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Heavy metal contamination of soils in China: standards, geographic distribution, and food safety considerations. A review

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Abstract

This article reviews the conditions of heavy metal contamination of China's soils. The article starts with a discussion of the official environmental standards of soils in China, in terms of heavy metal contamination, and the extent of that contamination. Then, the article discusses the geographic distribution of soil contamination, and the food safety impact. The problem in China is that the provinces with the highest rates of soil contamination are also provinces with the largest amount of food production. This results in high contamination of food, with 13.86 % of grain produced in China being affected by heavy metal contamination. Hunan Province represents the worst conditions: it is responsible for 32.1 % of China's cadmium (Cd) emissions, 20.6 % of its arsenic (As) emissions, 58.7 % of its mercury (Hg) emissions, and 24.6 % of its lead (Pb) emissions. While Hunan Province produces about 15 % of the total rice output of the country, according to official data, 13 % of the total area of the province has been contaminated with waste and heavy metals from mines. In many areas, especially those closer to mines, the agricultural production exceeds the official food safety standards.

Zusammenfassung

Dieser Beitrag analysiert die Schwermetallkontamination von Böden in China. Es werden die offiziellen Boden-Umweltstandards Chinas sowie das Ausmaß und die Auswirkungen von Schwermetallkontaminationen auf die Lebensmittelproduktion Chinas diskutiert. Als Problem zeigt sich, dass die Provinzen, die den stärksten Bodenkontaminierungsgrad aufweisen, gleichzeitig die Provinzen mit der höchsten Lebensmittelproduktion sind. So sind z. B. 13,86 % des in China produzierten Weizens mit Schwermetallen kontaminiert. Eine besondere Rolle kommt hierbei der Provinz Hunan zu: Sie ist für 32,1 % der Cadmium-Emissionen (Cd) Chinas verantwortlich sowie für 20,6 % der Arsen-Emissionen (As), 58,7 % der Quecksilber-Emissionen (Hg) und 24,6 % der Blei-Emissionen (Pb). Rund 15 % der Reisproduktion Chinas findet in der Provinz Hunan statt. Allerdings sind offiziellen Daten zufolge 13 % der Böden Hunans mit vorrangig aus dem Bergbau stammenden Schwermetallen kontaminiert. In vielen Bergbau nahen Gebieten wird eine Agrarproduktion trotz des Überschreitens offizieller Umweltstandards durchgeführt.

Keywords soil contamination, heavy metals, geographic distribution, contaminated food, China

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1. Introduction

The problem and the extent of soil pollution and contamination are not well known in China. People do know that not all the food they eat is healthy, but they do not know the scale of the problem. Indeed, until very recently, little was known of the true extent of soil contamination in China, since the government has consistently refused to make comprehensive soil contamination data public (*Hsu* 2014). In 2013, Beijing's lawyer *Dong Zhengwei* requested soil pollution data from the Ministry of Environmental Protection, including information on the causes and methods for dealing with the problem. The request was declined on the grounds that the data was a 'state secret'. Nevertheless, at the end of 2013, the government released limited information on soil pollution, partly because of the strong public reaction against that refusal. Despite the lack of details, the released data caused widespread concern (*He* 2014a). In April 2014, the government issued a more comprehensive report about the country's soils (*He* 2014b). The report showed that 16.1 % of the soil samples (19.4 % for agricultural soils) were contaminated with organic and chemical contaminants, as well as heavy metals and metalloids such as lead, cadmium, and arsenic (*Zhao* et al. 2014). Chinese officials say that an area the size of Taiwan is so polluted that farming should not be allowed there at all (*Wong* 2014).

Contamination of soils differs from water or air pollution in that it is usually not visible and can easily go undetected, as it may take years from the beginning of contamination to the appearance of harmful effects. Moreover, soil contamination accumulates over time, and diffuses or dilutes much slower than water or air pollutants (*Zhang* 2014).

