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Research Article

Quality Improvement in Vegetable Greenhouse by Cadmium Pollution Remediation

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Greenhouse vegetable production (GVP) has grown in importance as a source of public vegetable consumption as well as income for farmers. Due to the high cropping index, substantial agricultural input, and confined environment, numerous contaminants can accumulate in GVP. Polluted soil is treated with metal cadmium pollution remediation technology in order to improve the quality of vegetable greenhouse soil and increase crop yields. The heavy metal cadmium-contaminated soil in vegetable greenhouses is rectified utilizing three methods: chemical remediation, bioremediation, and physical remediation. Soil restoration with broom sedge planting might result in a 9.78 percent reduction in cadmium pollution. Planting broom sedge has a root > stem > leaf effect on pollution remediation. The elimination of cadmium from the soil around the anode can be as high as 75.1 percent. The clearance rate of the soil near the anode was 75.1 percent and 77.9 percent, respectively, when the anode cadmium mass fraction dropped fast. Hence this paper focuses on the reduction of cadmium pollution to improve the quality of GVP crop to yield more benefit. Chemical leaching is faster, more efficient, and less dangerous, with a higher application value. The approach of bioremediation is of low cost and creates no secondary contaminants. Physical electrodynamics is easy to understand and has a distinct effect.

1. Introduction

Greenhouse vegetable production (GVP) is a method of agricultural production that uses a lot of energy. As a link between the inorganic and organic boundaries, soil plays an important role in protecting the environment and maintaining ecological balance [1]. Heavy metal cadmium has infiltrated the soil through numerous means in recent years, causing contamination, due to the emission of three wastes, incorrect agricultural product usage, and sewage irrigation. Cadmium (Cd) is a nonessential natural component found in plants and in the ecosystem. Cadmium is a hazardous heavy metal contaminant found in soil. It may be found in the environment, meta sediments, and soils naturally. Cadmium contamination is one of the most prevalent types of heavy metal pollution in farming, and it causes the greatest amount of damage. The major natural causes of Cd contamination include geological weathering of rocks and human sources such as pesticide application or soil pollution from the disposal or reuse of industrial or municipal wastes [2].

Human activity such as urban waste disposal, mining, metal manufacture, and the use of artificial phosphate fertilizer increases Cd risks to the ecosystem and is hazardous to human health. In recent decades, the frequent pollution accidents caused by heavy metal cadmium have brought much harm to human beings. Cd is a very hazardous, soil-persistent, main heavy metal pollutant [3], which is relatively easily absorbed by plant roots, contaminating the food chain and resulting in bioaccumulation in the human body, causing hazardous consequences [4]. There are a number of parameters that might influence Cd absorption by plants, with pH being one of the most important. The adsorptive capacity of soils for Cd triples with each pH unit rise in the range [4–7]. Related research shows that waste water with cadmium discharges into the paddy and makes the rice dead and accumulates in the liver and kidneys through the food chain, causing acute or chronic poisoning. This makes people pay great attention to the problem of heavy metal pollution in farmland soil, and the problem of soil safety and soil management cannot be ignored [5].

Cd absorption from the soil and distribution among shoots and roots is a carefully controlled process involving a number of critical players: root cell plasma membrane metal transporters, xylem and phloem loading/unloading, and leaf/shoot sequestration and detoxifying [6]. Cadmium must pass the cell membrane to reach the root cells (symplast), which is made easier by the existence of several outlets and metal exchangers. Conventional heavy metal cleanup approaches, such as physical and chemical procedures, are being employed; however, they are ecologically damaging, costly, and difficult to apply. Numerous studies on heavy metal bioremediation employing biological material such as live plants or microorganisms from contaminated soil and water have been published. Phytoremediation, a rapidly advancing technique, is an environmentally benign, low-tech, premium, and green solution to these problems [7]. Cadmium causes water shortages, ionic imbalances, discoloration, necrosis, and eventually cell mortality, genotoxicity, and yield decrease in plants. Cadmium may enter and persist in crops through the soil and then pass through the food chain and impact the human body. It damages the liver, kidneys, and bones of the human body. As a result, the objective of this research paper was to minimize heavy metal cadmium contamination in vegetable greenhouse soil by chemical remediation, bioremediation, and physical remediation.

The rest of the paper is organized as follows: in Section 2 a detailed study of vegetable greenhouse cadmium pollution of chemical remediation technology, physical remediation technology, and bioremediation technology is elaborated. In Section 3, the detailed analysis and discussion of the experiment carried out on samples of plant using chemical remediation technology, physical remediation technology and bioremediation technology are presented. In Section 4, conclusions are presented followed by references.

