Research Progress on Farmland Soil Heavy Metal Pollution and Remediation Technologies in the Yangtze River Basin

Yujing Zhang¹, Wanjing Wu¹, Duwei Zhang¹, Hongkun Huang²* and Ping Fang¹*

¹ College of Environmental Science and Engineering, Tongji University, Shanghai, China
² Rural Energy and Environment Agency, Ministry of Agriculture and Rural Affairs, Building 24, Maizidian Street, Chaoyang District, Beijing, China
Email: fangping2000@tongji.edu.cn; huangdusk@126.com

Abstract. Farmland pollution directly affects the economic benefits of crops and food security. In recent years, the condition of farmland soil in China is not optimistic, and its pollutants are mainly heavy metals. Soil is the basic condition for biological survival and the final melting and disintegration of pollutants. China's soil pollution control work urgently, soil pollution control situation is more serious. In the process of economic transformation advocated by the state, pollution control should be strengthened, and soil ecological remediation technology should be vigorously studied and popularized, so as to effectively prevent soil pollution and meet the needs of sustainable development in China. This paper studies the research progress of heavy metal pollution and remediation technology in farmland soil in the Yangtze river basin, analyzes the current situation of farmland soil pollution in representative cities in the Yangtze river basin, and summarizes the main remediation methods of heavy metal pollutants, especially in farmland soil.

1. Introduction

1.1. Current Situation of Soil Heavy Metal Pollution in China
In recent years, China’s environmental problems have become increasingly serious, the state of the soil environment is not optimistic, industrial and mining, agricultural soil problems are prominent. The soil is mainly mixed pollution, mainly inorganic pollutants, followed by organic matter. (The excess points accounted for 82.8% of the total). According to the national soil pollution investigation bulletin released in 2014, the total over-standard rate of soil pollution in China is 16.1%. The pollutants are mainly cadmium, mercury, arsenic, copper, lead, chromium, zinc and nickel. Cadmium pollution is the most serious, exceeding 7% [1]. Heavy metal pollution is more serious in the south than in the north, in the southwest and central and southern regions, soil pollution is relatively serious in areas such as the Yangtze river delta, the pearl river delta and the old industrial bases in the northeast [2]. According to the estimation of the environmental protection department, by 2011, about 150 million acres of China's arable land was polluted by heavy metals, accounting for 8.3% of the total. Every year, 12 million tons of grain was polluted by heavy metals, causing direct economic losses of up to 20 billion yuan [3]. According to the 2014 national soil pollution survey bulletin, among the environmental quality of different types of land in China, cultivated land has the highest rate of point over-standard, with 19.4%. The main pollutants are heavy metals and organic pollutants. The quality of farmland soil is related to the safety of agricultural products. China is a large agricultural country, and food security...
cannot be ignored. Therefore, how to deal with heavy metal pollution in agricultural soil is the primary task at present.

1.2. Status and Sources of Heavy Metal Pollution in Farmland Soil in the Yangtze River Basin

1.2.1. Pollution Status. The Yangtze River basin is the largest river system in China, covering 19 provinces, cities and autonomous regions. The cultivated land area in the basin reaches more than 24.6 million hectares, accounting for 1/4 of the cultivated land area in China. The main types of soil in the Yangtze river basin are paddy fields and arid lands, and Yangtze river basin is an important grain production base in China. In this paper, the present situation of soil pollution in China is analyzed from the heavy metal pollution of farmland soil in the provinces flowing through the Yangtze River basin. However, according to the “national land consolidation plan (2016-2020)” [4]. China is expected to reduce the cultivated land area by more than 70 million mu due to ecological conversion and adjustment of agricultural structure. Therefore, it is impossible to directly analyze the main situation of farmland soil pollution through the change of agricultural cultivated land area in major areas, so the following two aspects are summarized:

(1) According to the ministry of agriculture key laboratory for the control of environmental pollution to the country 24 provinces and cities, land survey in the Yangtze river main provinces, the western minority regions such as Tibet, Qing Hai, soil pollution situation is relatively good, Sichuan, Hunan, Anhui, Jiangxi and other provinces of agricultural pollution problem is most serious, Chongqing, Yunnan, Hubei, Shanghai farmland have different levels of heavy metal pollution problems [5-6].

