Application of Nanomaterials in Repairing Heavy Metal Pollution Soil

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Abstract. Due to the acceleration of industrialization and urbanization, a series of environmental problems have arisen, among which heavy metal pollution in the soil environment is difficult to be naturally transformed into harmless substances, which has led to food security, life safety and other issues. Heavy metal contamination in soil has become one of the key issues for scholars at home and abroad. This paper mainly introduces the present situation and harm of heavy metal pollution in soil. The research status of nanomaterials in heavy metal contamination of soil was reviewed. The application of nano-materials combined with phytoremediation was discussed. The effects of nanomaterials on soil enzymes and plant enzymes were introduced. The future research directions of nanomaterials in remediation of heavy metal contaminated soils are prospected. It provides a theoretical basis for the development of practical, efficient and safe remediation technology for heavy metal contaminated soil.

1. Introduction

Nowadays, more and more attention has been paid to environmental issues, and food safety has become a particular concern through the emergence of various major diseases. The harm caused by heavy metal pollution to agricultural pollution is very representative. It accumulates through the food chain and finally enters the human body, posing a serious threat to human health. It is reported that the soil area polluted by heavy metals in China is about 20 million hm², accounting for 1/5 of the total cultivated land area. The crop loss caused by soil heavy metal pollution is over 10 million tons every year, and the grain polluted by heavy metals is about 12 million tons every year, with an annual economic loss of over 20 billion [1]. According to the survey, 16.1% of the country's soil points were above the designated limit, with 11.2% being slightly polluted, 2.3% moderately polluted and 1.1% being severely polluted [2]. Generally speaking, the south in China is more polluted than the north in terms of soil pollution. The main grain-producing areas in China, such as the Pearl River Delta, the Yangtze River Delta and the old industrial base in northeast China, have obvious soil pollution problems [2]. The average Cd concentration of rice soil in northeast Plain, southeast coastal area and Yangtze River basin was 0.19, 0.21 and 0.26 mg·kg⁻¹, respectively. The average soil Cd content of 22 rice-growing provinces in China is 0.45 mg·kg⁻¹, among which the average Cd content of rice soil in Hunan is 1.12 mg·kg⁻¹, which is the highest [3].

Soil heavy metal pollution has caused harm to the personal safety of the people, and all kinds of signs show that soil heavy metal pollution in China needs to be solved urgently. How to reduce the increasingly serious soil heavy metal pollution, and then remediation reduction utilization of the
problem has been extremely urgent. Therefore, the research and development of heavy metal contaminated soil treatment technology, improve soil environmental quality, ensure the safety of soil ecology and agricultural products and human health, is a social and economic sustainable development of China's realistic needs.

2. Application of nanomaterials in soil contaminated by heavy metals

Nearly 30 years, many scholars at home and abroad research out many management methods to control soil heavy metal pollution, including engineering measures, physical and chemical measures, biological measures and ecological measures. Each of these measures all have their own characteristics, contains many specific implementation plans. These measures applied to different types of soil pollution of heavy metals play a key role. However, these methods have some limitations, such as high cost, complex operation, poor treatment effect, secondary pollution to the environment and so on.

In recent years, nanomaterials have gradually become one of the key research directions of heavy metal soil remediation. Due to their huge specific surface area, high activity point and excellent photoelectric properties, nanomaterials have been listed as one of the eight cross fields in the field of environmental improvement by the United States nanotechnology initiative [4]. Current research of the application of nanotechnology in environmental pollution control mainly focused on the preparation of new materials and application of nano technology, the environment is the interface procedure, etc., mainly including the oxide mineral membrane and micro interface, aerosol interface reaction, all kinds of preparation of nano repair agent and its application in catalytic and degradation of pollutants, etc., in particular, mainly in the processing of organic/inorganic pollution, catalytic purification wastewater pollution gas. Their application in the repair of contaminated soil is just beginning [5]. Many scholars have begun to pay attention to the role of nanomaterials in remediation of heavy metals in soil, including nanomaterials, nanometal compounds, carboxymethyl cellulose (CMC) stable nanometal compounds, nanomaterials and composite nanomaterials.

