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Study on the Effect of Biochar, Bentonite and Lignite on the Remediation of Heavy Metal Contaminated Soil

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Abstract

The in-situ repair of heavy metals in contaminated soil is to change the status of the presence of heavy metals in soil by applying some active passivation repair materials to the soil, and by dissolving precipitation, ion exchange adsorption, redox, organic convergence and other reactions, reducing the effective concentration, migration and biological effectiveness of heavy metals in the soil. This method is low-cost, simple to operate, fast-acting and suitable for large-scale promotion, and plays an irreplaceable role in the restoration of heavy metal contaminated soil. This paper summarizes the effect of passivation repair of biochar, bentonite and lignite on heavy metal contaminated soil. This paper analyzes the current situation of research in this field and the main problems in this field, and in the future, we should focus on the potential environmental risk of passivation repair agent to soil-crop system and the long-term stability evaluation of the field effect of passivation material repair.

Keywords

Heavy Metal; Soil; Chemical Industry; Biochar.

1. Introduction

With the rapid progress of China's industrialization and urbanization, soil heavy metal pollution has become increasingly prominent. Chemical industry, mining, smelting and other industrial "three wastes", urban transportation, atmospheric sedimentation, livestock and poultry manure, urban sludge, pesticides and fertilizers have become major pollution sources (Brown et al., 2004). According to statistics, the area of arable land polluted by heavy metals in China is about 2.0 × 107 hm^2, accounting for about 20% of the total arable land area. It is mainly moderate to light pollution (Wei and Chen, 2001). Food and food safety problems caused by heavy metal pollution is not uncommon (Liu et al., 2006). According to the analysis of heavy metal content in soil samples from 26 cities in China in 2011, it was found that the average content of each metal exceeded the background value of the soil environment, among which lead and cadmium pollution was particularly serious, which were 41.9 and 91.4 times the background value, respectively. There is a large difference in soil heavy metal content in the regions, and the degree of pollution in provincial capitals and prefecture-level cities is also different. At present, the technologies for remediation of heavy metal contaminated soils can

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be divided into two categories: 1) The total amount of heavy metals in the soil is reduced by various means. Engineering measures and phytoremediation are the main representatives. The former includes the new soil replacement method and the physical separation method, and the latter involves plant extraction technology and plant volatilization technology. 2) By changing the existing form of metals in the soil, the mobility and bioavailability, in situ chemical passivation technology and microbial repair are its main representatives. After heavy metals enter the soil, they not only have a negative impact on the number of soil microorganisms, population structure, and soil enzyme activity, leading to a decline in soil fertility, but also interfere with the normal metabolism of the crop, causing a decline in crop yield and quality, and eventually accumulate in the human body through the food chain harm to human health (Chen et al., 2008; Teng et al., 2008). At present, the technologies for remediation of heavy metal contaminated soils can be divided into two categories: 1) The total amount of heavy metals in the soil is reduced by various means. Engineering measures and phytoremediation are the main representatives. The former includes the new soil replacement method and the physical separation method, and the latter involves plant extraction technology and plant volatilization technology. 2) By changing the existing form of metals in the soil, the mobility and bioavailability, in situ chemical passivation technology and microbial repair are its main representatives. Soil heavy metal pollution involves a large area, and generally has to go through the bottlenecks of remediation cost and remediation efficiency, and at the same time undergo the test of secondary pollution. The cost of engineering measures is high, the natural properties of the soil are destroyed, the target biomass for phytoremediation is low, the remediation period is long, and the subsequent treatment of the plant is difficult. The actual application process has been restricted to varying degrees. The in-situ passivation repair technology has lower costs and simple operation. It is effective and suitable for large-scale pollution control, and has attracted widespread attention from environmental workers. This article reviews the recent research progress on chemical passivation and remediation of soil heavy metal pollution, as well as the existing problems and suggestions from the aspects of chemical passivation and remediation materials for soil heavy metal pollution (biochar, bentonite and lignite), passivation mechanism, and repair effects. It is helpful to carry out the remediation of soil heavy metal pollution.

