Remediation Effect of Biochar on Heavy Metal Contaminated Soil

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Abstract. The remediation effect of biochar on Cu, Cd, Pb and Hg compound contaminated soil was studied by adding different concentrations (0%, 5%, 10%) of pig manure carbon and fruit charcoal into the soil contaminated by tailings by biochar and plant pot experiment. The results showed that the addition of biochar could effectively reduce the content of heavy metals in soil, and the effect of fruit charcoal was significantly better than that of pig manure charcoal, and when the addition of fruit charcoal was 10%, the remediation effect of copper, cadmium, lead and mercury compound contaminated soil was the best.

Keywords: Compound heavy metal pollution, Biochar, Remediation of soil.

1. Introduction

Soil is a kind of limited and non-renewable natural resources, which directly or indirectly affects the living environment and life health of human beings, animals and plants. However, with the deepening of industrialization and urbanization, soil pollution problems of varying degrees have appeared in China and even in the world, among which soil heavy metal pollution is particularly prominent [1]. Natural phenomena such as volcanic eruption are the natural sources of soil heavy metal pollution, but human factors such as metallurgy and chemical industry, mineral exploitation, abuse of pesticide and chemical fertilizer are the main causes of soil heavy metal pollution. According to incomplete statistics, 16% of soil and 19% of agricultural soil in China have heavy metal pollution problems in up to 24 provinces (cities), and the pollution situation is increasingly intensified, and the pollution scope is gradually expanded [2]. Heavy metal pollutants in the soil have the characteristics of low migration rate, strong enrichment effect, and not easy to be degraded by microorganisms, and can pollute water resources and plants and other media, and then damage human health, which runs counter to the concept of "sustainable development". Therefore, the remediation of heavy metal contaminated land is
not only a hot spot of soil science research, but also an important mission and urgent task for researchers.

At present, the remediation methods of heavy metal contaminated soil mainly include physical remediation methods, chemical remediation methods and bioremediation methods, whose essence is to remove and immobilization of heavy metals in soil, effectively reducing their bioavailability. Before a large number of studies have shown that the traditional method, heat treatment method, the physical, chemical, such as chemical modifier to repair method has some effect in soil heavy metal pollution repair [3-4], but the comprehensive stability of the administrative cost, convenient practice feasibility, effectiveness, and the existence of secondary pollution in the process of governance, in compliance with local plant habit, found that there were certain limitations, cannot meet the needs of large-scale popularization and application. Therefore, in order to further explore the sustainable remediation and treatment scheme of heavy metal contaminated soil, biochar was selected in this paper to study its remediation effect on heavy metal contaminated soil, in order to provide reference for remediation and treatment of heavy metal contaminated soil.

2. Materials and methods

2.1. Experimental materials

The test fruit charcoal is fired from apple trees and purchased from Shaanxi Yixin Bio-energy Technology Development Co., Ltd., pH is 9.81. The tested pig manure carbon was purchased from Qingdao Beerka Co., Ltd., pH = 10.22. The tested soil is farmland topsoil in Tong guan gold my area. The potted plant was large-leaf spinach, and the organic fertilizer was purchased from Yang ling. Inductively Coupled Plasma Mass Spectrometer, Multi-element Mixed Standard Solution, Multi-element Mixed Internal Standard Solution and Mixed Tuning Solution were purchased from Agilent Technologies Ltd.

2.2. Experimental design

In this study, the pot experiment method was adopted, and 250 mm ×200 mm (upper diameter × height) plastic flower pot was selected, and the bottom of the pot was covered with net gauze. The heavy metal contaminated soil was removed from rocks, weeds and plant roots, and then screened through a 5 mm sieve for use. The sifted surface layer soil, tailings, organic fertilizer and biochar were mixed in a set proportion (the mass ratio of surface layer soil, tailings and organic fertilizer in the mining area was 2:1:0.01) and then loaded into the pot. The height of the soil was about 4-6 cm from the top of the pot. Each pot keeps a total weight of 2.5kg and compacts naturally. Sow the same number of seeds in the same plant, thin the seedlings one week after the emergence, and keep the same number of healthy seedlings in each pot. Different concentrations (0%, 5%, 10%) of pig manure carbon and fruit charcoal was added respectively, and each treatment was repeated for 3 times.