Heavy metal contamination of soils is a major contributor to poor soil health. Heavy metals in the soil are toxic for all living things, from microorganisms to plants and animals, and their removal from the soil is a cumbersome process. These toxins disturb and alter both natural and manmade ecosystems, and may cause terminal diseases when transported to humans via the food web (*Wang* et al. 2001). *Table 1* lists the most common heavy metals found in Chinese soils, common items that may contain these substances, some of their sources, and the conditions associated with exposure to them. Almost all of these contaminants are the byproducts of industrial activities, mining operations, coal burning, or are emitted into the air with the exhaust fumes of vehicles (*Hornby* 2015).

The aim of this paper is to give a broad introduction of the conditions of heavy metal soil contamination in China, through a discussion of the standards developed to classify the levels and types of contaminated soils, the extent and geographic distribution of the main contaminants, and the impact of soil contamination on people's diet and health through the ingestion of contaminated grains. Soil contamination is a very important problem in China, and this paper should help the reader to better understand the extent of the problem, and the urgency and difficulties in addressing it.

Table 1 The uses, sources, and potential damages of heavy metals. Source: adopted from Hornby (2015)

Heavy metals	Used in	Produced by	Condition
Cadmium (Cd)	Pigments and batteries	Coal and zinc mining and phosphate fertilizers	Painful joint swelling and bone deformities
Nickel (Ni)	Stainless steel and alloys	Burning oil and coal Mining waste	Rashes and lung damage
Arsenic (As)	Gold mining, wood treatment, animal feed and poisons	Dust from mining and smelting and leaches from agricultural use	Withers crops and causes cancer
Copper (Cu)	Wiring, pipes and alloys	Coal combustion and mining waste	Diarrhea and nausea
Mercury (Hg)	Fluorescent bulbs, chemicals, coal burning and gold production	Coal burning, coal and metals mining and smelting	Fatigue, physical deformities and mental illnesses
Lead (Pb)	Batteries, paint, and solder	Waste from tanning	Learning disabilities and stomach pains
Chromium (Cr)	Stainless steel and alloys	Mining and smelting waste and coal burning	Hexavalent chromium is toxic
Zinc (Zn)	Galvanized steel and alloys		Anemia and damage the pancreas and kidneys

2. Standards and extent of heavy metal contamination of soils

In 1995, the Ministry of Environmental Protection (*MEP* 1995) of China introduced the Environmental Quality Standard for Soils guidelines to inform about the acceptable concentrations of soil contaminants and contamination measurement techniques (*Zhang* et al. 2015). The standard values, put into effect on 1 March 1996, were divided into three classes, used for different soil functions (see *Table 2*) (*MEP* 1995):

- Class 1 values represent the natural background. This standard is used for nature reserves (except for the places with high Soil Environmental Background Value, meaning soils with naturally high proportions of heavy metals), centralized potable water sources, and some other soils requiring protection.
- Class 2 lands may be devoted to agriculture, since their level of pollution is considered safe for the production of food. For Class 2 soils, a distinction is made depending on the acidity or alkalinity of the soils, splitting the soils into three categories: soils with a pH value ≤ 6.5, soils with a pH value between 6.5 and 7.5, and soils with a pH value > 7.5, because different pH environments influence the effects of the contaminants. These lands may be used as croplands or pasturelands. If the heavy metal concentrations of a soil exceed the maximum values defined in Class 2, it is rated as too contaminated for growing grains for consumption.
- Class 3 land cannot be used for farming. Lands with such high levels of heavy metal contamination may be found near factories and mines, but in some cases such high levels of heavy metals may also be natural (*MEP* 1995). If the concentrations are higher than the values in Class 3, the plants stop growing and probably die.