2. Material and Method

2.1. Vegetable Greenhouse Cadmium Pollution Chemical Remediation Technology. Engineering methods and chemical remedies are both used in soil remediation technologies. Adding fresh soil, removing topsoil, electrical remediation technology, leaching method, and washing method are some of the engineering measures. Chemical reagents and soil heavy metal ions are used in the leaching and washing methods to decrease heavy metal concentrations in soil [3]. Chemical remediation, as indicated in Table 1, is the use of chemical remediation in soil, which includes complicated leaching, in situ passivation, and other approaches. The key to this technology is the selection of the passivator, eluent, and the determination of the dosage [4]. Chemical repair is an early, relatively mature, and effective method [5], including chemical leaching technology, chemical oxidation remediation technology, and soil performance improvement technology.

2.1.1. Chemical Passivator Type. The commonly used passivators include inorganic passivator and organic passivator. Inorganic passivators mainly include industrial waste, lime, red mud, fly ash, silicon fertilizer, calcium magnesium phosphate, dolomite, clay mineral, and antagonistic substances. Organic passivators are mainly derived from livestock manure, crop straw, peat, leguminous green manure and composting, and natural extraction of polymer compound. Lime is widely used passivator in the present experimental research.

(i) Passivation Mechanism The mechanism of chemical passivation is mainly to reduce the activity of cadmium in the soil by changing the soil properties, which involves precipitation fixation, adsorption and ion exchange, ion antagonism, and chelation. Most passivators work with a variety of mechanisms.

(ii) Precipitation/Fixation With this mechanism, most passivators reduce the availability of cadmium in soil. The application of alkaline substances like lime can obviously improve the soil pH value and reduce the solubility and activity of cadmium in the soil. In addition, when the passivator with carbonate ion, silicate ion, and hydroxyl ion is added to the soil, cadmium ions can react with these anions to produce hardly dissolved sediment, which can reduce the availability of soil cadmium [6].

(iii) Adsorption and Ion Exchange Clay minerals such as zeolite have strong ion exchange ability, and the availability of cadmium in soil can be reduced by ion exchange and specific adsorption of cadmium ions [7]. In addition, lime can increase soil pH value, increase the negative charge on the soil colloid surface, enhance the adsorption of cadmium ions, and reduce the bioavailability of cadmium in soil.

(iv) Ion Antagonism According to studies, cadmium interacts with a variety of nutrients, including zinc, selenium, copper, manganese, iron, calcium, potassium, phosphorus, and nitrogen, in ways that are either synergistic, antagonistic, or unrelated [8]. Therefore, the application of zinc can suppress the absorption of cadmium. The antagonists of cadmium are zinc sulphate and lanthanum.

(v) Chelation Organic amendments contain a variety of organic ligands, such as amino, imido, ketone, hydroxyl, and thioether, that can chelate with heavy metal ions like cadmium to create insoluble chelate, lowering heavy metal ion bioavailability.

2.2. Vegetable Greenhouse Cadmium Pollution Bioremediation Technology. Bioremediation, which includes animal remediation, phyto remediation, and micro bioremediation,

Table 1: Chemical remediation of cadmium pollution in soil.

Method	Complexation and leaching	In situ passivation
Definition	Cleaning the cadmium in the soil with a drenching agent and then concentrating on the cadmium in the leaching solution.	It reduces the solubility, diffusivity, and biological toxicity of pollutants after various chemical reactions after adding passivating agent to contaminated soil.
Advantage	It is fast and efficient.	It is simple and easy to choose the suitable passivating agent according to the degree of contaminated soil and the property of the soil. Most of the passivating agents are the byproduct of industry and having the lower cost.
Shortcoming	The remediation effect is affected by soil types, eluent resistance, and the occurrence form of cadmium. The eluent is expensive and may pollute groundwater, causing nutrient loss and soil fertility decline. The development of technology and equipment is relatively backward.	Only the occurrence of cadmium has been changed and it is not completely removed from the soil. Long-term monitoring is needed to prevent activation.
Remarks	It is suitable for sandy soil and sandy loam with good water permeability and heavy pollution. The selection and treatment of leaching solution is the key technology.	It is the key to find the passivating agent with low price, friendly environment, and continuous effect.

is the utilization of specific organisms' habits to adapt, inhibit, and ameliorate cadmium pollution, as indicated in Table 2.

2.3. Animal Remediation. The employment of parasitic organisms in the soil, such as earthworms and rodents, to absorb heavy metals is known as animal remediation. Researches on the use of lower animals to remediate cadmium pollution are still limited to the laboratory stage. The earthworm has a significant cadmium enrichment capacity, according to the findings, and the earthworm's enrichment steadily increases when the earthworm culture period is extended [9]. The efficiency of animal remediation is low, which is not an ideal remediation technique.

2.4. Phytoremediation. Plant extraction, plant volatilization, plant degradation, plant root filtration, and rhizosphere microbial degradation are all examples of phytoremediation techniques that employ plants to absorb, disintegrate, alter, or immobilise toxic and harmful contaminants in the soil. Plant extraction remediation, or the use of hyper accumulator plant features to remediate cadmium and other heavy metal polluted soil, is the most extensively utilised method [10]. More than 10 hyper accumulator plants, including cruciferae and cramineae, are with better remediation effect of cadmium contaminated soil. Some ornamental plants, cropland weeds, and woody plants are also the source of hyper accumulator plants for remediation of cadmium contaminated soil [11].