(2) According to the bulletin of the ecological environmental protection bureau of major cities in the Yangtze River basin, the soil point exceeding rate in Sichuan province is 34.3%, while 1.20% of the soil points are heavily polluted. The main pollutants are Cadmium, Nickel, Copper, Chromium and organic matter. In Hunan, 28,000 hectares of farmland are polluted, accounting for 13% of the province’s total soil area. In some parts of Jiangxi province, 44 percent of the cultivated land is polluted, with Cadmium, Copper, Mercury and Arsenic as the main pollutants. Heavy metal pollution in the soil reduces grain output by more than 800,000 tons and causes economic losses of up to 200 million yuan. The cultivated land reserve in Chongqing is relatively small, but the average area of soil acidification is 38.5%. About 400,000 hectares of cultivated land in Hubei province is polluted by waste water, waste gas and solid waste, accounting for 10% of the province’s cultivated land area. The soil in some parts of Shanghai is seriously polluted by Cadmium. Zhang found that in some areas of Yunnan farmland soil, cadmium, chromium and lead single factor pollution exceeded the standard, among which cadmium had the greatest impact on the soil quality of Yunnan farmland [7].

Outlined above description: as the economic development and industrial structure adjustment, the destruction of human activities on the soil environment has caused cannot be ignored, the influence of major cities in the Yangtze river basin of cultivated land, forest land and unused land area showed a trend of decrease, most polluting in cultivated land, how to maintain the interests of the soil and the balance between environmental protection, is the biggest difficulties we are facing.

1.2.2. Source of Pollution. Due to the incoordination between the rapid economic development and the development of environmental protection skills, the atmospheric pollutant settlement through the atmosphere, the waste water in rivers and lakes flowing through the farmland, and the long-term and excessive use of chemical fertilizers and pesticides, the cultivated land pollution in the Yangtze River basin is more serious. Table 1 is the source analysis of heavy metal pollution in farmland soil.
2. Methods for Remediation of Heavy Metal Pollution in Farmland Soil in the Yangtze River Basin

2.1. Physical Repair Method

In physical remediation technology, soil exchange method, soil replacement method and soil turnover method refer to the replacement of contaminated and uncontaminated soil, which is quick and simple, but easy to cause secondary pollution, so it is not suitable for large-scale treatment and remediation. In the electric restoration method, Su used the approximate electrode method to remove the key Ni of the soil, and the removal rate reached 67.2%, which increased by 29.7% compared with the traditional fixed-click electric restoration method [8]. In the heat treatment method, Qiu respectively studied the fixation effect of anaerobic and aerobic heat treatment and zeolite enhanced heat treatment on soil polluted by Cu and Zn [9]. The results showed (1) the anaerobic heat treatment had a better fixation effect on soil heavy metals than the aerobic heat treatment, and the fixation effect would be enhanced as the temperature increased. (2) adding zeolite treatment at different temperatures on the soil heavy metal fixed effect is obvious different, between 200 and 450 ℃ zeolite fixed effect of copper and zinc in the soil have no obvious influence, 500 ℃, to contain heavy metals and fixed effect is improved obviously, and under 500 ℃ when adding zeolite enhanced aerobic treatment compared with normal aerobic treatment, the weak acid copper and zinc can extract the state quality ratio decreased by 12.7% and 12.1%, residue state quality than increased 8.6% and 12%. Table 2 is main physical remediation methods of heavy metal contaminated soil.

