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Research on Plant-amendment Combined Remediation Technology of Heavy Metals Contaminated Soil

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Abstract: With the rapid development of industrialization and urbanization, the problem of heavy metal pollution in soil is becoming more and more serious, posing a serious threat to the ecological environment and human health. Phytoremediation technology is valued for its environmental friendliness and cost-effectiveness. In order to provide a scientific basis for the remediation of heavy metal contaminated soil and the promotion of the safe, efficient and sustainable use of heavy metal contaminated cultivated soil, We reviewed the application of plants, amendments, and plant-amendment combinations in the remediation of heavy metal contaminated soils, and The effects of different plants and amendments and their combined application on heavy metal contaminated soil were discussed.

Keywords: Heavy metals pollution, soil, phytoremediation, soil amendment, combined remediation technology.

1. Introduction

As industrialization and urbanization continue to develop, heavy metal emissions in the environment are increasing. After the discharged heavy metals are washed by rain, they spread into the water and soil with ground runoff. Due to their refractory degradation, strong accumulation and high toxicity, heavy metals in the environment are not only difficult to disappear[1], but also circulate and accumulate in the food chain of the entire ecosystem, threatening the stability of the ecosystem and the health of the population. In recent years, the environmental biological effects of heavy metals, the accumulation and migration rules of heavy metals in the ecosystem, and the environmental remediation of heavy metal pollution have received more and more attention.

Phytoremediation of heavy metal contaminated soil has the advantages of low cost, easy implementation and environmental friendliness. However, there are some limitations to phytoremediation, such as the effect of remediation is affected by factors such as ecological environment, soil type, and plant adaptability[2]. Heavy metal compound pollution is gradually aggravated in the actual environment, and the effect of a single remediation technology is limited, and it has gradually been unable to meet the needs of environmental governance. Scholars at home and abroad have begun to turn their attention to the joint remediation technology system, and put forward the idea of joint remediation of two or more technologies, which provides a new idea for the environmental remediation of heavy metal composite polluted soil. Therefore, the technology of plant-amendment combined remediation of heavy metal contaminated soil has attracted more and more attention because it is simpler and more economical, has good remediation effect and wide range of application.

2. Phytoremediation

Phytoremediation has been widely recognized and applied because of its cost-effective, environmentally friendly properties. According to the accumulation and transport mechanism of heavy metals, phytoremediation techniques can be divided into plant extraction, plant volatilization, plant fixation and plant degradation. Plant extraction is the most common phytoremediation technology, and its mechanism of action is mainly that heavy metals are absorbed by plants and transported to the aboveground part, which is also one of the few ecological and green environmental protection technologies that can directly remove heavy metals from in-situ soil. The mechanism of plant volatilization is that plants convert the heavy metals absorbed into the body into volatile forms and release them into the atmosphere through transpiration. The mechanism of plant fixation is mainly through the adsorption, accumulation and precipitation of heavy metals by plant roots, which reduces their effectiveness and bioavailability[3]. The mechanism of plant degradation is mainly through the degradation or conversion of pollutants into a stable state through plant root exudates, mainly targeting most organic pollutants and a few heavy metals.

Good tolerance of plants to heavy metals is the primary condition for achieving phytoremediation. Tolerance level mainly depends on its own detoxification and regulation ability. Therefore, it is very important to select the soil contaminated with heavy metals. Plants that can grow normally in the environment of compound pollution and show strong tolerance to heavy metal stress have potential utilization value for the remediation of heavy metal compound pollution[4-6]. Sousa et al. showed that Solanum syllabus was not only a super-accumulating plant of Cd, but also had a strong tolerance to high concentrations of Pb and Zn, and could accumulate and fix Pb and Zn within a certain range, but the tolerance mechanism was still unclear. Therefore, it is of practical significance to explore the tolerance of remediation plants in heavy metal composite polluted soil, analyze their tolerance regulation mechanism, and develop remediation plants for heavy metal compound

pollution[7]. In addition, combined with the literature research and our previous research, it was found that most of the remediation plants only had a good remediation effect on one or two heavy metals, and the remediation effect on heavy metal composite polluted sites was insufficient. A study showed that the removal rate of Cd by Canna could reach 60.37% in a single Cd contaminated environment, while the removal rate of Cd by Canna was only 23.74% in a combined Ca, Cu and Pb contaminated environment. Therefore, the development of targeted auxiliary restoration methods to maintain the efficiency of phytoremediation is also the focus of current research.

