ISSN: 2688-8645

Progress in Research on Heavy Metal Pollution and Prevention in Soil-Crop Systems

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Abstract

Soil contamination in China mainly involves inorganic pollution. Of all types of inorganic pollution, heavy metals in the soil puts forward rigorous challenges to the environment. Admittedly, human activities such as industrial and agricultural production, mineral exploration, fuel combustion, and vehicle emissions have unavoidably introduced heavy metals to the soil-crop system constantly, resulting in an increasingly severe impact on agricultural products. This study was carried out to address the following specific objectives: (1) review the sources of heavy metal pollutants and their harm to the soil-crop system, (2) elaborate on the status quo of heavy metal pollution in the system, and further assess the potential human health risks, (3) sum up current soil remediation technologies and control measures to provide references for reducing health risks and guaranteeing fo od safety.

Keywords

Heavy metals; Soil-crop system; Human health risks; Sources; Hazards; Bioavailability.

1. Introduction

At present, soil pollution in China has entered a period of concentrated and frequent occurrence, posing a serious threat to the health of residents and the safety of agricultural products, and has aroused widespread concern among environmental protection departments and research institutions at all levels. In January 2019, with the implementation of the Law of the People's Republic of China on the Prevention and Control of Soil Pollution, the "Survey on the Status of Soil Pollution on Land of Enterprises in Key Industries" and the "Survey on the Status of Soil Pollution in Agricultural Production Areas" were launched in various parts of China. In January 2019, with the implementation of the Law of the People's Republic of China on the Prevention and Control of Soil Pollution, the "Survey on the Soil Pollution Status of Enterprise Sites in Key Industries" and the "Survey on the Soil Pollution Status of Agricultural Product Production Areas" have been carried out in different parts of China.

The results of the comprehensive survey and analysis show that the situation of heavy metal pollution in China's soil is not optimistic. North, Southwest, Central and South, Yangtze River

ISSN: 2688-8645

Delta and Pearl River Delta regions, and the soils around industrial, agricultural and mining industries have been contaminated to different degrees [1-3]. Soils around industrial, agricultural and mining industries are contaminated to varying degrees [1-3], mainly with Cu, Zn, Cd, Ni, Pb, Cr and Hg, as well as the metal-like As. Soil heavy metals enter the atmosphere, water and agriculture through the external environment. Heavy metal contamination of crops is widespread worldwide, and in the northern part of Ethiopia [4] In Ethiopia [4], a large amount of heavy metals are present in vegetables grown in the northern part of the country, and in Bangladesh [5], the levels of Cr, Ni, As, Cd and Pb in crops around industrial areas are higher than the maximum standards. and half of the rice grown in active mining areas in China contains heavy metals above the limits set by Chinese food security standards [6]. With With the intensification of industrialisation and urbanisation, a series of industrial and agricultural activities have exacerbated heavy metal pollution in soil-crop systems, seriously affecting the rational use of natural resources and endangering the health of the population. The pollution of heavy metals in soil-crop systems has been aggravated by a series of industrial and agricultural activities, which seriously affects the rational use of natural resources and endangers the health of residents. Researchers at home and abroad have proposed powerful physical, chemical, biological, agro-ecological and engineering remediation techniques to address the problem of heavy metal pollution in soil-crop systems in different regions, soil types and crops[7-10]. The best remediation technologies are selected based on the principle of local adaptation and taking into account economic and feasible factors; governments and relevant research institutions at all levels at home and abroad also attach great importance to the remediation technologies. Governments and relevant research institutions at all levels at home and abroad have also attached great importance to a series of prevention and treatment measures. In recent years, the potential health risks posed by heavy metal pollution In recent years, the potential health risks associated with heavy metal contamination have attracted considerable attention, and there is a need to accurately assess the potential risks posed by heavy metal contamination in soil-crop systems and to To ensure soil ecology and food safety, to reduce human health risks and to improve the national economy, it is necessary to take appropriate measures to effectively manage and control heavy metal contamination in soil-crop systems. To ensure soil ecology and food safety, reduce human health risks and improve the national economy. Therefore, the evaluation of the risk of soil heavy metal pollution and its prevention and remediation has become a hot topic of concern for many scholars at home and abroad.

