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Current Situation of Heavy Metal Pollution in Farmland Soil and Phytoremediation Application

Yanfei HUANG, Guifen CHEN, Liumei XIONG, Yuyi HUANG *

Agricultural Resource and Environment Research Institute, Guangxi Academy of Agricultural Sciences, Nanning 530007, China

Abstract Phytoremediation technology is a newly-developed way of soil heavy metal pollution repair with high efficiency and good ecological comprehensive benefit. This paper briefly introduces the soil heavy metal pollution status at home and abroad, and focuses on the analysis of harm, sources and current situation of soil heavy metal pollution at home and abroad as well as mechanism and application of phytoremediation. Finally it discusses the key problems in phytoremediation technology that need to resolve in the future.

Key words Soil pollution, Heavy metal, Phytoremediation, Application status

1 Introduction

Soil is the basis of agricultural production, and deterioration of soil environment will pose a direct threat to human food safety. With the rapid development of mining and smelting technology, the soil heavy metal pollution has become increasingly prominent. Since the occurrence of "Minamata disease" and "itai-itai disease" in Japan, the heavy metal pollution has aroused strong concern, and gradually become a hot topic[1]. Over the past two years, some safety incidents have appeared successively at home, such as Guangxi Longjiang cadmium pollution, Guangdong rice cadmium pollution and Hunan blood lead, attracting the attention of the government and the society. Obviously, the remediation of soil heavy metal pollution has become an increasingly hot spot in environmental science, and it is also a worldwide ticklish problem[2]. The phytoremediation of soil heavy metal pollution is a quick, effective and sustainable means of repair. This paper will analyze the current soil heavy metal pollution at home and abroad and application of plant technology in the remediation of soil heavy metal pollution.

2 Current situation of soil heavy metal pollution

2.1 Soil heavy metal pollution hazards Heavy metals have the characteristics of stability and poor mobility, and once they enter human body, it will pose a threat to human health. The soil heavy metal also damages soil microbial structural diversity, and affects the ecological balance of the soil[3]. Heavy metal pollution can quickly diminish soil fertility and heavy metals accumulate in the edible parts and enter food chain through crop uptake. In addition, through runoff and leaching, it can pollute surface and groundwater, aggravate water environment, affect food safety and endanger human life[4].

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* Corresponding author. E-mail: hyywife@163.com

2.2 Heavy metal pollution sources of farmland soil Natural factors and human factors are the main way to cause soil heavy metal pollution. Natural factors include soil parent material, soil-forming process and atmospheric deposition effects[5]. Human factors mainly include three aspects: sewage irrigation (irrigation of wastewater from mining production)[6]; atmospheric deposition (heavy metal particles in the air settling into the soil via rain); use of chemical fertilizer and pesticide (such as the use of phosphate fertilizer containing Cd, organic fertilizer containing Zn and Cu, pesticides containing Hg, Cu, Zn and As)[7].

2.3 Heavy metal pollution of farmland soil at home and abroad According to statistics, the world's annual emissions are as follows: 15000 t of Hg, 3400000 t of Cu, 5000000 t of Pb, 15000000 t of Mn and 1000000 t of Ni[8]. In 1200 paddy soil sampling survey points of the United States, Huang *et al.*[9] (2009) find that about 63% of the sampling points are polluted by Pb, Cr, Cd and Cu to varying degrees. In Japan, about 472000 ha of farmland is polluted by Cd, accounting for 82% of total farmland polluted by heavy metals[10]. According to the survey by the Ministry of Agriculture, China currently has 26.67 million ha of arable land subject to different degrees of heavy metal pollution; 64.8% of farmland in sewage irrigation areas is polluted by heavy metals, and the polluting area reaches more than 3.3 million ha; the annual grain losses are up to 12 million t, with total losses of at least 20 billion yuan[11]. And the Cd and Hg pollution is most serious. According to statistics, the area of China's farmland polluted by Hg reaches 32000 ha, and the area of farmland polluted by Cd reaches 13300 ha[12]; pollution involves 11 provinces and 25 regions, and it is relatively severe in Southwest China (Yunnan, Guizhou, Guangxi), Central China (Jiangxi, Hunan), the Pearl River Delta and Yangtze River Delta region; the content of Pb and Cd in Southwest is significantly higher than the background value, the content of Cd in Liaoning exceeds the background value of about 23.02 times; the content of Cu in Guangdong reaches 2.92 times of the background value[13].

3 Phytoremediation for soil heavy metal pollution

3.1 Concept In 1977, Brooks first proposed the concept of super-accumulation plants[14]. USEPA (United States Environmental Protection Agency) believes that phytoremediation technology is to use the plant's characteristics of absorption and enrichment, decomposition and transformation and stable chelation, in order to clear or reduce harmful pollutants.

3.2 Mechanism Currently, the means of repairing soil heavy metal pollution is to remove and reduce the total amount of heavy metals in soil, and decrease the mobility of heavy metals in soil through the passivation to lower bioavailability. By using the plant's characteristics of absorption and enrichment, decomposition and transformation and stable chelation, phytoremediation is to reduce crop absorption so as to achieve the purpose of preventing or mitigating harm.

3.2.1 Phytovolatilization. Phytovolatilization refers to the uptake and transpiration of contaminants, primarily organic compounds, by plants. The contaminant, present in the water taken up by the plant, passes through the plant or is modified by the plant, and is released to the atmosphere (evaporates or vaporizes). Banuelos *et al.*[15] (1997) find that kenaf, fescue and other plants can make soil trivalent selenium change into methyl selenium to be volatile and eventually removed from the soil. Rugh *et al.*[16] (1996) transduce Hg reductase gene into *Arabidopsi sthaliana*, and find that the transgenic *Arabidopsi sthaliana* can absorb highly toxic Hg in soil, and reduce it into lowly toxic Hg0.