In April 2014, the Ministry of Environmental Protection (MEP) and the Ministry of Land and Resources (MLR) of China published a collaborative evaluation of the conditions of the country's soils. This was the first time that the government carried out an assessment of the country's soil contamination and released it to the public (*MEP* 2014). The evaluation built on in-depth analyzes of soils carried out between 2005 and 2013, sampling soils from over 70 % of the country's land area. Compared to a previous small-scale survey conducted during the 1980s (referred to in *Zhang* 2014), the data indicate a significant increase in heavy metal contaminants in surface soils. Of all the samples analyzed, 16.1 % of the soil examined was found to be contaminated with heavy metals such as Cd, As, Pb, and Hg. Farmlands were proportionally the most contaminated land: 19.4 % of the land used for agricultural activities was contaminated with heavy metals (*Table 3*). Assuming that the contaminated areas are proportional to the number of surveyed samples, this means that about 26 million ha were contaminated. The Vice Minister, *Wang Shiyuan*, acknowledged that an additional area of 3.31 million hectares of agricultural land was contaminated to a smaller degree (*He* 2014a). In addition, another 3.2 million hectares were found to be so contaminated that agricultural practices should be banned there (*Wong* 2014). Unfortunately, although this soil quality report represented an important step towards the country's openness regarding contamination, it failed to shed light on crucial details and did not offer solutions to China's contamination problems (*Bale* 2014).

Table 2 Official Soil Environmental Standards in China (mg/kg). Source: adopted from MEP (1995)

Heavy metals		**Class 1** (natural background)	**Class 2** pH < 6.5	pH 6.5–7.5	pH > 7.5	**Class 3** pH > 6.5
Cadmium (Cd)	≤	0.2	0.3	0.3	0.6	1.0
Arsenic (As)	Paddy field ≤	15	30	25	20	30
	Dryland ≤	15	40	30	25	40
Mercury (Hg)	≤	0.15	0.3	0.5	1.0	1.5
Copper (Cu)	Cropland ≤	35	50	100	100	400
	Orchard ≤	-	150	200	200	400
Lead (Pb)	≤	35	250	300	350	500
Chromium (Cr)	Paddy field ≤	90	250	300	350	400
	Dryland ≤	90	150	200	250	300
Zinc (Zn)	≤	100	200	250	300	500
Nickel (Ni)	≤	40	40	50	60	200

Table 3 Degrees of soil contamination according to ecosystem types. Source: adopted from MEP (2014)

Ecosystem type	% of land contaminated	Degrees of exceedance in these area (in %)			
		Slight (1)	Light (2)	Moderate (3)	Severe (4)
Nation-wide	16.1	11.2	2.3	1.5	1.1
Farmland	19.4	13.7	2.8	1.8	1.1
Woodland	10.0	5.9	1.6	1.2	1.3
Grassland	10.4	7.6	1.2	0.9	0.7
Unused	11.4	8.4	1.1	0.9	1.0

Notes: The degree of soil contamination in this table is divided into four levels, based on the Class 2 quality standards of *Table 2*: Slight (1): exceeds Class 2 quality standards less than 2 times; Light (2): exceeds Class 2 quality standards between 2 and 3 times; Moderate (3): exceeds Class 2 quality standards between 3 and 5 times; Severe (4) exceeds Class 2 quality standards over 5 times. Soil that does not exceed Class 2 quality standards are not contaminated (*MEP* 2014).

3. Geographic distribution of soil contamination

Soil contamination in China tends to be locally different. Soil contamination is more severe in the south than the north, particularly in the Yangtze River Delta, Pearl River Delta and the traditional industrial base in south-east China (*Xinhua News Agency* 2014) (*Fig. 1*), with the main contaminants being Cd, Ni, Hg, and As. However, the increase in Cd contents has affected soils all over the country, with a 50 % rise in the coastal and south-eastern regions, and a 10 % to 40 % rise in the north-eastern, and western areas of China (*Zhang* 2014). *Zhao* et al. (2014) further point out that lands in some regions, especially those close to mines and industries, have been suffering particularly badly from severe contamination, and the quality of soils dedicated to growing crops should be given particular attention.