2. The Sources and Hazards of Heavy Metals in the Soil-crop System

2.1. Source

The sources of heavy metal pollution in soil-crop systems are complex, and there are differences in the sources of heavy metal pollution between different types of heavy metals, so let us take the four typical heavy metals As and Cd, Cr, Pb and Hg as examples for source analysis. As is a naturally occurring substance and is recognized as a "class I carcinogen" by the International Agency for Research on Cancer (IARC). Cd is a highly toxic pollutant, and Zhang et al. [11] used Cd isotope ratios to analyze the sources of Cd in agricultural soils near industrial areas. The relative contribution of smelting and phosphate fertilizers to Cd accumulation in agricultural soils was 14%, 7%, 20% and 59%, respectively. Cr pollution in soil-crop systems is mainly caused by atmospheric deposition, fertilizer application (N, P, K), sewage irrigation, and nearby industrial activities (mining, Fertilizers are an important source of Cr in agricultural soils [12]; among the sources of Pb pollution, in addition to industrial, mining and agricultural pollution sources, it is worth noting that traffic pollution is a major factor. In addition to industrial, mining and agricultural pollution sources, it is worth noting the impact of traffic pollution, as the Pb content of petrol ranges from 400 to 1 000 mgkg-1 [13], and a large amount of vehicle exhaust Hg-contaminated soils are mainly located near mines and industrial areas [14], while for agricultural soils, in addition to atmospheric deposition, sewage irrigation and In addition to atmospheric deposition, human activities such as sewage irrigation, sludge application and irrational use of fertilisers and pesticides can all contribute to soil Hg pollution.

2.2. Hazards

Soil contamination with heavy metals firstly affects its own environment, with changes in soil physicochemical properties, microbial communities and enzyme activity. The stress of most heavy metals can reduce soil pH, decrease the capacity and cation exchange, degrade the organic matter in the soil, and also cause the lack of nutrients such as fast-acting potassium, alkaline nitrogen and effective phosphorus and their reduced effectiveness, resulting in the weakening of the soil's ability to supply nutrients to crops[15]; at the same time, the increase in the level of heavy metal pollution can damage the enzyme active groups and spatial structure, reduce the biosynthesis of enzymes and At the same time, the increase of heavy metal pollution will damage the enzyme active groups and spatial structure, reduce the biosynthesis of enzymes and cause a decrease in enzyme activity [16], which will inhibit the growth of microorganisms, resulting in a significant decrease in the number of soil microbial populations and a gradual decrease in community diversity.

Increased soil heavy metal content can affect seed germination (hexavalent Cr concentrations >0.1 mgL-1 in soil can inhibit rice seed germination [17]) and It also inhibits the uptake and transport of mineral elements such as Ca and Mg by crops. Heavy metals in the crop The heavy metals in the crop induce the production of substances (H_2O_2, C_2H_4, etc.) that have a negative effect on enzyme activity and metabolism, causing a negative effect on metabolism and enzyme activity in the crop. Cd can have a negative effect on the metabolism and enzymatic activity of the crop, causing direct damage to the crop, thus inhibiting its growth and leading to a significant decrease in yield and quality of agricultural products [18]. can bind to sulfhydryl amino acid proteins in the crop [19], causing protein inactivation and, in severe cases, crop death. also destroys chlorophyll [20], promotes the decomposition of ascorbic acid, accumulates free proline and inhibits the activity of nitrate reductase. Trace amounts of soil As can promote crop growth and development, but excessive As can inhibit water and nutrient uptake and transport by the root system, as well as root activity, and reduce the transpiration of the crop. The damage to the crop can be manifested as stunted root development, uneven seedling emergence, curled and wilted leaves, resulting in root, stem and leaf death and crop yield and quality. The damage to the crop is manifested as stunted root development, poor seedling emergence, curled and wilted leaves, resulting in root, stem and leaf death, and reduced crop yield and quality [21].