The tolerance mechanisms of cadmium hyper-accumulator plant are mainly compartmentation, anti-oxidation, and chelation. The compartmentation effect utilizes a large number of ligand residues in plant cell walls, including heavy metal ions, ion exchange, adsorption, and complexation, to influence the diffusion of heavy metal ions into cells [12]. The advantages of phytoremediation technology are simple implementation, less investment, and little damage to the environment, but there are also some shortcomings. These plants have usually slow growing, low biomass, long repair cycle, and difficulty to be widely applied.

Phytoremediation technology has the advantages of being easy to implement, little investment, and little environmental impact, but it also has certain drawbacks, such as sluggish growth, low biomass, a long remediation cycle, and a limited applicability [13].

2.5. Micro Bioremediation

2.5.1. Method. Some microbes can be employed to fix, migrate, or convert heavy metals in the soil, therefore lowering toxicity and facilitating detoxification. The mechanisms include cell metabolism, absorption, precipitation, and redox reaction. The metabolites of some microbes, such as S2- and PO43-, can react with Cd2+ to produce precipitation and reduce the toxicity of cadmium [14]. Microorganisms currently used for remediation of cadmium contaminated soil include bacteria, fungi, and some small algae.

2.5.2. Mechanism of Action. Obligate microorganism can promote the composition of heavy metal and micro object. Therefore, inoculation of obligatory microorganisms into polluted soil can help microorganisms absorb heavy metals [15]. The common obligate microorganisms include bacteria, fungi, endophytic mycorrhizae, and ectomycorrhizae [16]. In conclusion, these microbes can be used to immobilise heavy metals in soil and reduce the mobility of heavy metals in soil from the absorption of heavy metals [17].

2.6. Vegetable Greenhouse Cadmium Pollution Physical Remediation Technology. Physical remediation refers to the use of physical method to dilute, remove, and fix cadmium in soil in order to reduce the impact on the soil environment. The classification of physical remediation is shown in Table 3. The change of soil method is commonly used, including adding new soil, changing soil, topsoil, and deep ploughing [18]. Adding new soil entails adding a specified

Table 2: Bioremediation of cadmium pollution in soil.

Method	Animal repair	Microbioremediation	Phytoremediation
Definition	The use of earthworms, voles, and other soil animals to absorb soil cadmium	Reducing, adsorbing, accumulating cadmium, or changing the rhizosphere environment by microorganisms to promote the uptake of cadmium in plants	Extract: the use of hyperaccumulator plants to enrich the cadmium in the soil on the parts of the plant harvested and concentrated
			Volatilization: the use of plants to absorb cadmium in the soil and convert it into gas to volatilize into the atmosphere
			Stable: cadmium activity in soil by cadmium - resistant or super - resistant plants
Advantage	Improving soil structure and enhancing soil fertility	In situ remediation, improvement of soil environment, soil improvement, low cost	Low cost, low cost, in situ remediation, little impact on the environment, increase soil fertility and organic matter content, and concentrate on the above ground part to reduce two times of pollution, clean and beautify the social environment, and repair the soil and surrounding water
Shortcoming	Unable to deal with high concentration of cadmium contaminated soil	Strong specificity, concentration limit, difficult to separate from soil	With a single nature and selectivity, compared with other remediation methods, the cycle will be longer. Soil environment and artificial conditions may lead to biological invasion. If plants are not collected in time, there will be two pollution types and limited cadmium tolerance.
Remarks	Further study	Development potential and application prospect	Extract: the key is to find plants with high yield and hyper concentration
			Volatilization: more soil for the remediation of se, hg, as contaminated soil
			Stable: more used for remediation of contaminated soils, smelters, sludge, and other contaminated soils

amount of clean soil. The term “soil change” refers to the process of removing polluted soil and replacing it with clean soil. The polluted topsoil is turned into the bottom layer by deep ploughing [19]. Soil leaching is a method of transferring cadmium from solid soil to liquid via a leaching solution, followed by wastewater recovery.

Thermodynamic remediation method uses high frequency voltage to generate electromagnetic wave, which heats the soil, so that the pollutant is desorbed from the soil particles [20]. Electrokinetic remediation refers to the insertion of electrodes in the contaminated soil to obtain the direct movement of cadmium ions in the soil under the action of electric field, so as to achieve the purpose of clearing cadmium.

3. Results

3.1. Cadmium Contaminated Soil Remediation by Chemical Technology

3.1.1. Case Study of Chemical Leaching Remediation of Cadmium Contaminated Soil in the United States. Chemical leaching to remediate heavy metal polluted soil has reached a commercial level in the United States. Table 4 shows the demonstration projects of chemical leaching remediation of cadmium contaminated soil in the United States.

