incidents and impacts from heavy metal pollution have been widely reported in this area. For example, in June 2014, 315 children living around Dapu industrial area in Hengdong county were reported with excessive Pb concentrations in their blood, 10 of which had been sub-chronically poisoned. Another heavy metal survey published in November 2014 from an environmental protection organization showed that the As content of river sediments exceeded national standards by 700 times and the Cd content in some paddy soils exceeded the standards by 200 times in the Sanshiliuwan mining area from Chenzhou City (Cao and Li, 2014). Regulations have been issued by the province – for example - an ‘Implementation Plan (2012-2015)’ of heavy metal pollution control in the Xiangjiang river basin, which has been set to close illegal factories, control industrial pollution sources and decrease heavy metal emissions and remediate the legacy contaminated sites. In 2016, standards for soil remediation of heavy metal contaminated sites (DB43/T1165-2016) were issued by the Environmental Protection Department of Hunan and Hunan Provincial Bureau of quality and technical supervision. These provided the remediation standard for 11 heavy metals in residential land, commercial land and industrial land (Table 8). These remediation targets are higher than the national standard in GB15618-1995. For example, DB43/T1165-2016 values are: Cd-7, 20, 20 in residential land, commercial land and industrial land, respectively; GB15618-1995 values are: Cd-0.3, 0.3, 0.6, 1 in Standard II pH <6.5, 6.5-7.5, >7.5, Standard III, respectively; GB15618-2018 screening values are: Cd-0.3, 0.4, 0.6, 0.8 for paddy pH≤5.5, 5.5<pH≤6.5, 6.5<pH≤7.5, pH>7.5, respectively. Details of how Hunan’s standards were derived are not clear, but they may be pragmatic and risk-based.

Table 8. The remediation standard of heavy metal in contaminated sites for Hunan Province (first 3 columns), compared to the national standards (all concentrations in mg/kg).

Elements	Residential land	Commercial land	Industrial land	National Standard I soil	National Standard II soil			National Standard III soil
pH					<6.5	6.5-7.5	>7.5	>6.5
Pb	280	600	600	35	250	200	200	400
As	50	70	70	15	30	25	20	30
Cd	7	20	20	0.2	0.3	0.3	0.6	1
Hg	4	20	20	0.15	0.3	0.5	1	1.5
Cr	400	610	800	90	250	300	350	500
Cr^{+6}	5	30	30	--	--	--	--	--
V	200	250	250	--	--	--	--	--
Mn	2000	5000	10000	--	--	--	--	--
Cu	300	500	500	35	50	100	100	400
Zn	500	700	700	100	200	250	300	500
Sb	30	60	60	--	--	--	--	--

Note: see Table 5 for more information on the national standards.

EQSs are considered impractical as remediation targets, because of the high costs/time required to achieve such a level of clean-up (Cai et al., 2006; Qiu et al., 2007; Wen et al., 2010; Wu and Zhou, 1991; Xia and Luo, 2007; Yu et al., 2010). A crucial aspect of any remediation targets is the after-use of the land. Land for residential or agricultural use would require more stringent limits than amenity land, for example.

The new soil EQSs have added some further details. For example, they add one other organic contaminant – benzo-a-pyrene, and GB15618-2018 gives a newly added soil screening value and soil control value at the pH level of 5.5. Under GB36600-2018, different land uses are considered when developing soil EQSs. These two standards provided one method for identifying soil heavy metal contamination; If the content of pollutants exceeds the screening value, but is not higher than the background value of the soil environment, it is not included in the management of contaminated land. However, some considerations are still not resolved; for example, more contaminants still need to be considered and soil ecological protection still needs to be addressed.

7. Current situation and future priorities

China is highly reliant on its ‘best quality’ soils for food security and agricultural production. It has been estimated that 20% of China total arable land is contaminated (Lin, 2004; Zhao et al., 2007). This may be different from the situation in most developed countries, where a higher proportion of agricultural land is not contaminated. For example, a higher (~93%) proportion of European agricultural land is considered safe for food production (Tóth et al., 2016). The reality is that China will need to produce food for human consumption on soils which are already deemed ‘contaminated’. Scientifically based risk assessments are necessary to inform practical decisions about the most practical land use options. For example, important research is currently being conducted in China and elsewhere to understand where and how ‘contaminated’ land can be used to support food production. This requires knowledge of soil chemistry and soil-crop plant transfers of contaminants (Tangahu et al., 2011; Xu et al., 2005). If China makes these changes/meets these priorities, it can be leading the world in approaches to contaminated land management. It is in this context that China is committed to conducting the most detailed and comprehensive soil survey to date. MEP-PRC carried out a nation survey covered 6,300,000 km^2 soil area from April 2005 to December 2013, and several geochemistry surveys by MLR-PRC have been completed from 1999 to 2014, which covered 68% of total arable land (MEP-PRC, 2016). There are several areas where revisions are being considered, to bring China to a leading position internationally. It is hoped that the new regulatory approaches can be further developed to:

1. Increase the range of analytes for which standards are set. Most focus so far has been on inorganics, but there is a wide array of organic contaminants for which standards can be set.
2. Critically important to the science-based risk assessment of contaminants in soils is the incorporation of speciation and bioavailability into the measurement and evaluation criteria. On initial screening, soils and sites may be deemed 'contaminated', but after a second tier analysis they may be shown to be suitable for crop production and use. Selection of appropriate and validated measurement and evaluation tools is a priority. If this is done in a scientifically transparent and defensible way, China will have a robust and internationally leading system for soil management in place.
3. Derivation of standards has focused on human receptor endpoints. However, consideration of soil biology/ecological endpoints will be necessary to protect ecosystem health.
4. National and regional/local scenarios of land use type/usage. This addresses residential/urban re-use of industrial land, as well as varying agricultural scenarios, such as different agricultural systems and cropping regimes.

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