2. Repair Material

The bioavailability of soil heavy metals is closely related to its various existing forms. The amount of heavy metals absorbed by plants depends on the effective amount in the soil, not the total amount. In-situ chemical passivation repair (Guo et al., 2006) is to add one or more substances to heavy metal contaminated soil and change the chemical form of heavy metals in the soil through a series of reactions such as adsorption, precipitation, ion exchange, and redox Existing state, reducing its mobility and bioavailability in soil, thereby reducing the toxicity of heavy metals to soil organisms and migration accumulation in agricultural products. At present, the passivation repair agents for soils polluted by heavy metals mainly include silicon-calcium substances, phosphorus-containing materials, organic materials, clay minerals, metal oxides, biochar and new materials, etc., their properties and structures, selection of target heavy metal elements, and passivation mechanism is different. This article mainly introduces the role of biochar, bentonite and lignite in remediation of heavy metal pollution.

2.1. Biochar

Biochar refers to a type of carbon-containing, stable, highly aromatic solid matter obtained by pyrolysis of biomass under anoxic or anaerobic conditions. Agricultural waste such as straw, wood and urban domestic organic waste such as garbage and sludge are It is an important raw material for preparing biochar. Biochar has a large porosity, specific surface area, a large

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amount of negative charges and a high charge density on the surface, and can absorb a large number of exchangeable cations. It is a good adsorption material, and it is also rich in soil nutrients N, P, K, Ca, Mg and trace elements can not only repair and treat cadmium-contaminated soil, but also increase soil organic matter, soil fertility, and increase crop yield after being applied to farmland (Guo et al., 2013). Biochar has effects on the form, migration and bioavailability of heavy metals in contaminated soil. Studies (Jiang et al., 2012) found that the application of rice straw biochar reduced soil acid-extractable Cu, Pb, and Cd by 19.7%, 18.8%, and 5.6%, respectively.

2.2. Bentonite

Bentonite is a clay rock with Montmorillonite as the main mineral. The chemical structural formula is (MgCa) O · Al_2O_3 · $5SiO_2$ · H_2O. The structural unit of bentonite is composed of Si—O tetrahedron and Al—O_4 $(OH)_2$ octahedron (Hamidpour et al., 2010; Sun et al., 2015). It has a large specific surface area, cation exchange capacity and adsorption performance, is widely used in heavy metal polluted water body repair practice. The study found that the addition of bentonite can effectively alleviate the toxic effect of Cd stress on crop seedlings, and the resistance to stress has been improved to a certain extent (Shi et al., 2012; Guo et al., 2017). And it has a good repair effect (Sun et al., 2015).

2.3. Lignite

Lignite is a type of China's abundant natural humic acid-rich substances, which has an adsorption effect on a variety of heavy metal ions (Ding et al., 2017). Because humic acid contains functional groups such as phenolic hydroxyl, carboxyl, methoxy, and quinone groups, it has properties such as ion exchange, complexation or chelation, adsorption, and redox properties, which can make heavy metal ions complex or chelate. Combined fixation or adsorption fixation can reduce the bioavailability of heavy metal ions and reduce plant uptake (Zou, 2007). Xiao (2017) studied the effects of humic acid on the form of heavy metal lead and rapeseed antioxidant enzyme activity in Pb-contaminated soil. It was found that humic acid could reduce the content of weakly acid-extracted and reducible Pb in Pb-contaminated soil, which could reduce the contents of oxidized Pb and residue Pb increased, and with the increase of the amount of humic acid, the Pb in the soil changed more obviously.

3. Passivation Mechanism

3.1. Biochar

Biochar can increase soil active adsorption sites, with a large amount of negative charges and large cation substitution on the surface, which can generate electrostatic interactions with heavy metal ions, increase soil's ability to adsorb heavy metal ions, and affect the migration and transformation of heavy metals in the soil (Ma et al., 2017). At the same time, because there are more oxygen-containing functional groups on the surface of biochar (such as carboxyl and hydroxyl groups), heavy metal ions easily form metal complexes with these functional groups, so that the exchangeable heavy metal ions in the soil are converted into stable residues.

3.2. Bentonite

The main component of bentonite is montmorillonite. Its crystal structure is similar to that of montmorillonite. It is a layered silicate mineral composed of two silicon-oxygen tetrahedrons and one aluminum-oxygen octahedron. Adsorption of heavy metals mainly through ion exchange (Xie et al., 2018). At the same time, bentonite has a large specific surface area and cation exchange capacity, which makes it have strong adsorption performance, increase soil adsorption capacity of heavy metal ions, and increase soil heavy metal residue content.