3.1.2. Passivation Restoration Experiment of Vegetable Greenhouse Contaminated Soil by Clay Mineral and Fertilizer. To investigate the remediation effect of single and compound treatments on cadmium pollution in vegetable fields of the northern sewage irrigated area and to find a better passivation treatment, clay minerals, sepiolite, phosphate bone meal, and organic fertilizer humic acid were chosen as passivators.

3.1.3. Experimental Setup. Clay mineral sepiolite is purchased from Yixian, Hebei. The chemical formula is Mg4Si6O15(OH)2·6H2O. The surface area is 22.7 m2·g-1 and the pH value is 10.1. The phosphate fertilizer bone meal is purchased from the Tengzhou Chemical Plant in Shandong. The pH value is 9.51, and the effective phosphorus content is 9.5%. The main chemical components are hydroxyapatite [Ca10 (PO4) 6 (OH) 2] and amorphous calcium hydrogen phosphate (Ca HPO4). Organic manure humic acid is purchased from Shanxi and processed by lignite. The vegetable for test is lettuce. The test site is located in northern sewage irrigated area of Tianjin. The soil type is the tidal soil. The basic physicochemical properties of the tested soil are as follows: the pH value is 8.38, the cation exchange amount is 19.2 cmol·kg-1, the organic matter content is 2.14%, the soil cadmium content is 1.71 mg·kg, and 1.12 passivation treatments are set up in the test. Test

Table 3: Physical remediation of cadmium pollution in soil.

Method	Definition	Advantage	Shortcoming	Remarks
Soil	Adding a large amount of uncontaminated soil to contaminated soil, covering the surface, or mixing the contaminated soil.	Not restricted by soil conditions, the effect is remarkable, and it is completely stable.	It requires a lot of manpower, material resources, high cost, land occupation, leakage, and secondary pollution. It destroys soil structure and reduces soil fertility.	Suitable for shallow root plant planting areas and polluted areas with poor mobility of pollutants
Change of soil	Replace the contaminated soil in part or all with nonpolluted soil			The thickness of soil change is greater than that of the plough layer
Go to the topsoil	According to the characteristics of cadmium contaminated surface soil, tillage activated the lower layer of soil			Prevent the two pollution types of the changed soil
Turn the soil depth	To spread the accumulation of cadmium on the surface to a wider range, so as to dilute it to a bearable value.			Suitable for heavy soil contaminated areas with fertilizer
Heat treatment	Heating the contaminated soil to evaporate the cadmium from the soil	Simple process	The destruction of organic and structural water in the soil and the disposal of the volatile matter	More suitable for volatile heavy metals: Hg, As
Electric repair	DC voltage is applied at both ends of the contaminated soil, and cadmium in the soil is taken to the electrode under the action of an electric field to collect soil samples	The economy is feasible, the operation is simple, the cycle is short, and the efficiency is high.	The effect of remediation is influenced by soil environment, soil components and heavy metals, which can easily lead to the change of soil basic physical and chemical changes.	The clay silt, which is used for low permeability, is still in the experimental stage and less successful.
Vitrification	Melting the polluted soil at high temperature and forming vitreous material after cooling	Permanent cadmium fixation	Energy consumption, complex technology, and difficult practical operation	

Table 4: The chemical leaching remediation of cadmium contaminated soil in greenhouse experiment in the United States.

Experimental sample	Target heavy metal	Eluent
Vegetable fields 1	Hg, Cd	KI solution
Vegetable fields 2	Ag, Cr, Cu, Cd	Leaching test
Vegetable fields 3	Cd, Cu, Cr, Hg, Pb	Acid
Vegetable fields 4	Cr, Pb, Cd	Leaching test

scheme and the type and dosage of passivation materials are shown in Table 5. Each processing set is repeated 3 times and arranged according to the random group.

3.1.4. Test Plant Sample Preparation. Passivators are uniformly dispersed on the soil surface and mixed with soil (20 cm depth) by human or mechanical means, followed by the planting of vegetables a month later. Passivators were applied in May, 2014, and the lettuce was sowed and planted in June, 2014. The lettuce is harvested and collected in 30 days after the emergence of the seedling. Rinse the veggies two times with distilled water after harvesting. Dry out with filter paper, and weigh and record the fresh weight. After the sample is placed in a blast oven at 105°C for 30 min, it is dried at 70°C for 48 h, and the weight of dry weight is recorded. The dried sample is comminuted and mixed with a small pulverizer, and the wet digestion is used. The soil sample is sampled by using S sampling method, and the fresh soil in plough layer (0–20 cm) is collected in each cell. It is grinded after air drying and followed by 1 mm and 0.15 mm aperture sieves for spare. The effective cadmium in soil sample is extracted by TCLP method. The leaching solution with the pH value 2.88 ± 0.05 is prepared by analysis of pure glacial acetic acid. The ratio of soil to solution is 1 : 20 and the solution is centrifugally filtered after 20 h at room temperature [21].