Fajardo et al. have shown that 5% nanometer zero-valent iron (nZVI) is more effective in remediation of lead and cadmium contaminated soils. NZVI has a short reaction life and its long-term effectiveness has not been clarified [6]. Su et al. reported that the removal capacity of iron sulfide nanoparticles for cadmium was up to 85 mg·g⁻¹, which was more than twice as effective as the removal efficiency of zero-valent iron nanoparticles, and aging had no negative effect on their adsorption capacity [7]. Song et al. used nano-m WCNTS as adsorbents to repair the sediments contaminated by cadmium and phenanthrene in situ, and the results showed that nano-m WCNTS had good adsorption performance, which could significantly reduce the release of phenanthrene and cadmium in the sediments and reduce the environmental hazards brought by phenanthrene and cadmium to the overlying water [8].

3. Application of nanomaterials and plants in remediation of heavy metal contaminated soil

Phytoremediation is an environmentally friendly technology with good regional acceptability and good solutions for natural pollutants. Nano phytoremediation (the nanomaterials included in phytoremediation) is a green technology that includes nanomaterials used to adsorb pollutants, degrade nanomaterials, and plants used to accumulate degraded but still polluting substances. Compared with other phytoremediation technologies alone, the application of nanomaterials to phytoremediation has the potential to improve decontamination efficiency and regeneration rate [9].

Wang et al. showed that nano silicon in the soil contaminated by four heavy metals, cadmium, lead, copper and zinc, could promote the growth of rice, improve the yield of rice, and reduce the accumulation of heavy metals in rice, especially cadmium in grain [10]. Li studied the absorption of cadmium, by silver nanoparticles with different concentrations on lettuce, and found that the cadmium content in the root of lettuce increased significantly when the concentration was 1000 g/L [11]. Liu et al. studied the effects of nano-hydroxyapatite on rapeseed and Chinese cabbage in lead-polluted soil, and found that rapeseed had better lead toxicity resistance than Chinese cabbage, and the restoration
The effect of planting rapeseed was better than Chinese cabbage [12]. Tamez et al. studied the absorption, transport and effect of nanoscale copper in zucchini and found that the concentration of copper in the treated plants was higher than that of the control plants, and the addition of nanoscale copper did not cause adverse effects on plant growth and chlorophyll. The activity of ascorbic peroxidase in plants treated with different concentrations of copper decreased compared with the control group [13]. Lacalle et al. evaluated the remediation effect of brassica napus with organic modifier and nanometer zero-valent iron particles, and the research showed that plants significantly promoted the activity and functional diversity of soil microbial community. Nanometer zero-valent iron particles did not cause any toxicity [14]. Zhang et al. found that micro-/nano-hydroxyapatite could reduce the concentration of available heavy metals in the soil and improve the pH value of the soil. Micron hydroxyapatite increases the richness and diversity of fungal communities, but nanometer hydroxyapatite shows the opposite result [15].

4. Conclusion and prospect
At present, the remediation of heavy metal contaminated soil by nanomaterials is still in the experimental stage, and the mechanism of nanomaterials in the remediation process of heavy metal contaminated soil is not clear, so there are few practical applications in contaminated sites. Different nanomaterials will have different effects on soil environment, thus changing soil biodiversity and soil properties. In recent years, nanomaterials and nanotechnology have made important breakthroughs in remediation of heavy metal pollution, but they also bring some risks to the ecological environment and human health. Therefore, attention should be paid to the biological environmental safety of nanomaterials and nanotechnology. This paper discusses the research of nanomaterials in remediation of heavy metal contaminated soil and explores the influence of nanomaterials on heavy metals in soil. It provides a theoretical basis for the development of practical, efficient and safe remediation technology for soil contaminated by heavy metals, which is of great theoretical and practical significance for promoting the in-depth development of soil pollution control.

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