3. Soil Amendment

At present, there are many studies on combining different soil amendments for combined soil remediation. Wan et al. carried out single and interactive experiments on three amendments, lime, fly ash and biochar, in acidic rare earth tailings soil with three dosage gradients (low: 10 g/kg, medium: 25 g/kg, and high: 50 g/kg). The results showed that the combined application of different amendments could effectively increase soil pH and cation exchange, and achieve good improvement results. Tsadilas et al. [1] found that the combined application of municipal sludge and fly ash on the disturbance of acidic mine soil achieved good results and improved soil structure. Li et al. [2] used the combined cultivation method of amendment and surface plant planting to restore acid rare earth tailings, and the results showed that the soil quality was effectively improved and the growth and development of plants were promoted. Zhou et al.[4] combined lime, fly ash and biochar to remediate acidic soil, and the results showed that the combined application of amendments was more conducive to the improvement of comprehensive soil fertility than that of single application of soil improvement[8], and the combined remediation of amendments had a better effect on acidic mine soils. The application of organic matter on the basis of lime and zeolite can further increase soil pH, improve crop growth conditions, and effectively reduce soil pollutant content .

4. Plant-amendment Combined Remediation Technology

There are many limitations of a single amendment in the application of soil remediation, and this defect can be avoided by the combined repair of multiple amendments to achieve better improvement effect. Combined soil remediation technology has the advantages of low cost, high effectiveness, and enhanced phytoremediation effect [9] .Plants play an important and irreplaceable role in the process of ecological restoration. However, most of the heavy metal complex polluted sites have high heavy metal content and low nutrient content in the soil, which makes it difficult for plants to grow normally. Physical remediation methods such as the guest soil method can provide a relatively suitable substrate for plant growth, but this method is only suitable for small-scale polluted sites due to its low remediation efficiency and large investment. In contrast, amendment-assisted phytoremediation is more simple and economical. Studies have shown that amendments such as biochar, clay minerals and sludge can not only passivate soil heavy metals, but also regulate the physical and chemical properties of contaminated soil and promote plant growth. Li et al. [10] used fulvic acid, straw biochar and sepiolite to remediate Cd-polluted farmland by using amendments such as fulvic acid, straw biochar and sepiolite combined with wheat, which reduced the content of available Cd in soil by 39.86%-71.33% and significantly promoted the growth of wheat. Wang Lin et al. also showed that the phytoremediation technology of rapeseed combined with the application of chicken manure fertilizer amendment not only increased the biomass of rapeseed (127.80%), but also decreased the activity of Cd (37.0%). However, the concentration of Cd in the shoots of rape was also reduced[11], which was not conducive to plant extraction. Lebrun et al. [12] evaluated the remediation effect of biochar, fertilizer and ochre combined with filamentous sheartail of local characteristic plants on As and Hg contaminated sites, and proved that the soil physical and chemical properties were improved, the soil fertility efficiency was improved, and the plant growth state was better. However, the significant decrease in the activity of heavy metals in soil led to the decrease of heavy metal concentration in plants, which weakened the effect of plant extraction.

At present, most plant-improver combined remediation technologies mainly consider the combination of plant stabilization and amendment passivation to fix heavy metals in the soil or plant roots, but less consider the removal of heavy metals. Although plant-conditioner combined remediation technology can reduce the activity of heavy metals in soil, the removal rate of heavy metals may be reduced, which mainly depends on the relationship between plant biomass and heavy metal concentration in plants.

5. Suggestion and Prospect

We reviewed the application of plants, amendments and plant-amendment combinations in the remediation of heavy metal contaminated soils, and put forward the following suggestions for the research on the combined remediation of heavy metal contaminated soils by plants-amendments:

(1) Strengthen the research and development of different safe utilization technologies, find varieties with high stability and low accumulation of heavy metals, and establish a germplasm resource bank of varieties with low accumulation;

(2) find and cultivate more cash crops with strong resistance to heavy metals for the heavily polluted soil;

(3) Optimize soil safe utilization technology, coordinate two or more safe use methods, form a joint safe use technology system model, and improve the safe use efficiency of polluted soil.

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