3.1.5. Determination of Cadmium Content. The cadmium content of plant sample and the available cadmium content in soil are determined by ICP-MS. Statistical analysis of experimental data is carried out with Excel 2010 and SPSS 13.0. The significance of differences between different passivators is analyzed by variance analysis of and multi-comparison (LSD method). Figure 1 shows the effects of different passivators on the cadmium content in the edible part of lettuce. Figure 2 shows the effect of passivators on the available cadmium content of soil.

Table 5: Experimental treatment of passivation repair.

Number	Handle	Consumption
Ck	Control 1	0
Bom	Bone meal	0.5
Hua	Humic acid	0.5
Sep1	Sepiolite 1	0.5
Sep2	Sepiolite 2	1
Sep3	Sepiolite 3	1.5
Sep1+bom	Sepiolite 1+ bone powder	0.5 + 0.5
Sep2+bom	Sepiolite 2+ bone powder	1.0 + 0.5
Sep3+bom	Sepiolite 3+ bone powder	1.5 + 0.5
Sep1+hua	Sepiolite 1+ humic acid	0.5 + 0.5
Sep2+hua	Sepiolite 2+ humic acid	1.0 + 0.5
Sep3+hua	Sepiolite 3+ humic acid	1.5 + 0.5

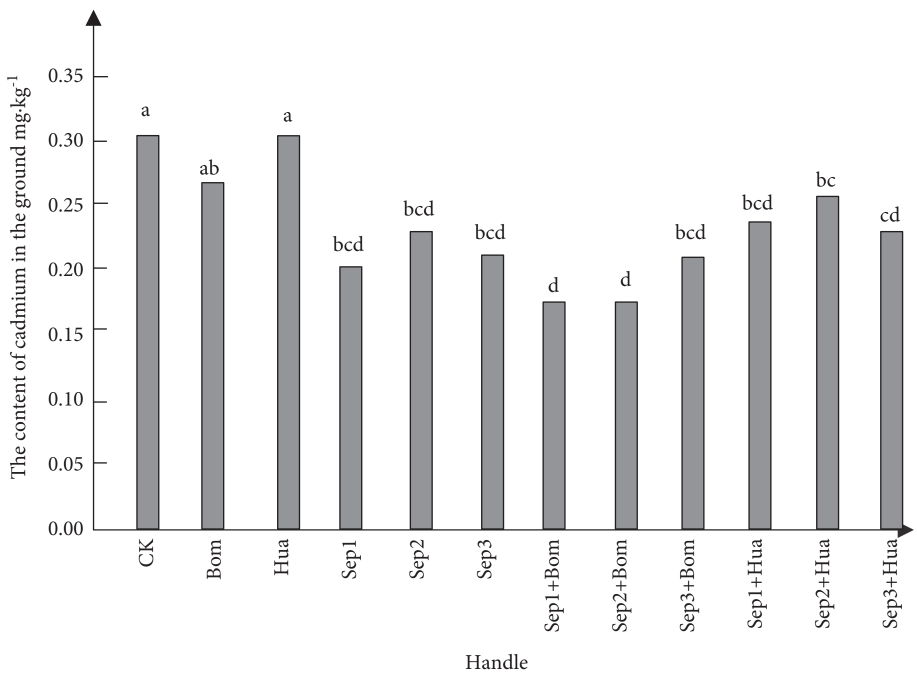

Figure 1: Effect of passivation treatment on the content of cadmium in the upper part of lettuce.

From Figure 1, it can be seen that, after passivation treatment, cadmium in the shoot of lettuce has an obvious decreasing trend with the decrease of 3.3%–39.7%. For the single passivation, the effect of sepiolite is the best and the decrease of the cadmium content in the shoot of lettuce is up to 30.8%. The second is bone meal with the decrease of 16.1%. Humic acid has no significant effect on the absorption of cadmium in lettuce. In addition, the effect of compound treatment is better than single treatment. The effect of Sep2+Bom treatment on reducing the cadmium content in lettuce is best, with the decrease of 39.7%, which is lower than the limit of cadmium content in leafy vegetables specified by GB2762-2012 0.2 mg·kg-1.

For improvement of the heavy metal pollution in 4 (Table 4) vegetable greenhouses, chemical leaching is used for remediation. Experimental results show that the chemical leaching can effectively remediate the pollution of heavy metal cadmium in soil. The cost of chemical leaching is relatively high. There is no cost report of leaching technology in China at present. In the United States, the cost of chemical leaching is 120–200 dollars/*t*.

From Figure 2, it can be seen that sepiolite and its compound treatment can obviously reduce the available cadmium content in soil, with the decrease of 12.16%–55.64%. The reduction effect of bone meal and compound treatment with sepiolite and bone meal is better, with the decrease of 55.64% and 54.12%, respectively.