2.3. Determination of heavy metal content in soil

After harvest, small soil drills with a diameter of 2 cm were used to take disturbed soil samples in each basin, 4 of which were taken from each basin. After mixing, the disturbed soil samples were dried and ground, and tested through a 0.149mm sieve. The content of heavy metals in soil was determined according to "Determination of 12 Metal Elements in Soil and Sediments -- Extraction of Aqua regia-Inductively Coupled Plasma Mass Spectrometry HJ 803-2016".

2.4. Data processing

The data of this experiment were processed by SPSS 19.0 software, and the t-test and multi-factor analysis of variance were selected for statistical analysis.
3. Results

3.1. Heavy metal pollution of the tested soil

The content determination results of chromium, nickel, copper, zinc, cadmium, lead, arsenic and mercury in the tested soil are shown in Table 1.

| Mental | Estimated value (mg/kg) | Risk screening value (mg/kg) | t      | P     |
|--------|------------------------|----------------------------|--------|-------|
| Cr     | 39.8                   | 250                        | -3376  | P<0.01|
| Ni     | 22.6                   | 190                        | -290   | P<0.01|
| Cu     | 146                    | 100                        | 81.4   | P<0.01|
| Zn     | 167                    | 300                        | -232   | P<0.01|
| Cd     | 1.10                   | 0.6                        | 86.6   | P<0.01|
| Pb     | 582                    | 170                        | 715    | P<0.01|
| As     | 7.93                   | 25                         | -2956  | P<0.01|
| Hg     | 2.87                   | 1.0                        | 325    | P<0.01|

Comparison of the tested soil chromium, nickel, copper, zinc, cadmium, lead, arsenic, mercury, and the soil environmental quality of farmland soil pollution risk control standard GB 15618-2018 "provisions of the farmland soil pollution risk screening value[5], found that the test of copper, cadmium, lead, mercury content in soil were higher than risk screening value, and chromium, nickel, zinc, arsenic levels are lower than risk screening value, and the data statistically significant difference (P < 0.01), indicating that the selected copper and cadmium lead mercury compound soil pollution. This result is consistent with the existing studies on the pollution types of gold mining area in Tongguan, Shaanxi Province [6-7].

3.2. Effects of different plants and biochar on remediation of heavy metal contaminated soil

A pot experiment was conducted to study the remediation of Cu, Cd, Pb and Hg compound contaminated soil with different plant types and biochar addition levels.

3.2.1. Effects of different biochar on soil copper content. The copper content of potted soil without adding biochar ranged from 155 mg/kg to 198 mg/kg, with an average value of 179 mg/kg. The content of copper in potted soil of 5% fruit charcoal was (148-182 mg/kg), with an average value of 167 mg/kg. The content of copper in potted soil of 10% fruit charcoal was (136 ~ 152 mg/kg), with an average value of 144 mg/kg. The copper content of potted soil with 5% pig manure carbon was (152 ~ 171 mg/kg), and the average value was 165 mg/kg. The content of copper in potted soil of 10% of pig manure carbon was (159 ~ 180 mg/kg), with an average of 168 mg/kg.

3.2.2. Effects of different biochar on soil cadmium content. The cadmium content of potted soil without biochar was in the range of (1.04 ~ 1.25 mg/kg), with an average of 1.17 mg/kg. Cd content in potted soil with 5% fruit charcoal content ranged from 0.96-1.33 mg/kg, with an average value of 1.18 mg/kg. Cd content in potted soil with 10% fruit charcoal content ranged from 0.92 mg/kg to 1.08 mg/kg, with an average value of 1.01 mg/kg. Cd content in potted soil with 5% pig manure carbon content ranged from 0.98 to 1.25 mg/kg, with an average of 1.08 mg/kg. Cd content in potted soil with 10% pig manure carbon content ranged from 1.06 mg/kg to 1.21 mg/kg, with an average of 1.15 mg/kg.
3.2.3. Effects of different biochar on soil lead content. The content of lead in potted soil without biochar was in the range of (638 ~ 773 mg/kg), with an average of 709 mg/kg. The content of Pb in potted soil with fruit charcoal content of 5% ranged from 617 mg/kg to 767 mg/kg, with an average of 679 mg/kg. The content of lead in potted soil with fruit charcoal content of 10% ranged from 527 mg/kg to 633 mg/kg, with an average of 589 mg/kg. The content of Pb in potted soil with 5% pig manure carbon was (654 ~ 685 mg/kg), with an average of 672 mg/kg. The lead content of potted soil with 10% pig manure carbon content was (636 ~ 655 mg/kg), with an average of 648 mg/kg.

