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Study on the effect of modified porous materials on heavy metal remediation in agricultural fields

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Abstract: With the rapid development of modern agriculture, the problem of heavy metal pollution and degradation of soil quality in agricultural soils has become increasingly serious, and the search for efficient, economical and environment-friendly heavy metal passivation materials has become a research hotspot for the solidification and stabilization of heavy metals in agricultural soils. In this paper, we summarize the remediation effect of porous materials on soil heavy metal pollution in view of existing studies, and analyze the changes of porous material properties and the influence on heavy metal remediation ability after modification and aging. Finally, the performance improvement of porous materials and their industrial application in the field of heavy metal pollution remediation are prospected.

Keywords: Porous materials; Heavy metals; Modification; Rehabilitation.

1. Introduction

The construction of high standard farmland is a key initiative to consolidate and improve food production capacity and guarantee national food security. According to statistics, about 0% of arable land in China is facing different degrees of lead (Pb) and cadmium contamination, which is difficult to biodegrade, and the addition of passivation agents to reduce their biological effectiveness is a more effective means of prevention and control at present. Modified porous materials (biochar) have become a research hotspot for soil heavy metal remediation because of their large specific surface area and high stability of porosity, and their strong adsorption capacity for heavy metals. To investigate the application and "aging effect" of modified porous materials on the remediation of heavy metal pollution in agricultural fields, to blunt the long-term stability of Pb in soils with different degrees of contamination, to investigate the impact on the biological effectiveness of typical crops and ecological risks, and to develop a more "green" and economical modified material for the remediation of heavy metal pollution in agricultural soils. The research and development of more "green" and economical modified materials and application technologies for the remediation of heavy metal pollution in agricultural soils will provide useful references for the prevention and control of heavy metal pollution in soil in the construction of high standard farmland.

2. Remediation of heavy metal pollution by porous materials

2.1. Direct remediation of heavy metals by porous materials

Porous materials can take advantage of their physicochemical properties such as high cation exchange capacity, high specific surface area and rich in a variety of active functional groups for direct adsorption of heavy metal pollutants through physical adsorption, electrostatic adsorption, ion exchange, cation-π bonding, redox, co-precipitation and complexation. Among them, porous materials can adsorb heavy metals to the surface and pores by physical van der Waals forces, hydrogen bonding and other forces, and adsorb the free heavy metal ions in the soil to the surface of porous materials to immobilize heavy metals. The ion exchange effect is an important mechanism of heavy metal passivation, which mainly includes the acidic functional groups (hydroxyl, carboxyl, etc.) on the surface of porous materials can provide H+, Ca2+, K+, Mg2+, and Na+ can exchange ions with heavy metal ions to achieve the purpose of heavy metal adsorption. Redox mechanism is that porous materials use their own functional groups to reduce the biological toxicity of heavy metals effectively by changing the chemical valence state of the variable heavy metals (Cr (VI), As (III), etc.), and the usually more toxic Cr (VI) and As (III) are oxidized and reduced to Cr (III) and As (V). Complexation is the surface of porous materials rich in oxygen-containing functional groups (carboxyl groups, hydroxyl groups, etc.) can provide heavy metal binding sites to form stable complexes, thus immobilizing heavy metals.

2.2. Indirect remediation of heavy metals by porous materials

The application of porous materials to soil affects the physicochemical properties (pH, CEC, mineral composition, etc.) of the soil, thus indirectly influencing changes in the fugitive morphology of heavy metals in the soil in order to reduce the biological effectiveness of heavy metals and their migration capacity. Among them, soil pH is an important influence on heavy metal sorption, and soil pH increases with the amounts of porous materials, thus increasing the complexation of heavy metal ions, weakening the ability of H+ to compete for heavy metal ions, and enabling the transformation of soil heavy metal morphology from unstable to oxidizable and residual migration. The CEC in the soil is increased by the application of porous materials, which possess a large number of cation exchange sites on their surface, making the biological effectiveness and migration of heavy metals weaker. The porous material contains a large number of mineral components, and the porous material applied to the soil will release minerals and form a mineral phase in its soil to immobilize heavy metals. Liang et al showed that the application of porous material will increase the concentration of phosphorus in the soil, which makes it form a mineral phase with heavy metal Pb to stabilize and immobilize in the soil, reducing the migration transformation of heavy metals.