3. Soil-crop System Heavy Metal Contamination Assessment and Human Health Risk Evaluation

3.1. Current Status Of Heavy Metal Contamination In Soil-crop Systems

With economic development, the sources of heavy metal pollution in soil-crop systems have gradually increased, and the environmental role has subsequently increased, exacerbating the degree of heavy metal pollution in the systems. The 2014 National Soil Pollution Survey Bulletin[22] shows that the total exceedance rate of soil in China is 16.1%, with inorganic type The distribution of Cd, Hg, As and Pb content shows a gradual increase from northwest to southeast and from northeast to southwest. The distribution of Cd, Hg, As and Pb showed a gradual increase from northwest to southeast and from northeast to southwest. In general, heavy metal pollution is more serious in the south-east than in the north-west, and in the south-west than in the north-east. The pollution of heavy metals such as As and Cd and Hg in

ISSN: 2688-8645

agricultural soils is more serious [23], and the pollution of heavy metals in industrial soils is more serious than that in agricultural soils. The content of many heavy metals such as As and Cd, Pb, Hg, Cu and Zn is higher than the background value of the soil environment [24]. The pollution of heavy metals in coastal areas is more serious than inland areas [25], and urban soils are more polluted with heavy metals than farmlands [26]. Heavy metals in soils enter crops through plant roots The heavy metals in the crops are then ingested by humans through food such as rice and vegetables, leading to human health risks. According to statistics [27], about 1/5 of the arable land in China is contaminated with heavy metals, and the annual loss of contaminated crop production is as high as 1.2107 t. According to statistics [28], about 1/5 of China's arable land is contaminated with heavy metals, and the annual loss of contaminated crops is as high as 1.2107 t, with an economic loss of about 21010 yuan. The consumption of food contaminated with heavy metals can cause functional disorders of the nervous and reproductive systems, and in serious cases can lead to cancer and other diseases, posing a great threat to human health. The increasing level of heavy metal pollution has brought about a series of negative impacts, which seriously restrict the sustainable development of China.

3.2. Soil-crop System Heavy Metal Contamination Assessment

In soil-crop systems, the degree of contamination of heavy metals is positively correlated with their concentration levels. In general the single factor pollution index method and the Nemerow integrated pollution index method are used to assess the contamination level of soil heavy metals according to our soil environmental quality standards and background values of heavy metals.

In addition, the presence of heavy metals in the soil can occur in a variety of forms and the effective state of heavy metals can also be used to assess the extent of heavy metal contamination in the soil. This is related to the physical and chemical properties of the soil itself, such as pH, redox potential (Eh), organic matter, particle size and soil type. The effective state of Cd, Cu, Pb and Zn showed a significant quadratic relationship with pH, with the highest effective state of Cd, Cu, Pb and Zn at around pH 6.5. and Zn were highest at pH 6.5 and decreased significantly with further increase in soil pH [29].

3.3. Soil-crop System Heavy Metal Enrichment Patterns

The enrichment or bioavailability of heavy metals varied significantly among crops and tissues of the same crop: wheat was more enriched for heavy metals than yew, especially for Cd, Hg and As, while Cr and Zn were more enriched in soybean, rice and maize. Wheat is more enriched in heavy metals than corn, especially for Cd, Hg and As [30], and Cr and Zn accumulate more in soybean, rice and corn than other heavy metals [31]. The accumulation of Cr and Zn in soybean, rice and maize was higher than that of other heavy metals [32]; the concentration of Cu and Cd in rice tissues in the soil-rice system was ranked as root > shoot and stem > grain The concentration of Cu and Cd in rice tissues in the soil-rice system was ranked as root>shoot, stem>shell and grain, while the concentration of Zn, Cd, Pb and As was ranked as root>shoot, stem>shell and grain [33]; there was a significant relationship between most vegetables and their corresponding soil There is a significant positive correlation between most vegetables and their corresponding soil concentrations of heavy metals, and vegetables are more enriched in Pb, Cd and Hg than other metals. The average concentrations of Pb, Cd and Hg in vegetables were 0.105, 0.041 and 0.008 mgkg-1 , which were lower than the maximum permissible concentrations (National Standard for Food Safety, Limits for Contaminants in Food). The average concentrations of Pb, Cd and Hg in vegetables were 0.105, 0.041 and 0.008 mgkg-1 , which were lower than the maximum permissible concentrations (GB 2762-2017)[34] of metals in vegetables: Pb≤0.3 mgkg-1 , Cd≤0.2 mgkg-1, Hg≤0.01 mgkg-1), but still have relatively high potential non-carcinogenic health risks [35], especially in the southwest of China. For example, the hazard index (HI) for three heavy metals in Guizhou Province was 0.274, and the

ISSN: 2688-8645

HI for Southwest China was 0.167 (HI is often used to indicate the overall non-carcinogenic risk of heavy metals to humans). (HI is often used to indicate the overall non-carcinogenic risk of heavy metals to humans, with HI < 1 indicating no non-carcinogenic risk and HI > 1 indicating a possible non-carcinogenic risk. The higher the HI value, the greater the possible non-carcinogenic risk).