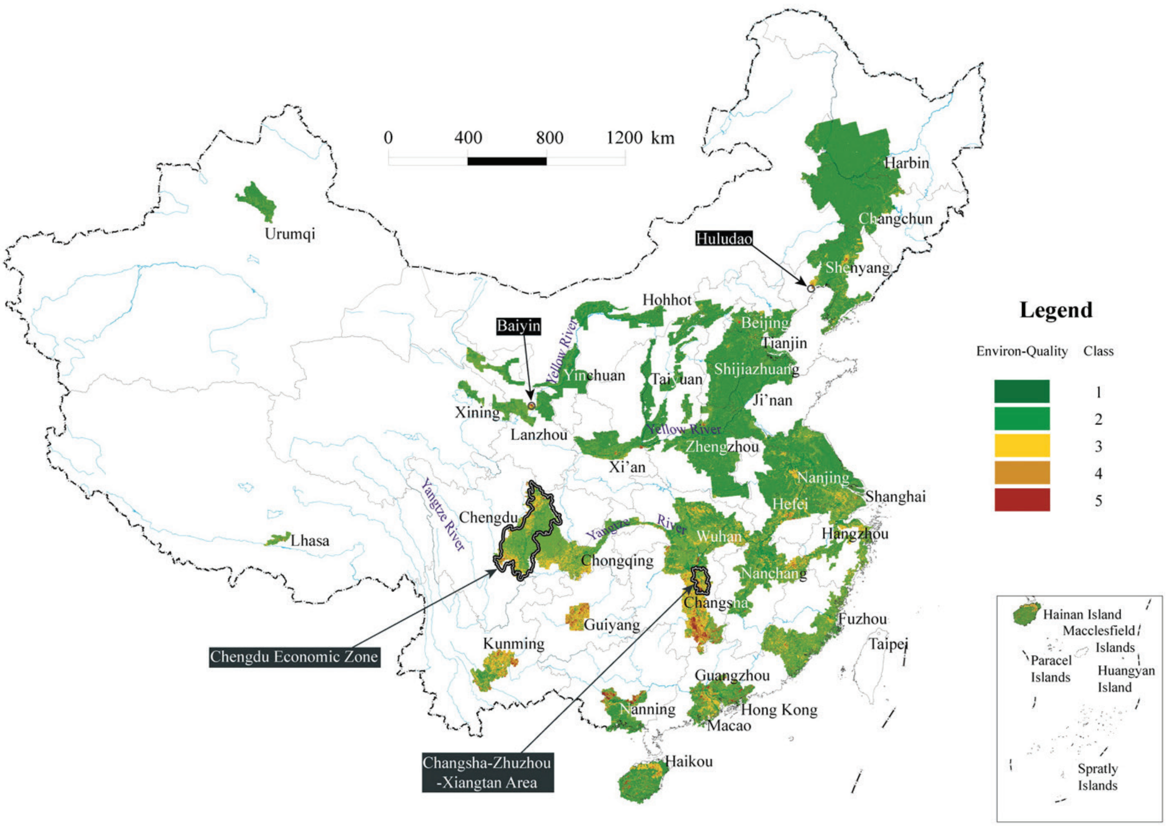

Fig. 1 Distribution of environmental quality class of As, Cd, Cr, Hg, and Pb in soils. Note: See Table 4 for the data for Classes 1-5 in the figure; white areas: soil quality unknown. Source: adopted from Yang et al. (2014: 129)

A number of scholars, apart from the Ministry of Environmental Protection (MEP), have attempted to estimate the degree and distribution of soil contamination in China. One of the most comprehensive studies was carried out by *Yang* et al. (2014), who used the standards illustrated in *Table 2*, but included only As, Cr, Cd, Hg, and Pb because they were the most common. Based on the standards presented in *Table 2*, *Yang* et al. (2014) defined new soil classes (*Table 4*), and adopted the veto method to assess the level of contaminants in each soil sample. The environmental quality class of each soil sample is determined by the lowest environmental quality class of its individual chemical elements. For example, if the environmental quality classifications for As, Cr, Cd, Hg, and Pb of one soil sample are classes 4, 2, 3, 2, and 2, respectively, then the environmental quality class of that soil sample is 4.