Table 1. The source analysis of heavy metal pollution in farmland soil [10-11].

| Source of pollution   | Pollution source analysis                                                                                                                                                                                                 |
|----------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Sewage irrigation    | Industrial, urban and agricultural sewage contains a large number of organic or inorganic pollutants, which are used to irrigate the soil, causing a certain amount of heavy metals to enter the farmland and cause soil pollution. For example, annual cadmium pollution caused by irrigation in Hunan province accounts for 69.9% of the total farmland soil pollution. |
| Atmospheric precipitation | The air pollution caused by industrial waste gas, automobile exhaust emissions, burning straw and other materials enters the soil through direct pollution and atmospheric subsidence. Although the use of chemical fertilizers and pesticides can improve soil fertility and crop yield, excessive or long-term application will result in heavy metal accumulation to different degrees in farmland soil due to the high content of nitrogen, phosphorus, arsenic and other elements, which will lead to soil fertility decline or even hardening and damage soil structure. |
| Agricultural supplies |                                                                                                                                                                                                                       |

2.2. Chemical Repair Method

Earlier soil chemical remediation technology development, technology is relatively mature, also it is the use of chemical remediation agent with pollutants in oxidation reaction, reduction reaction, adsorption, precipitation reaction, polymerization, complexation reaction, make the pollutants, was isolated from soil degradation, or into a low toxicity, non-toxic, harmless and stable sediment, and then getting rid of that. Lin showed that bone carbon can effectively reduce the bioavailability and phytotoxicity of heavy metals in soil, and can also be applied to the evaluation of genotoxicity in pollution remediation [12]. Li used organic acid and citric acid to leaching and repair the soil contaminated by Cd, Cu and Pb, and found that the removal rate of Cd, Cu and Pb by citric acid reached 90.4%, 82.5% and 38.6%, respectively. Among them, the elution capacity of different heavy
metals was Cu, Pb and Cd in order from large to small [13]. Table 3 is chemical repair method of heavy metal polluted soil

| Technical name                  | Repair measures                                                                 | Technical advantages                              | Technical disadvantage                                      |
|--------------------------------|--------------------------------------------------------------------------------|--------------------------------------------------|------------------------------------------------------------|
| Improved soil imported from other places | Contaminated soil is repaired by replacing uncontaminated soil or by covering contaminated soil with uncontaminated soil | High efficiency, simple operation                 | Large amount of engineering, high cost, damage soil structure, reduce soil fertility |
| Electro prosthesis              | Using the anode and cathode, the low power electric field is applied to conduct directional migration of underground heavy metal ions, which are enriched and collected in the click area | Environment friendly                               | The technology is not mature enough and the selectivity of heavy metals is not high enough |
| Heat treatment method           | High frequency voltage is used to heat the soil so that low melting point, volatile heavy metals volatilize from the soil | The effect is remarkable, the way is simple       | High energy consumption, high cost, and easy to cause secondary pollution |

| Technical name                  | Repair measures                                                                 | Technical advantages                              | Technical disadvantage                                      |
|--------------------------------|--------------------------------------------------------------------------------|--------------------------------------------------|------------------------------------------------------------|
| Chemical leaching method        | The soil is washed with a specific eluent, then the contaminants are separated and removed | High efficiency                                   | It is easy to cause secondary pollution and damage the soil structure. |
| Chemical fixation method        | It can effectively combine with heavy metal ions to produce sediment, reduce the mobility and bioavailability of heavy metal pollutants in soil, and realize soil remediation | The treatment effect is good, and the heavy metal contaminated soil can be repaired in large area | The heavy metals in the soil are not completely removed, but the existing form in the soil is changed, which is easy to cause secondary pollution |