4. Conclusion

The poor state of heavy metal contamination in the soil-crop system has a significant impact on the economy, environment, food safety and health, especially on the safety of agricultural products and the health of the population, and is of great concern to the community and government. Bioeffectiveness is a necessary parameter to assess the human health risk of heavy metals in food. The Human Intestinal Microbial Mimicry System (SHIME) can demonstrate the important role of intestinal microorganisms in the digestion and absorption of food, and can effectively investigate the influence of intestinal microorganisms and key physicochemical factors on the morphological transformation and bioeffectiveness of heavy metals, which has good environmental and health implications.

References

[1] Yang Q Q, Li Z Y, Lu X N, et al. A review of soil heavy metal pollution from industrial and agricultural regions in China: Pollution and risk assessment [J]. Science of the Total Environment, 2018, 642: 690-700.

[2] Huang Y, Wang L Y, Wang W J, et al. Current status of agricultural soil pollution by heavy metals in China: A metaanalysis[J]. Science of the Total Environment, 2019, 651: 3034-3042.

[3] Zhu D W, Wei Y, Zhao Y H, et al. Heavy metal pollution and ecological risk assessment of the agriculture soil inXunyang mining area, Shaanxi Province, northwestern China [J]. Bulletin of Environmental Contamination and Toxicology,2018, 101(2): 178-184.

[4] Gebrekidan A, Weldegebriel Y, Hadera A, et al. Toxicological assessment of heavy metals accumulated in vegetables and fruits grown in Ginfel River near Sheba Tannery, Tigray, Northern Ethiopia [J]. Ecotoxicology and Environmental Safety,2013, 95: 171-178.

[5] Islam M S, Proshad R, Asadul Haque M, et al. Assessment of heavy metals in foods around the industrial areas:Health hazard inference in Bangladesh [J]. Geocarto International, 2020, 35(3): 280-295.

[6] Du Y, Hu X F, Wu X H, et al. Affects of mining activities on Cd pollution to the paddy soils and rice grain in Hunan Province, Central South China [J]. Environmental Monitoring and Assessment, 2013, 185(12): 9843-9856.

[7] Zwolak A, Sarzyńska M, Szpyrka E, et al. Sources of soil pollution by heavy metals and their accumulation in vegetables: A review [J]. Water, Air, & Soil Pollution, 2019, 230(7): 1-9.

[8] Hu B F, Shao S, Ni H, et al. Current status, spatial features, health risks, and potential driving factors of soil heavy metal pollution in China at province level [J]. Environmental Pollution, 2020, 266: 114961.

[9] Huang J H, Peng S Y, Mao X M, et al. Source apportionment and spatial and quantitative ecological risk assessment of heavy metals in soils from a typical Chinese agricultural county [J]. Process Safety and Environmental Protection, 2019,126: 339-347.

[10] Bakhat H F, Zia Z, Abbas S, et al. Factors controlling arsenic contamination and potential remediation measures in soil-plant systems [J]. Groundwater for Sustainable Development, 2019, 9: 100263.

[11] Zhang X W, Yan Y, Wadood S A, et al. Source apportionment of cadmium pollution in agricultural soil based on cadmium isotope ratio analysis [J]. Applied Geochemistry, 2020, 123: 104776.

[12] Li X Y, Zhang J R, Ma J, et al. Status of chromium accumulation in agricultural soils across China (1989-2016) [J]. Chemosphere, 2020, 256: 127036.

[13] Xiong Q X, Li Z L, Xiong M. A brief discussion on research status of Pb2+ pollution and remediation technology in soil[J]. Guangzhou Chemical Industry, 2019, 47(17): 135-137 (in Chinese).

[14] Liu S J, Wang X D, Guo G L, et al. Status and environmental management of soil mercury pollution in China: Areview [J]. Journal of Environmental Management, 2021, 277: 111442.

[15] Wang H. Effects of heavy metal Cu, Zn and Cd stress on wheat growth and soil physical and chemical properties [D].Qingdao: Qingdao Agricultural University, 2017: 50-53 (in Chinese).