According to *Yang* et al. (2014), there are different reasons for the anomalous enrichment of harmful chemicals in the soil in different areas. In densely populated cities and developed mining areas, such as the Changsha-Zhuzhou-Xiangtan area in Hunan Province, the areas around the cities of Shenyang and Huludao in Liaoning Province, and Baiyin city in Gansu Province, high contents of harmful heavy metals, such as As and Cd, in the soil are primarily caused by human activities. However, *Yang* et al. (2014) found that most of these areas are urban, industrial, or mining lands rather than agricultural lands. In essence, they found that in most cases, heavy metals and pollutants do not have a significant effect on food security. However, they excluded visibly polluted areas, which biased the findings and made these conclusions somewhat questionable (*Yang* et al. 2014).

Indeed, other researchers obtained contrasting results to those found by *Yang* et al. (2014). For example, *Zhang* et al. (2015) carried out a meta-analysis of the contamination rate of heavy metals in topsoil (0-20 or 0-15 cm) of farmland throughout China, and found that the total contamination rate in Chinese farmland soil was 10.18 %, mainly from Cd, Hg, Cu, and Ni. Cd had the highest contamination rate of 7.75 %, followed by Hg, Cu, Ni and Zn; Pb and Cr had the lowest contamination rates, lower than 1 %. At the provincial level, the contamination rate of farmland soil by heavy metals is described by *Zhang* et al. (2015). Tianjin had the highest contamination rates, exceeding 70 %. Hunan Province, Guizhou Province, Guangxi Zhuang Autonomous region, and Guangdong Province had contamination rates of 56, 39, 36 and 31 % respectively, because of the large amount of mining and smelting activities, and chemical manufacturing plants, in these provinces. The contamination ratio by heavy metal in Sichuan, Hubei Province, ranged from 20 to 30 %.

Particularly problematic is the situation in Hunan Province. Hunan Province is home to 1,003 nonferrous metal enterprises which, in 2011, were responsible for a production output of 2.66 million tons of ten different metals, a business worth $60 billion (*He* 2014c). The government has been trying to control the harmful emissions for many years. However, in January 2016, an official of the Non-Ferrous Metals Management Bureau of Hunan Province acknowledged that the Xiang River basin (in Hunan Province) had almost 1,000 tailings and sludge disposal sites, producing 440 million tons of solid waste polluted with Pb, Hg, and Cd (*He* 2014c). Hunan Province was responsible for 32.1 % of China's Cd emissions, 20.6 % of its As emissions, 58.7 % of its Hg emissions, and 24.6 % of its Pb emissions. According to official data, 13 % of the total area of Hunan Province, about 11,000 square miles, has been contaminated with waste and heavy metals from mines (*He* 2014c).

Table 4 Classification and definitions of soil pollution levels used by Yang et al. (2014), based on the standards illustrated in Table 2. Source: adopted from Yang et al. (2014: 124)

Class	Level of pollution
1. Clean	Less than the standard for type 1
2. Relatively clean	Between the standards for types 1 and 2
3. Normal	Between the standards for types 2 and 3
4. Polluted	Greater than the standard for type 3 and less than twice the standard for type 3
5. Moderately to heavily polluted	Greater than twice the standard for type 3

4. Soil contamination and food safety

Zhang et al. (2015) describe the proportion of affected grain production in each province, and relate it to the total grain production in China. Combing the crop production and the heavy metal pollution ratios in the 32 provinces, *Zhang* et al. (2015) conclude that 13.86 % of the grain production was affected by heavy metal contamination. This amount was higher than the contamination rate of arable soil (10.18 %), because most contaminated soil is in southern China, in provinces with large grain production. *Zhang* et al. (2015) specify that while 13.86 % of the grain produced was affected by heavy metal contamination, it does not mean that this amount was polluted by heavy metal. The value might simply refer to a decrease of the quality or quantity of grain production due to heavy metal contamination.