3.2. Cadmium Contaminated Soil Remediation by Biotechnology. Different planting years (0, 5, 10, 15, 20, 25, 30 years) of soil samples in vegetable greenhouse are collected. Taking broom sedge as the research object, the remediation effect and accumulation characteristics of broom

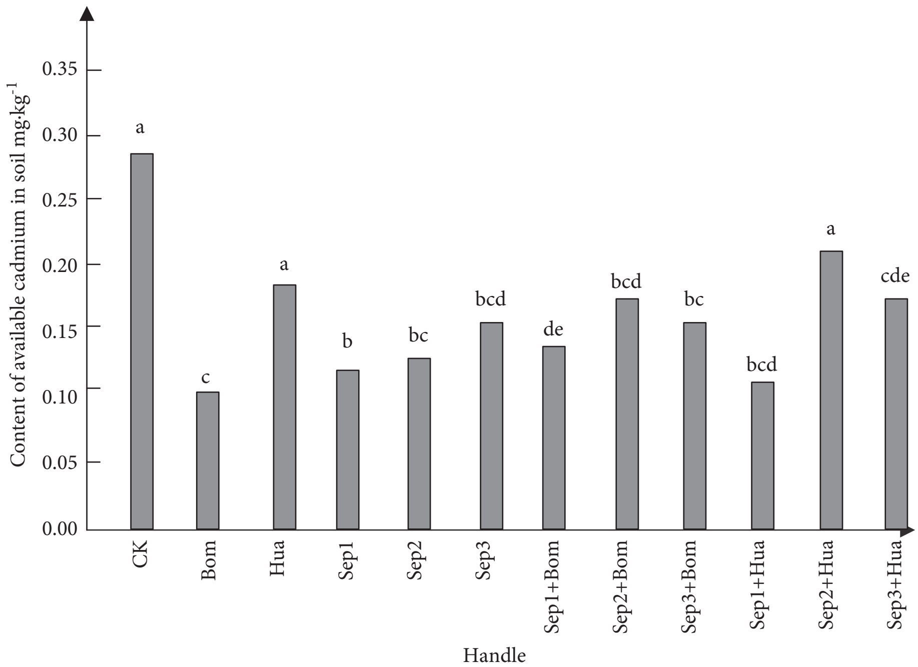

Figure 2: Effect of passivation treatment on the content of available cadmium in soil.

sedge planting on the contaminated soil with different planting years are researched.

3.2.1. Experimental Material and Measure. The test material is a broom sedge that was gathered in 2014 (wild specie). The location of the collection is the suburb of Xinxiang, Henan Province, with a geographical position of north latitude 35°21' and east longitude 113°50'. The soil sample is collected in harmless vegetable production base of Muye District, Xinxiang, in March 26, 2010. S multipoint (20 point) mixed sampling method is used for sampling soil. The planting years are 0, 5, 10, 15, 20, 25, and 30 years and the sampling depth is 0–20 cm. The plant roots, leaves, and rocks are removed from the air dried soil sample. The soil sample is filtered by 2 mm soil sieve and used for the cultivation of broom sedge. The other part is filtered by 1.0 mm and 0.2 mm soil sieve after being ground with agate mortar. Then it is stored in the polythene bag for determination of heavy metal content in soil.

The treated seven soil samples are placed in the seedling tray (square 50 hole) and sowing. The sample is cultured for 40 days after emergence. When the height of the seedling is 15–20 cm, the seedling is pulled out from the cavern and cleaned. After drying, the roots, stems, and leaves are separated. Then it is put into the oven at 105 °C for 2h and dried to constant weight at 70 °C. It is ground to powder and loaded into a polythene bag.

3.2.2. Determination of Heavy Metal Content. Microwave digestion inductively coupled plasma emission spectrometry is used for determination of heavy metal content.

3.2.3. Determination of Mass Fraction of Heavy Metal in Soil. The soil samples before and after planting broom sedge (filtered by 0.2 mm soil sieve) are weighed for 0.5 g (accurate to 0.0001) and put in PTFE digestion tank. 8 ml nitric acid, 2 ml perchloric acid, and 2 ml hydrofluoric acid are added in turn. After mixture and uniform encryption seal, it is put in the MAS microwave digestion instrument for digestion. After the digestion tank is cooled, the solution is transferred to the 50 ml polytetrafluoroethylene beaker and placed in the electric heating plate at 170 °C to dry up the acid. After adding 2ml0.2%HNO3 to dissolve the residue, it is transferred to the bottle with 25 ml capacity (GG-17 glass) and then to the polyethylene plastic bottle after shaking. The mass fraction of heavy metal cadmium is determined by Optima 2100DV inductively coupled plasma emission spectrometer.