3. Effect of porous material modification on heavy metal passivation

To improve the performance of porous materials for heavy metal remediation, researchers at home and abroad have modified different types of porous materials using magnetic modification, mineral modification, acid/base modification, and oxidant modification to optimize their specific surface area, pore structure, or surface functional groups in a targeted manner, and have conducted numerous studies on heavy metal remediation [6-7]. Ding et al used KOH to modify straw porous materials, and the specific surface area of porous materials increased by about 70%, and the maximum adsorption of Pb2+ increased by 2.6 times, respectively. The pore structure of the porous material was found to be greatly improved and the adsorption of Cr6+ was increased by 15.2 mg/g. Cui Zhiwen et al. applied a composite modified wheat straw porous material with KOH and FeCl3, and its adsorption performance of cadmium in water was improved by 27% compared with the single modification of KOH ... modified porous materials are good heavy metal passivators and have been widely used in the field of wastewater treatment, but the research and in situ remediation of agricultural soils The effect of porous materials on the remediation of heavy metals varies depending on the nature of raw materials, preparation conditions, application amount, etc. Especially, the mechanism and long-term stability of the effect of modification on soil physicochemical properties and passivation of heavy metals Pb and Cd after combining various methods for different porous materials are yet to be studied in depth.

4. Effect of material aging on its effectiveness in remediation of heavy metals

Porous materials applied to agricultural soils can promote soil water and fertilizer retention and reduce their biological effectiveness by their own complexation, chelation, and electrostatic adsorption in order to induce precipitation of heavy metal ions as new city hydroxides, phosphates, or carbonates. Mao Xinyu et al used HNO3-K2MnO4 modified porous materials to passivate soil Pb and found that ion exchange, complexation and co-precipitation reactions together contributed to the conversion of the active state of soil Pb to its potentially activated and residual states, and the degree of conversion was positively correlated with the amount of modified porous materials and the "aging effect". External studies on Pb remediation by passivation of modified porous materials have shown that the morphological distribution of soil Pb varies regularly over time and that the passivated heavy metals may be re-released into the soil environment with time and under the influence of changes in the physical and chemical properties of the soil under external environmental and agricultural production management, causing secondary pollution. In contrast, most of the existing passivation studies focus on the passivation effect in the shorter term (within 12 weeks/30 d) and do not reflect the long-term chemical behavior of Pb in the agricultural soil and water environment. Therefore, the long-term passivation effect of modified porous materials on soil heavy metals needs to be urgently investigated.

It has been shown that aging may reduce the stability of porous materials in the environment, leading to degradation, which may release endogenous contaminants and a range of components or exhibit high biotoxicity to certain microorganisms or plants, and that as porous materials continue to "age" soil physicochemical properties may change and affect heavy metal activity. The study has also shown that the aging process leads to the formation of a new soil. It has also been shown that the increased oxidation of porous materials due to aging enhances the interaction between functional groups on the surface of porous materials and contaminants, thus reducing the environmental risk of contaminants. Therefore, the long-term stabilization effect of porous materials on the solidification and passivation effectiveness of soil heavy metals also needs further attention.

5. Conclusion

Modified porous materials are good heavy metal passivators, but for different porous material materials, combined with a variety of methods for modification, information related to changes in adsorption properties of porous materials is to be added, and their effects on soil physicochemical properties and long-term passivation effects of heavy metals lead (Pb) and cadmium (Cd) are yet to be studied.

Optimizing the performance of modified porous materials, compounding organic fertilizers with materials such as porous materials with adsorption properties into composite porous materials in proportion, and applying them rationally will have good effects on the remediation of heavy metal pollution in agricultural soils, and also reduce the use of chemical fertilizers.