Contaminated land ends up producing contaminated grains. Hunan Province is also an important producer of rice, growing approximately 30 million tons annually, or about 15 % of the total rice output of the country. Due to its importance as a source of rice and the high heavy metal contamination, it is not surprising that much research has been done in this province. For example, *Song* et al. (2015) looked at the soil heavy metal contamination and the potential risk for residents of Suxian County of Hunan Province. They found that mining activities have caused local agricultural soil contamination with As, Pb, Cu and Cd in the ranges of 8.47-341.33 mg kg^{-1}, 19.91-837.52 mg kg^{-1}, 8.41-148.73 mg kg^{-1}, and 0.35-6.47 mg kg^{-1}, respectively, well above the official soil standards (cf. *Table 2*), in particular for As and Cd.

Contamination tends to be particularly high near mining activities, and to quickly diminish with increasing distance from the contamination sources. Researchers determined that the dietary exposure to Cd for people living in close proximity to mines significantly exceeded the tolerable daily intake level, and rice was identified as the primary source. A connection between prolonged exposure to Cd and kidney disease, osteoporosis, and increased cancer mortality rates has been found (*Table 1*). Besides Cd, the high levels of toxic Pb and As found in rice are also a cause for concern. An analysis of rice grown near the mining sites in Hunan Province determined that 65, 50, and 34 % of the samples exceeded the Chinese limits for Cd, As, and Pb concentration in food, respectively (*Zhao* et al. 2014).

For example, a study of the rice grain quality of a county in the Xiangjiang River basin in Hunan Province revealed that 60 % of the rice samples exceeded the food safety standard of China of 0.2 mg Cd kg^{-1}, and 11 % contained over 1.0 mg Cd kg^{-1} (*Zhao* et al. 2014). Similarly, *Song* et al.'s (2015) survey of Suxian County of Hunan Province found that the concentrations of Cd in rice was of up to 1.39 mg kg^{-1}, while the concentrations of As, Pb and Cu in rice were in the ranges of 0.02-1.48 mg kg^{-1}, 0.66-5.78 mg kg^{-1}, and 0.09-6.75 mg kg^{-1}, respectively. In Guangdong Province, *Zuang* et al. (2009) found broadly similar values for agricultural product contamination near the Dabaoshan mine. The highest values, found closer to the contamination sources, exceed considerably the maximum permissible levels for contaminants in foods in China (*Table 2*).

Nationwide, market basket studies examining the country-level contamination of rice grain concluded that between 2 and 13 % of the samples exceeded the official food safety standard limits. According to *Zhao* et al. (2014), "Cd intake from rice alone with a Cd concentration of 0.2 mg kg^{-1} would amount to 0.73 and 1.01 μg kg^{-1} body weight day^{-1} for the national average (for adults of 65 kg body weight); [exceeding] the FAO/ WHO tolerable daily intake (TDI) of 0.83 μg kg^{-1} body weight day^{-1}" (ibid.: 753).

5. Conclusion

Soil, like air and water, is the source of all life on earth, and the major source of food for humans and animals. It is a vital resource, which supports the existence, security, prosperity, and sustainable development of a country. If the soil becomes contaminated, there is potentially great loss to people.

As discussed in this article, China suffers from a great deal of soil contamination, including of agricultural land. Heavy metal contamination is particularly important close to mining and petrochemical industries. In some regions, such as in Tianjin, soil contamination does not have a great impact on food production, because there is less agriculture. However, some regions (such as Hunan Province) have both a large number of contaminating industries and a large amount of food produced.