[16] WENG Na, HAN Xiao. Research progress on the effect of heavy metal pollution on soil enzyme activity[J]. Agricultural Development and Equipment, 2016(10): 34-35, 39.

[17] Xue Luyan, Zhang Haifeng, Cai Kui, et al. On the hazards of heavy metal pollution in agricultural soils and remediation techniques[J]. Agriculture and Technology, 2020, 40(13): 41-42.

[18] Kotecha M, Medhavi, Chaudhary S, et al. Metals, Crops and Agricultural Productivity: Impact of Metals on Crop Loss [M]//Plant-Metal Interactions. Cham: Springer International Publishing, 2019: 191-216.

[19] Wu Jintao, Chen Xia. Contamination of agricultural products by heavy metal cadmium and its prevention and control measures[J]. Farmers' Advice, 2020(15): 226, 228.

[20] Li Jang. Causes, hazards and solutions of heavy metal pollution in soil[J]. Science, Technology and Innovation, 2019(12): 92-93.

[21] Zhang Qian, Du Haiyun, Sun Jiazheng, et al. Current situation of arsenic contamination in orchard soil and fruit in China and suggestions for control measures [J]. Shandong Agricultural Science, 2015,47(7): 131-135.

[22] Wang Y Y, Hao Y, Zhang H, et al. Cadmium and arsenic pollution in rice in the Pearl River Delta and the countermeasures [J]. Chinese Agricultural Science Bulletin, 2019, 35(12): 63-72 (in Chinese).

[23] Wang X N. Review on research advances of measures of soil heavy metal pollution control [J]. Journal of Anhui Agricultural Sciences, 2014, 42(29): 10070-10071 (in Chinese).

[24] Feng X B, Qiu G L, Fu X W, et al. Mercury pollution in the environment [J]. Progress in Chemistry, 2009, 21(Z1): 436-457 (in Chinese).

[25] Xie Shiqiang. Migration and transformation of different forms of mercury in the atmosphere[J]. China Chemical Trade, 2017, 9(14): 243.

[26] Ministry of Environmental Protection of the People's Republic of China, Ministry of Land and Resources of the People's Republic of China. National soil pollution survey bulletin [EB/OL]. (2014-04-17) [2020-12-15].

[27] Xie S W, Yang F, Feng H X, et al. Assessment of potential heavy metal contamination in the peri-urban agricultural soils of 31 provincial capital cities in China [J]. Environmental Management, 2019, 64(3): 366-380.

[28] Wang G Y, Zhang S R, Xiao L Y, et al. Heavy metals in soils from a typical industrial area in Sichuan, China: Spatialdistribution, source identification, and ecological risk assessment [J]. Environmental Science and Pollution Research, 2017,24(20): 16618-16630.

[29] Ge X Y, Ouyang Z, Yang L S, et al. Concentration, risk assessment and sources of heavy metals in soil around Bohai Rim [J]. Acta Scientiae Circumstantiae, 2019, 39(6): 1979-1988 (in Chinese).

[30] Pan L B, Wang Y, Ma J, et al. A review of heavy metal pollution levels and health risk assessment of urban soils in Chinese cities [J]. Environmental Science and Pollution Research International, 2018, 25(2): 1055-1069.

[31] Zhao Q G, Luo Y M. The macro strategy of soil protection in China [J]. Bulletin of Chinese Academy of Sciences,2015, 30(4): 452-458 (in Chinese).

[32] Zhao Q G, Huang G Q, Qian H Y. Ecological agriculture and food safety [J]. Acta Pedologica Sinica, 2007, 44(6):1127-1134 (in Chinese).

ISSN: 2688-8645

[33] Li S M, Wang H J, Zhu X, et al. Effects of soil pH and organic matter on the content of bioavailable heavy metals [J].Journal of Yunnan Normal University: Natural Sciences Edition, 2021, 41(1): 49-55 (in Chinese).

[34] Wang S Y, Wu W Y, Liu F, et al. Accumulation of heavy metals in soil-crop systems: A review for wheat and corn[J]. Environmental Science and Pollution Research, 2017, 24(18): 15209-15225.

[35] Peng J Y, Li F X, Zhang J Q, et al. Comprehensive assessment of heavy metals pollution of farmland soil and cropsin Jilin Province [J]. Environmental Geochemistry and Health, 2020, 42(12): 4369-4383.