3.2.4. Determination of Mass Fraction of Heavy Metal in Broom Sedge. The root, stem, and leaf of broom sedge are taken 0.5 g and put in microwave digestion tank. For each digestion tank, 5 ml concentrated nitric acid (95%) and 2 ml hydrogen peroxide are added in order. After digestion, the solution is transferred to a small beaker and the digestion tank is cleaned with 0.2% dilute nitric acid for 3 times. The small beaker is put on the electric heating plate 170 C to drive acid to the near dry. After adding 2 ml 0.2% nitric acid to dissolve the residue, it is transferred to the 25 ml volumetric bottle and finally fixed the volume with 0.2% dilute nitric acid solution. Mass fraction of heavy metal cadmium is determined by inductively coupled plasma emission spectrometer. Experimental results are shown in Figures 3 and 4. Figure 3 shows the remediation effect and Figure 4 shows the absorption and accumulation characteristics.

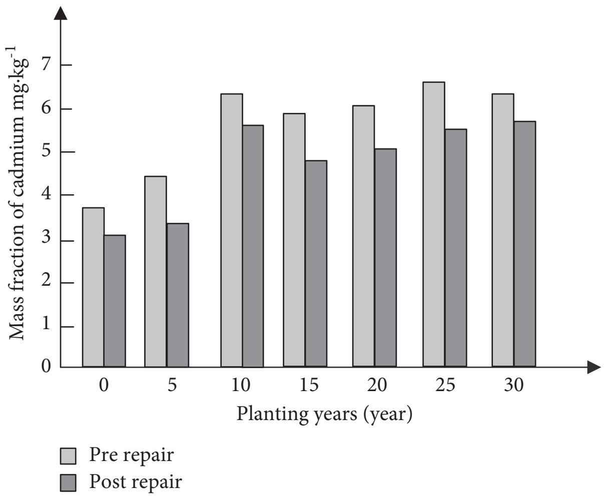

Figure 3: Effect of repair of greenhouse in different planting years of broom sedge vegetable soil cadmium.

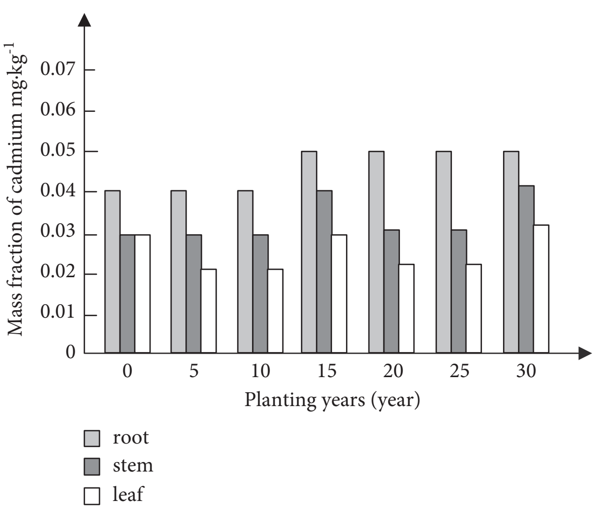

Figure 4: The characteristics of greenhouse vegetable soil with different planting years of cadmium absorption and accumulation of broomsedge.

From Figure 3, it can be known that, after planting broomsedge, the content of cadmium pollution decreased significantly. With broomsedge planting, the absorption and accumulation of the heavy metal cadmium are related with the concentration and the remediation efficiency is unrelated with the planting year. From Figure 4, the sorting of the accumulation of cadmium in the root, stem, and leaf is root > stem > leaf. The remediation efficiency of broomsedge on vegetable greenhouse cadmium contaminated soil is 9.78%.

3.3. Electrokinetic Remediation of Cadmium Pollution in Soil

3.3.1. Experimental Setup and Measure. Platform scale, electronic balance, atomic absorption meter, pH meter, centrifuge, and mixer spectrophotometry are the primary instruments and equipment utilized in electrokinetic remediation. Electrolyzer is a self-designed 25 cm × 5 cm×10 cm organic glass trough. High purity graphite electrode is used as electrode material. Experimental reagents are mainly cadmium sulphate, copper sulphate, concentrated sulfuric acid, concentrated nitric acid, phosphoric acid, hydrochloric acid, and sodium hydroxide. All of the reagents employed are of analytical purity. Soil sample is collected in the wild field. Heavy metal pollution solution is compounded according to the demand for pollutants and added to the quantitative soil sample to form the contaminated soil. The moisture content of the contaminated soil samples is 44.3%. The contaminated soil is then layered into the electrolyzer and compacted evenly. The experimental model is stably stabilized in the laboratory for 72 h. The mass fraction of heavy metals in pollutants is determined by atomic absorption spectrometry and determination of pH value and temperature of samples is obtained by acidity meter and thermometer.

3.3.2. Experimental Result. The selected heavy metal pollution factors are Cd and Cu. The used voltage is 0.5 V/cm. In the experiment, 50 ml working fluid with the 0.05 mol·L-1concentration is added into the electrode chamber. Remediation experiment is carried out after connecting the reaction unit with the power supply. The pH value and mass fraction of heavy metal contaminants are measured at a fixed time interval. The cumulative time of the experiment is 32 h. Changes of the mass fraction of heavy metal in all samples and the pH value in the electrolyzer are shown in Figures 5 and 6 ("+" represents the anode, "-" to represent the cathode).