2.3. Bioremediation Methods
Bioremediation mainly USES biological metabolic activities to absorb, enrich and transform heavy metals in the soil to reduce the pollution degree of heavy metals. The method is low-cost and environmentally friendly. However, its repair cycle is long and is greatly affected by the environment. Gu showed that such as biomass, sorghum, corn as material selection, experiment concluded: with mild cadmium pollution of farmland, the content of cadmium in plant height is influenced by plant varieties and the content of cadmium in soil is bigger, other than corn plant aboveground enrichment coefficient for the heavy metal cadmium were greater than 1, and have the enrichment characteristics of cadmium and the grain amaranth on heavy metal cadmium enrichment coefficient of the highest, has a good ability of heavy metal enrichment [14]. Huang studied the indigenous microbial
remediation of chromium in the soil, and found that the indigenous microorganisms in the chromium residue yard soil could be activated under the stimulation of nutrients, thus remediation of chromium contaminated soil [15]. In the technique of ecological remediation of heavy metal contaminated soil by biological enzymes, Lin found that the leach-amylose had a good removal effect on the available heavy metals in the soil, and the removal rates of Cd, Cr, Cu, Ni and Zn under the best leaching conditions were 82.36%, 75.02%, 38.38%, 34.69% and 57.54%, respectively [16]. Fu found that earthworms had a certain enrichment effect on heavy metals in the soil, which also indicated that earthworms had a certain selectivity for the enrichment of heavy metals. The order of absorption of some heavy metals was Zn, Cu, Pb and Hg, and the enrichment amount would change with time [17].

Table 4 is main bioremediation methods for heavy metal contaminated soil.

| Technical name                  | Repair measures                                                                 | Technical advantages                                                                 | Technical disadvantage                                                                 |
|---------------------------------|----------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|
| Phytoremediation                | Plant extraction of heavy metal elements from soil was carried out by using plants with strong absorption or accumulation ability to specific heavy metals. | Environment friendly, The cost is low, Large area remediation of soil, without secondary pollution | Long repair cycle, The requirement to plant environment is high, has certain limitation. |
| Microbial remediation method    | Biological adsorption and enrichment, biological transformation and biological dissolution and precipitation were used to remediation contaminated soil | Soil microorganisms are widely distributed, with low environmental requirements, small individuals, rapid reproduction, strong metabolic capacity, strong ability to repair heavy metals, and no secondary pollution | Microbial poor genetic stability and susceptibility to heavy metal concentration and other external factors limit the remediation effect of heavy metal contaminated soil |
| Enzyme repair technique         | The required enzymes were isolated and purified from microorganisms and plants with specific degradation functions, so that the enzymes could combine with heavy metal pollutants in the soil to form complexes and reduce the heavy metal content in the soil. | The environmental requirement is low and the enzyme repair effect is good. | Time is long and cost is high |
| Animal repair technique         | Some lower animals in the soil are used to absorb heavy metals in the soil and then decompose the toxicity of pollutants in the soil through their own metabolism. | It can improve soil quality and maintain soil fertility. | Unable to deal with soil contaminated by high concentrations of heavy metals. |
3. Conclusion
Due to the large population in the Yangtze River basin and the concentration of a large number of industrial and agricultural enterprises, human activities have caused different levels of environmental pollution, and soil is the final manifestation of a variety of pollution forms, among which arable land is linked to the safety of agricultural products, the sustainability of agricultural development, ecological environment and many other issues. In the face of severe soil pollution problems, the government and all sectors of society are doing their best to improve the situation. At the technical level, many scholars also carry out a lot of research in related aspects. In terms of the technology of remediation of heavy metal pollution, there are scientific and feasible remediation methods in China, but they still need to be improved. In addition, it is necessary to control the sources of pollution. The mode of “pollution first, treatment later” cannot go on for a long time.