3.2.4. Effects of different biochar on soil mercury content. The influence of biochar on soil mercury content was analyzed. The mercury content of potted soil without biochar was in the range of (6.72 ~ 7.04 mg/kg), with an average value of 6.89 mg/kg. Cd content in potted soil with 5% fruit charcoal content ranged from 6.58 mg/kg to 7.47 mg/kg, with an average value of 6.95 mg/kg. Cd content in potted soil with 10% fruit charcoal content ranged from 5.91 mg/kg to 6.80 mg/kg, with an average of 6.41 mg/kg. Cd content in potted soil with 5% pig manure carbon content ranged from 6.81 mg/kg to 7.23 mg/kg, with an average of 7.00 mg/kg. Cd content in potted soil with 10% pig manure carbon content ranged from 6.27 to 7.83 mg/kg, with an average of 6.94 mg/kg. Further statistical analysis of the data (Tab. 3 and 4) showed that the mercury content of potted soil with 10% fruit charcoal was significantly lower than that of potted soil without biochar.

4. Conclusions

The comprehensive analysis of the above data showed that the addition of biochar could effectively reduce the content of heavy metals in soil, and the effect of fruit charcoal was significantly better than that of pig manure charcoal. When the addition amount of fruit charcoal was 10%, the remediation effect of copper, cadmium, lead and mercury compound contaminated soil was the best.

A large number of studies have shown that biochar plays a positive role in the treatment of heavy metal pollution in soil or water [8-10], and its mechanism is closely related to the physicochemical properties of biochar. Biochar is produced by pyrolysis of biomass rich in carbon under low temperature and anaerobic conditions. Generally alkaline, it can significantly increase soil pH, promote the formation of heavy metal ions in the soil to form metal hydroxide, carbonate or phosphate and precipitate, and effectively fix heavy metals, thus reducing bioavailability. Biochar has fluffy texture, high porosity of internal structure and large specific surface area, and can absorb a large number of metal ions. Studies have shown that biochar is mainly reversible and non-physical adsorption of heavy metals. At the same time, the surface of biochar has a large number of negative charges and is rich in oxygen-containing functional groups, which has a high cation exchange capacity. Metal ions can form complexes with functional groups located on the surface, which has a positive significance for the fixation of metal ions. The physical and chemical properties of biochar prepared from different sources and pyrolysis temperatures are different, and the adsorption and curing effects of heavy metals are also different. According to different sources, biochar can be divided into several types: straw, shell, wood, feces, sludge and other types. The results show that the carbon content of wood carbon, straw carbon, shell carbon, feces and sludge carbon decreases successively. The average pH value of biochar is 9.15, and the median pH value of straw carbon, sludge carbon, feces carbon, wood carbon and shell carbon decreases successively. Shells charcoal, charcoal, wood charcoal of straw, waste and sludge carbon of specific surface area decreases, and in turn the woodiness carbon surface between (0.28 ~ 391.12 m²/g), pig carbon in surface area (5.72 ~ 166.9 m²/g), between the same condition, the greater the specific surface area of biochar, the surface of the negatively charged and functional groups, the adsorption of metal ions, fixed effect better, this has to do with this study the repairing effect of fruit of charcoal was superior to that of pig carbon is consistent. However, no consensus has been reached on the adsorption and fixation effects of biochar from animal and plant sources on heavy metals. Therefore, the structure and physical and chemical properties of the two kinds of biochar should be further studied in the follow-up research, and the mechanism of biochar
remediation of heavy metal contaminated soil should be explored based on the morphology of heavy metals.

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