From Figures 5 and 6, it can be seen that the method of point dynamic remediation can effectively reduce the cadmium content in soil. Figures 5 and 6 show the change of cadmium mass fraction of cadmium near the two poles of soil after electrokinetic remediation. The cadmium content near the anode decreases gradually from the initial state of 575.8 mg 575.8 mg·kg-1 to the end of 143.5 mg·kg-1. Therefore, cadmium is migrated to the cathode under the action of electric field, and the mass fraction of cadmium decreases faster in the vicinity of the anode. The migration rate of cadmium in the vicinity of the anode is greater than the migration efficiency of cadmium far from the anode. In the experiment, the removal efficiency of cadmium in the soil near the anode is 75.1% and 77.9%. Electrokinetic technology can effectively remove cadmium in the contaminated soil, which is convenient and effective.

In the chemical remediation technology, the passivation effect increases with the increase of the amount of passivator and the time of passivation. The appropriate addition of lime in lateritic red soil decreases the soil available cadmium content greatly. After adding 0.7% lime for 30 d to the southern acid soil, the effective cadmium in the soil is reduced by 28.17%. The release of calcium, magnesium, and phosphate fertilizer in acid soil can significantly increase the pH value in soil and reduce the content of exchangeable and effective cadmium. With the base fertilizer of 5 g/kg alkaline coal cinder, the content of cadmium in brown rice of early

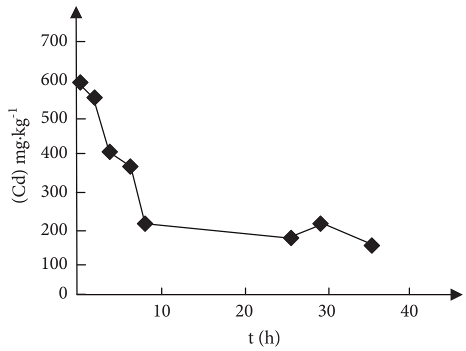

Figure 5: The change curve of cadmium in soil (+).

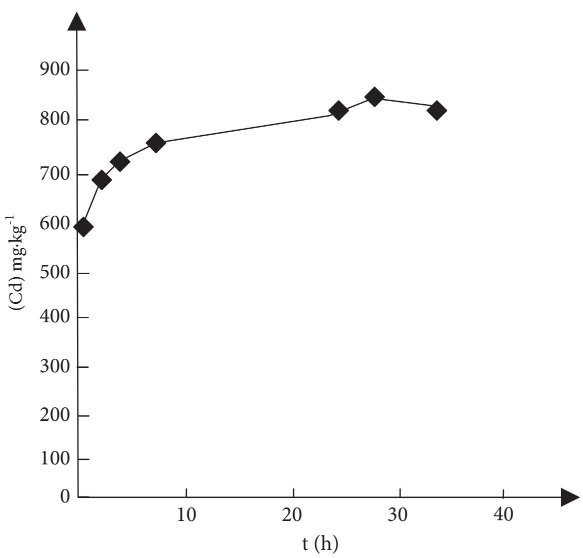

Figure 6: The change curve of cadmium in soil (-).

rice could be reduced by 75.4%, and the content of cadmium in brown rice of late rice decreased by 87.9%. The adsorption capacity of red mud to cadmium is up to 22.25 g/kg. The content of effective cadmium after the treatment of red mud can be reduced by 31% compared with the control treatment.

4. Conclusion

Cadmium pollution in agriculture soil is quite harmful, and the source of contamination is widespread. Therefore, it is necessary to remediate the cadmium contaminated soil. Zeolite can reduce the cadmium concentration in the leaves of potted lettuce by 86%. Sepiolite can significantly promote the growth of spinach and reduce the cadmium content in water spinach. Spraying zinc and selenium can reduce the absorption of cadmium by 37.01% and 31.63%. The content of cadmium in Chinese cabbage treated by rare Earth is 89.4%–98.08% compared with the control treatment. Organic fertilizer can promote the conversion of exchangeable cadmium to organic binding state and manganese oxide bound cadmium, thus reducing the available cadmium content in soil. Because of the particularity of the passivation mechanism, most passivators only temporarily reduce the effective form of cadmium by various effects. Therefore, the passivation remediation could introduce secondary pollution to the soil in the later period. It is proposed that the study is improved from the following elements for the remediation of cadmium contamination in vegetable greenhouse. Attention should be paid to the development of high efficiency and low cost cadmium pollution barrier, passivation products, and standardization technology. A single remediation method is often difficult to adapt to the remediation of a variety of heavy metal contaminated soil. It is necessary to adopt the combination of chemical and biological methods for remediation and optimization. Chemical remediation can be combined with other remediation methods, such as phytoremediation and micro bioremediation. For the selection of the passivator, it is necessary to ensure that the passivation effect of the heavy metal is obvious and simple.

Data Availability

The data used are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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