Soil contamination is difficult to tackle. First, it is difficult to monitor and easy to ignore, since it is usually not visible. Farmers would normally not be aware of the extent of contamination of their land.

Second, it is caused by the economic activities that local governments encourage in their region. The manufacturing, coal burning, mining and petrochemical sectors are important sectors of the Chinese economy. These industries provide local governments with the taxation incomes they need to function, and employ many more people than the number of farmers negatively affected by soil contamination. For this reason, local governments are reluctant to curtail them, or control the pollutants emitted, as the increasing costs would drive away these industries to regions with less strict rules (*Delang* 2017).

Third, it is expensive and time consuming to remove the contaminants, which in the present climate of a slowing economy is difficult to implement or justify. Soil contamination reduces the total amount of productive farmland available in China, and much of the contaminated land is in regions where the soil is highly productive (*UN News Centre* 2010). However, it is cheaper to lease land in other countries than to clean it up at home, hence China's push to lease agricultural land in Europe (*van der Ploeg* et al. 2015), Asia (*Visser* and *Spoor* 2011), South America (*Puyana* and *Costantino* 2015; *Oliveira* 2018), and Africa (*Brautigam* 2015).

The Chinese government is making efforts to address soil contamination. For a start, it has finally (through the nationwide survey of 2014) been willing to acknowledge that there is a problem. This is an important first step. In addition, the government is slowly transitioning towards a cleaner economy, for example gradually shifting from coal to renewable energy. Nevertheless, changes are slow. People still expect economic growth, and the government is pressed to provide it, to foster social stability and guarantee its survival. It is unlikely that soil contamination will decrease any time soon.

References

Bale, R. 2014: China's other pollution problem – its soil. Reveal – from the Centre of Investigative Reporting, 15 October 2014. – Online available at: https://www.revealnews.org/article-legacy/chinas-other-pollution-problem-its-soil/, accessed 08/01/2018

Delang, C.O. 2017: China's soil pollution and degradation problems. – London

He, G. 2014a: Special report: the legacy of Hunan's polluted soils. China Dialogue, 7 July 2014. – Online available at https://www.chinadialogue.net/article/show/single/en/7076-Special-report-the-legacy-of-Hunan-s-polluted-soils, accessed 08/01/2018

He, G. 2014b: Special report: The victims of China's soil pollution crisis. China Dialogue. – Online available at https://www.chinadialogue.net/article/show/single/en/7073-Special-report-The-victims-of-China-s-soil-pollution-crisis, accessed 15/12/2016, accessed 08/01/2018

He, G. 2014c: The soil pollution crisis in China: A cleanup presents daunting challenge. Yale Environment 360. – Online available at: https://e360.yale.edu/features/the_soil_pollution_crisis_in_china_a_cleanup_presents_daunting_challenge, accessed 08/12/2018

Hornby, L. 2015: Chinese environment: Ground operation. Financial Times, 1 September 2015. – Online available at: https://www.ft.com/content/d096f594-4be0-11e5-b558-8a9722977189, accessed 08/01/2018

Hsu, A. and *W. Miao* 2014: Soil pollution in China still a state secret. Scientific American. – Online available at: http://blogs.scientificamerican.com/guest-blog/soil-pollution-in-china-still-a-state-secret-infographic/, accessed 08/01/2018

MEP (Ministry of Environmental Protection) 1995: Environmental quality standards for soils (GB 15618-1995) (in Chinese). Beijing: Ministry of Environmental Protection. – Online available at: http://kjs.mep.gov.cn/hjbhbz/bzwb/trhj/trhjzlbz/199603/W020070313485587994018.pdf, accessed 08/01/2018