The method of porous material modification should be simple and practical in order to reduce the production cost and promote industrialization. Combining porous material technology with nanotechnology can produce new materials with stronger environmental applications, which can not only improve the use of biomass energy and increase its economic value, but also avoid the pollution hazards caused by chemical modification. At present, the research about the application of ball milling modification technology in the modification of porous materials is still in the initial stage, and in the follow-up research, the adsorption performance of porous materials can be improved by perfecting the preparation process, which is of great significance for the future large-scale application of porous materials in environmental pollution remediation.

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References

[1] Ji W G, Wang K, Meng J B, et al. Distribution characteristics and risk assessment of soil heavy metal pollution in China[J]. Agricultural Research and Application, 2020,33(5):22-28.

[2] Gholizadeh M, Hu X. Removal of heavy metals from soil with biochar composite: a critical review of the mechanism[J]. Journal of Environmental Chemical Engineering, 2021, 9(5): 105830.

[3] Cui X Q, Hao H L, Zhang C K, et al. Capacity and mechanisms of ammonium and cadmium sorption on different wetland-plant derived biochar [J]. Science of the Total Environment, 2016,539:566-575.

[4] Tang X J, Shen H R, Chen M, et al. Achieving the safe use of Cd- and As-contaminated agricultural land with an Fe-based biochar: A field study[J]. Science of the Total Environment, 2020, 706: 135898.

[5] Liang Y, Cao X D, Zhao L, et al. Biochar- and phosphate-induced immobilization of heavy metals in contaminated soil and water: implication on simultaneous remediation of contaminated soil and groundwater[J]. Environmental science and pollution research international, 2014,21(6): 4665-4674.

[6] Wang L W, Yong S O, Daniel C W, et al. New trends in biochar pyrolysis and modification strategies: feedstock, pyrolysis conditions, sustainability concerns and implications for soil amendment[J]. Soil Use and Management,2022,36(3):358-386.

[7] Ji H Y, Wang Y Y, Liu Y X, et al. Advance in preparation and application of biochar and modifiedbiochar research[J]. Journal of Nuclear Agricultural Sciences,2018,32(11):2281-2287.

[8] Ding Z, Hu X, Wan Y, et al. Removal of lead, copper, cadmium, zinc, and nickel from aqueous solutions by alkali-modified biochar: Batch and column tests [J]. Journal of Industrial & Engineering Chemistry, 2016,33:239-245.

[9] Cui Y F, Ren Y F, Wang W, et al. Adsorption characteristics and mechanism of cadmium in water by alkali and magnetic composite modified wheat straw biochar [J]. Environmental Science, 2020,41(07):3315-3325.

[10] Zhong X, Chen Z W, Li Y Y, et al. Factors influencing heavy metal availability and risk assessment of soils at typical metal mines in Eastern China [J]. Journal of Hazardous Materials, 2020,400:123289.

[11] Sun D Z, Li F Y, Jin J W, et al. Qualitative and quantitative investigation on adsorption mechanisms of Cd(II) on modified biochar derived from co-pyrolysis of straw and sodium phytate [J]. Science of The Total Environment, 2022, 829: 154599.

[12] Mao X Y, Zhai S M, Jiang X S, et al. Effects and mechanisms of different modified biochar on influencing physio-chemical properties and immobilization of Pb and Cd in farmland soil [J]. Environmental Engineering, 2022:1-14. http://kns.cnki.net/kcms/detail/11.2097.X.20220803.2033.020.html

[13] Jia M Y, Yu J P, Li Z, et al. Effects of biochar on the migration and transformation of metal species in a highly acid soil contaminated with multiple metals and leached with solutions of different pH[J]. Chemosphere,2021,278:130344.

[14] Xing J, Xu G R, Li G B. Comparison of pyrolysis process, various fractions and potential soil applications between sewage sludge-based biochar and lignocellulose-based biochar [J]. Ecotoxicology and Environmental Safety, 2021, 208: 111756.

[15] Javed M B, Kachanoski G, Siddique T. A modified sequential extraction method for arsenic fractionation in sediments[J]. Analytica Chimica Acta, 2013, 787:102-110

[16] Xing Y H, Luo X S, Liu S, et al. A novel eco-friendly recycling of food waste for preparing biofilm-attached biochar to remove Cd and Pb in wastewater [J]. Journal of Cleaner Production, 2021,311:127514.