3.2.2 Phytostabilization. Phytostabilization involves the establishment of a plant cover on the surface of the contaminated sites with the aim of reducing the mobility of contaminants within the vadose zone through accumulation by roots or immobilization within the rhizosphere, thereby reducing off-site contamination. The process includes transpiration and root growth that immobilizes contaminants by reducing leaching, controlling erosion, creating an aerobic environment in the root zone, and adding organic matter to the substrate that binds the contaminant. Simon[17] (2005) finds that *Festuca rubra* can effectively stabilize the metals in mining wasteland; *Vetiveria zizanioides* can effectively reduce the content of Pb, Zn and Cu in tailings[18]. Tang and Fang[19] (2001) find that *Polygonum microcephalum* and *Rumex hastatus* have the potential for stabilizing soil-contaminated metals.

3.2.3 Phytoextraction. Phytoextraction, the use of plants for the recovery of metals from waste repositories, is a green and novel technique for metal recovery. Using the hyperaccumulation capacity of plant, it stores and treats one or more heavy metals in soil aboveground by absorption and transport, so as to reduce the heavy metal content of the soil. Currently, more than 700 kinds of heavy metal hyperaccumulation plants have been found at home and abroad. There are more than 300 kinds of Ni hyperaccumulation plants, 21 kinds of Zn hyperaccumulation plants, and 16 kinds of Pb hyperaccumulation plants[20]; Cd hyperaccumulation plants include *Crassulaceae*, *Salicaceae*, *Kalimeris integrifolia*, *etc.*, and Salixmatsudana can accumulate the highest content of Cd at 47.19 mg /kg[21]; Mn hyperaccumulation plants include *Schima superba Gardn. et Champ.*, *Phytolacca acinosa Roxb*, and the leaves of *Phytolacca acinosa Roxb* can accumulate 1929.9 mg /kg of Mn[22]; As hyperaccumulation plants include *Pteris vittata*, *Pteris cretica*, *etc.*; Cu hyperaccumulation plants include *Commelina communis*, *Lamiaceae*, *etc.*[23]; Hg hyperaccumulation plants include Canadian poplar and mangrove[24].

3.3 Current application of phytoremediation technology The study results of Xiang Yaling *et al.*[25] (1994) show that Urticaceae plays a significant role in remediation of farmland contaminated by Cd. Shen Libo *et al.*[26] (2010) use the crop rotation of hyperaccumulation plant *Sedum plumbizincicola* X. H. Guo et S. B. Zhou sp. Nov. A and rice, and phosphorus repair agent for paddy cadmium pollution remediation, and find that combing the two repair methods can not only remove heavy metals in the soil but also ensure food production. Chen Tongbin *et al.*[27] (2005) establish phytoremediation demonstration project for arsenic-contaminated soil in Chenzhou and use Pteris vittata to repair arsenic contamination in soil, and the results show that arsenic remediation efficiency reaches 71.84%. Li Tingqiang *et al.*[28] (2007) use hyperaccumulator *Sedum alfredii* to repair the mine soil pollution, and find that the content of available Zn and Cd in rhizosphere is significantly reduced. Obviously, phytoremediation technology plays an important role in soil heavy metal remediation.

4 Conclusions and discussions

Phytoremediation technology is a newly-developed way of soil heavy metal pollution repair with high efficiency and good ecological comprehensive benefit. This paper briefly introduces the soil heavy metal pollution status at home and abroad, and focuses on the analysis of harm, sources and current situation of soil heavy metal pollution at home and abroad as well as mechanism and application of phytoremediation. Phytoremediation technology is safe and environment-friendly, with good comprehensive economic and ecological benefits. However, there are a number of phytoremediation technology issues to be resolved. (i) Most of the hyperaccumulators for phytoremediation are shallow-rooted plants having small biomass and long growth cycle, with single remediation goal. There is an urgent need to screen and cultivate the plants with many absorbing types, strong ability and large biomass. (ii) Most of the hyperaccumulators have a stringent demand on growth environment, and are difficult to plant, repair and apply, so it is necessary to study the functional genes of hyperaccumulators and breed the hyperaccumulators suitable for practical application. (iii) It is necessary to give full play to the role of root microbe in remediation of soil contaminants, and select the microorganisms that can promote plant's absorption of heavy metal ions. (iv) It is necessary to use different kinds of remediation technologies, and explore the junction between phytoremediation and chemical remediation, or bioremediation. (v) How to deal with the hyperaccumulators after phytoremediation to avoid the secondary pollution is a major problem faced by the future phytoremediation technology.

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(From page 15)

the construction of ecological civilization and better promote the coordinated development.

4 Conclusions

The new urbanization has rich connotation, and its realization needs multi-dimensional concept, policy and way. It plays an important role in leading, supporting, and controlling new urbanization based on ecological civilization and eventually make the two fuse and create synergy[6]. In order to promote the new urbanization and the construction of ecological civilization, we should optimize the use of land resources, and provide space protection for the new urbanization and the construction of ecological civilization; vigorously develop the financial sector to provide financial support for the new urbanization and the construction of ecological civilization; provide information support for the new urbanization and the construction of ecological civilization by improving the information infrastructure; stick to the people-oriented principle and strive to build livable city of ecological civilization; establish ecological compensation mechanism to promote the coordinated development of regional new ecological town; establish scientific and rational planning to provide a blueprint for promoting synergy between new urbanization and the construction of ecological civilization.

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