MEP (Ministry of Environmental Protection) 2014: The national soil pollution condition investigation communique (in Chinese). Beijing: Ministry of Environmental Protection. – Online available at: http://www.gov.cn/foot/site1/20140417/782bcb88840814ba158d01.pdf, accessed 08/01/2018

Oliveira, G.D.L. 2018: Chinese land grabs in Brazil? Sinophobia and foreign investments in Brazilian soybean agribusiness. – Globalizations **15** (1): 114-133, doi:10.1080/14747731.2017.1377374

Puyana, A. and *A. Costantino* 2015: Chinese land grabbing in Argentina and Colombia. – Latin American Perspectives **42** (6): 105-119, doi:10.1177/0094582X15594394

Song, D., D. Zhuang, D. Jiang, J. Fu and *O. Wang* 2015: Integrated health risk assessment of heavy metals in Suxian County, South China. – International Journal of Environmental Research and Public Health **12** (7): 7100-7117, doi:10.3390/ijerph120707100

UN News Centre 2010: Land degradation among China's food supply challenges, says UN expert. UN News Centre, December 2010. – Online available at: http://www.un.org/apps/news/story.asp?NewsID=37151#.V3pnhdIkpyc, accessed 08/01/2018

van der Ploeg, J.D., J.C. Franco and *S.M. Borras Jr.* 2015: Land concentration and land grabbing in Europe: a preliminary analysis. – Canadian Journal of Development Studies **36** (2): 147-162, doi:10.1080/02255189.2015.1027673

Visser, O. and *M. Spoor* 2011: Land grabbing in post-Soviet Eurasia: the world's largest agricultural land reserves at stake. – The Journal of Peasant Studies **38** (2): 299-323, doi:10.1080/03066150.2011.559010

Wang, Q.R., Y. Dong, Y. Cui and *X. Liu* 2001: Instances of soil and crop heavy metal contamination in China. – Soil and Sediment Contamination **10** (5): 497-510, doi:10.1080/20015891109392

Wong, E. 2014: One-fifth of China's farmland is polluted, state study finds. The New York Times, April 17 2014. – Online available at: http://www.nytimes.com/2014/04/18/world/asia/one-fifth-of-chinas-farmland-is-polluted-state-report-finds.html?hpw&rref=science&_r=1,accessed 08/01/2018

Xinhua News Agency 2014: China alerted by serious soil pollution. Xinhua News Agency, 17 April 2014. – Online available at: http://www.china.org.cn/environment/2014-04/17/content_32129341.htm, accessed 08/01/2018

Yang, Z.F., T. Yu, Q.Y. Hou, X.Q. Xia, H.Y. Feng, C.L. Huang, L. Wang, Y. Lv and *M. Zhang* 2014: Geochemical evaluation of land quality in China and its applications. – Journal of Geochemical Exploration **139**: 122-135, doi:10.1016/j.gexplo.2013.07.014

Zhang, Y. 2014: Soil quality in China – policy implications. Europe China Research and Advice Network (ECRAN). Short Term Policy Brief 98. – Online available at: https://pdfs.semanticscholar.org/1e4a/1c0ab49da926c858a7f99d0a81910b67f68a.pdf, accessed 08/01/2018

Zhang, X.Y., T.Y. Zhong, L. Liu and *X.Y. Ouyang* 2015: Impact of soil heavy metal pollution on food safety in China. – PLOS ONE **10** (8): e0135182, doi:10.1371/journal.pone.0135182

Zhao, F.J., Y.B. Ma, Y.G. Zhu, Z. Tang and *S.P. McGrath* 2014: Soil contamination in China: current status and mitigation strategies. – Environmental Science and Technology **49** (2): 750-759, doi:10.1021/es5047099

Zhuang, P., B. Zou, N.Y. Li and *Z.A. Li* 2009: Heavy metal contamination in soils and food crops around Dabaoshan mine in Guangdong, China: implication for human health. – Environmental Geochemistry and Health **31** (6): 707-715, doi:10.1007/s10653-009-9248-3