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3.3. Lignite

Lignite is an organic passivation agent. It is rich in humic acid. Humic acid contains active groups such as carboxyl, hydroxyl, carbonyl, and methoxy groups. It has excellent adsorption performance. At the same time, lignite has a high oxygen content. These oxygen are mainly It is present in the carboxyl and hydroxyl groups and is the active site of ion exchange (Lafferty et al., 1990; Murakami et al., 2001). Therefore, humic acid can adsorb and chelate with heavy metal ions, increase the adsorption and chelation of heavy metals in the soil, thereby reducing the exchangeable content of heavy metals, increasing the content of residues, and inactivating heavy metals in the soil.

4. Prospects of Passivation Repair Technology for Heavy Metal Pollution

4.1. Influence of Passivating Agent on Soil-crop System

In order to ensure the repair effect, the amount of repairing agent is generally much higher than the amount of soil modifier (such as fertilizer). Therefore, the passivation repairing agent has various effects on soil texture, aggregates, physical and chemical properties, respiratory strength, enzyme activity and microbial community structure. The potential impact of the existence of properties must be considered; in addition, for the use of certain industrial wastes as passivating agents, such as red mud, fly ash, municipal solid waste, etc., may themselves contain a certain amount of harmful ingredients, excessive application will These harmful elements are brought into the soil and cause secondary pollution. Excessive application of chemical substances will also cause obvious changes in soil physical and chemical properties, which in turn affects soil biological activity and the supply of nutrients required by crops.

4.2. Repair Effect Stability

Passivation repair only changed the occurrence form of heavy metals in the soil, and the total amount did not change. At present, the evaluation of remediation effects mainly depends on short-term effect indicators such as changes in soil heavy metal morphology and crop heavy metal absorption during the crop growth period, but changes in soil pH, Eh, and organic matter will cause re-release of fixed metals. In addition, the long-term stability of the passivating agent in the field soil is a key factor affecting the remediation effect of contaminated soil. The geochemical transformation of the passivating agent in the soil will lead to the reactivation of heavy metals and the increase of crop absorption. Therefore, a large number of long-term field positioning tests are needed to evaluate the stability of the repair effect.

4.3. Multiple Repair Techniques

Strengthen the combined use of chemical restoration, plant extraction, and agronomic measures, and give full play to their respective strengths to achieve the ideal restoration effect of heavy metal contaminated soil. For example, you can take the passivation repair after plant extraction, or use the auxiliary repair technology mainly based on passivation repair and plant intercropping, or you can carry out various auxiliary repairs by combining low-accumulation crop varieties with passivation repair technology. To minimize the accumulation of soil heavy metals in crops.

4.4. Evaluation System of Restoration Effect

In China, when evaluating the effect of contaminated soil remediation, the increase or decrease of the total amount of pollutants is still the main evaluation index (Xu, 2007), such as the plant extraction technology widely used in heavy metal contaminated soil remediation. In situ chemical passivation repair technology has attracted much attention in recent years due to its quick results, simple operation, and suitability for large-scale promotion. However, chemical passivation repair only changed the morphology of soil heavy metals, and the total amount did

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not change. Therefore, the evaluation system with the goal of reducing the total amount is obviously inappropriate, and a quantitative evaluation technology system such as soil passivation repair technology evaluation methods should be studied and established.

4.5. Field Repair

There are few examples of on-site remediation of heavy metal contaminated soil in China. During the rapid progress of industrialization, contaminated farmland in industrial and mining areas, sewage irrigation areas and suburbs of large and medium cities urgently need to be repaired. The research results of the laboratory should be applied to the field restoration of heavy metal contaminated farmland in time, and its repair effect, economic benefits, and Adjust research directions and priorities.

5. Summary

In general, the implementation of a successful heavy metal contaminated soil remediation process must first prevent heavy metal pollutants from continuing to enter the soil and achieve source control; second, understand the bioavailability of heavy metal pollutants in farmland, and then carry out heavy metal environmental risks Evaluate and formulate corresponding passivation repair strategies. The formulation of remediation measures is based on two factors: one is the cost of remediation, which is an economic feasibility assessment; the other is the remediation effect and its stability, which is the long-term localization monitoring of the remediation effect of heavy metal pollution, including soil heavy metal morphology and soil biological activity. , The dynamic changes of crop growth and soil environmental quality, and at the same time consider whether it is necessary to continue to apply passivation agents in order to achieve long-term sustainable and safe use of the soil contaminated by heavy metals after repair.

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