References
[1] Bulletin of National Survey of Soil Pollution [EB/OL] (2014-04-17) (in Chinese).
[2] Hu P J, Li Z and Wu L H 2018 Remediation technology, problems and countermeasures of heavy metal pollution in farmland soil in China Research of Agricultural Modernization 39 (04) 535-542 (In Chinese).
[3] Wang M C 2011 Isolation, Purification, Structural Analysis and Biological Activity of Polysaccharides from Caraway Stalks (Nanjing Agricultural University) (in Chinese).
[4] National Land Remediation Plan (2016-2020), Ministry of Land and Resources, National Development and Reform Commission (in Chinese).
[5] Li F 2004 Phytoremediation of cadmium-contaminated soil Guangdong Trace Element Science (08) 22-26 (in Chinese).
[6] Zeng Y M, Mao K M and Li Y M 2005 Harm of cadmium pollution in soil and its control measures Journal of Yunnan Agricultural University (03) 360-365 (in Chinese).
[7] Zhang X H, Xiong Q and Li Y 2019 The levels and distribution of lead, cadmium and chromium in farmland soils in Yunnan Environment and Occupational Medicine 36 (03) 238-241 (in Chinese).
[8] Zhang C C 2019 Sources of heavy metals in farmland Hunan Agriculture (06) 35 (in Chinese).
[9] Chen S B, Wang M, Li S S, et al. Status and problems of heavy metal pollution prevention and control in Chinese farmland soils Earth Science Frontiers 1-9 (in Chinese).
[10] Su C J, Yu Z F, Cai Z P, et al. 2019 Research on strengthening electric remediation of heavy metal contaminated soils Resource Conservation and Environmental Protection (10) 21-23 (in Chinese).
[11] Qiu S F, Wei L, Yu W J, et al. 2018 Fixation of Cu and Zn in soil by enhanced zeolite heat treatment Journal of Safety and Environment 18 (02) 711-715 (in Chinese).
[12] Luo Y H 2019 Research progress on heavy metal contaminated soil remediation Southern Agriculture 13 (22) 73-76 + 86 (in Chinese).
[13] Zhang Z D, Zhang Q and Song Z F 2019 Research progress on soil heavy metal pollution remediation Jilin Agriculture (18) 73 (in Chinese).
[14] Lin A J, Zhang X H, Su Y H, et al. 2007 Research on bone carbon repairing soil contaminated by heavy metals and reducing genotoxicity Environmental Science (02) 232-237 (in Chinese).
[15] Li Y H, Hu X J, Song X Y, et al. 2012 Effect and mechanism of citric acid on leaching and remediation of heavy metal compound contaminated soil Journal of Shenyang University (Natural Science Edition) 24 (02) 6-9 (in Chinese).
[16] Pang X P, Liang H Y and Ao Y M 2019 Heavy metal contaminated soil remediation technology and its research progress China Resources Comprehensive Utilization 37 (08) 88-90 (in Chinese).
[17] Gu Y, Jiang P, Tan L, et al. 2019 Studies on the enrichment characteristics of cadmium in soil by six plants Chinese Agricultural Science Bulletin 35 (30) 119-123 (in Chinese).
[18] Huang S H 2009 *Study on Chromium Pollution Characteristics of Chromium Slag Yard and Microbial Remediation of Chromium Contaminated Soil* (Central South University) (in Chinese).

[19] Lin W S, Wu H Q, Hu J P, et al. 2015 Bio-enzyme ecological restoration of heavy metal contaminated soil *Journal of Environmental Engineering* 9 (12) 6147-6153 (in Chinese).

[20] Fu X Y, Qin S, Yang L, et al. 2009 Research on the enrichment of heavy metals in soil by earthworms *Journal of Agro-Environment Science* 28 (01) 78-83 (in Chinese).

[21] Ma J N 2019 Technical characteristics and development prospects of phytoremediation of farmland soils *Rural Science and Technology* (20) 120-121 (in Chinese).

[22] Yang H, Huang X, Lin Z Z, et al. 2019 Research progress on microbial remediation technology of heavy metal contaminated soils *Applied Chemical Industry* 48 (06) 1417-1422 (in Chinese).

[23] Zhou J H, Huang R X, Fan H B, et al. 2016 Research progress on contaminated soil remediation technology *Research of Soil and Water Conservation* 23 (03) 366-372 (in Chinese).