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Research Progress of Heavy Metal Contaminated Soil Remediation Methods in China

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Abstract: In order to effectively remediate heavy metal pollution in soil, a variety of physical, chemical and biological remediation method of materials have been proposed in the past decades. In practical application, these restoration methods have their own advantages and disadvantages in terms of scope of application, efficiency and cost. Therefore, this newspaper summarizes several common soil remediation technologies in combination with the relevant literatures in the field of heavy metal contaminated soil collected by CNKI. It is found that most physical remediation technologies have the advantages of simple equipment, easy popularization and sustainability, but they are limited to small areas and highly polluted soils; Compared with logistics repair technology, chemical repair technology with low cost, high efficiency and wide application range is used by more people; In recent years, bioremediation technology, which has the advantages of small environmental disturbance, no secondary pollution, stable and harmless products, has solved the ecological damage caused by physical and chemical remediation. The research on the remediation of heavy metal contaminated soil will help to have a comprehensive understanding of this field, which is of great significance to attract more scholars to participate in it, and provide solutions for the current ecological civilization construction of the government and other departments from the aspect of remediation of heavy metal contaminated soil ecological environment.

Keywords: Heavy metal pollution, Soil, Repair technology.

1. Introduction

Soil is the basis for human survival and development. However, with the continuous development of cities, a large number of pollutants produced by industry and agriculture cause serious deterioration of soil ecological environment quality. Among all kinds of soil pollution, heavy metal pollution is very difficult to control because of its high toxicity, easy accumulation and difficult recovery. Moreover, the polluted soil in the city may enter the human body through the ground dust, food chain and other ways. When the content of heavy metals entering the human body exceeds the maximum treatment capacity of the human body, it will cause various diseases, such as liver, kidney, intestines and stomach, nerve tissue damage, and even teratogenesis, carcinogenesis and mutagenicity in serious cases. High concentrations of heavy metals will also have adverse effects on soil microorganisms, soil fertility, groundwater, surface water and other aspects, thus posing a threat to the health of people's living environment.

In order to effectively repair heavy metal pollution in soil, people have proposed a variety of physical, chemical and biological remediation methods to improve the soil environment by reducing the total concentration of pollutants, reducing their bioavailability, and curbing the diffusion of heavy metal pollutants. The application scope, efficiency and cost of these remediation methods have their own advantages and disadvantages. Sorting out and summarizing the research progress in this field will help to make a reasonable assessment of the applicability, development status and prospects of different soil remediation technologies, and provide solutions for building a beautiful motherland with blue sky, green earth and clear water from the aspect of repairing the soil ecological environment polluted by heavy metals.

2. Physical Repair Method

Physical remediation mainly uses physical methods to reduce the content of heavy metals in soil, thereby reducing the degree of heavy metal pollution in soil. Most of the physical remediation technologies have the advantages of simple equipment, easy popularization and sustainable high yield, but there are some disadvantages in the specific implementation, such as high cost, high requirements for the concentration of heavy metals in the contaminated sites and the need for phase media with different physical characteristics of the soil.

The essence of encapsulation technology, landfill technology and soil replacement technology is to physically seal the pollutants. Packaging technology is described as a technology that fills contaminated soil in place in a reasonably designed physical closed system to eliminate the off-site diffusion of pollutants and the biological contact of on-site pollutants [1]. The soil replacement technology is similar to the encapsulation, which is to realize the soil restoration by deep turning of the contaminated soil to the bottom layer, covering the contaminated soil with clean soil, digging away the contaminated soil and replacing it with clean soil [2]. Douay et al. [3] repaired the contaminated kitchen garden (garden planting vegetables for food) near the Metaleurop Nord smelter in northern France by soil replacement. The pollution rate of vegetables decreased from 84.8% before repair to 17.4%. However, after 6 years of repair, the concentration of Cd and Pd in the soil increased by more than 2 times. This experimental data proved that the same as the packaging technology, the soil replacement technology also has the disadvantage of long-term maintenance after repair. This shortcoming leads to the high cost of physical repair technology, which is not easy to be accepted. The soil landfill technology is improved on the basis of the former two. The contaminated soil is excavated from the original location

and transported to the landfill site with landfill permit for centralized treatment. The centralized treatment strategy effectively reduces the economic cost of the soil landfill technology. Therefore, it has been widely used in the remediation of heavy metal contaminated soil in China [4]. However, these three methods require a lot of human resources, so the remediation cost is high and is only applicable to small areas of soil pollution.

The principle of heat treatment technology is to heat and treat the polluted soil by various treatment means according to the volatility of pollutants, so as to volatilize the pollutants in the soil, and then use negative pressure or use a carrier device to collect the volatilized steam to clean the soil, and the collected steam containing heavy metals is released into the atmosphere after treatment (usually carbon adsorption). The technical principle limits that the soil type must be relatively permeable and homogeneous soil, so that the pollutants can be heated and volatilized in the soil. The repair efficiency and cost of this technology are positively correlated with temperature and treatment time [5]. O "Brien et al. [6] found that when the heating temperature for the treatment of contaminated soil is above 220 ℃, the soil characteristics will deteriorate. Therefore, when applying the heat treatment technology, the trade-off between soil treatment efficiency and soil remediation measures should be fully considered before selecting the appropriate heating temperature. Zhao et al. [7] It is proposed that the water content, soil particle size and initial concentration of pollutants should be controlled within 10-20% in practical application to improve the remediation efficiency. Aiming at the problem of tail gas pollution from heat treatment technology, the method of tail gas treatment based on volatile organic compounds (VOCs) control technology in the field of air and water pollution is given. These improved measures improved the remediation efficiency of heat treatment technology and reduced the disturbance of remediation process to soil.

Vitrification technology uses high temperature to melt minerals in soil and isolate heavy metals in small volume glass materials to achieve the effect of removing heavy metals [8]. Meuser [1] estimated the data. After thousands of years of weathering, the leached chemical elements in the glass material are only 0.1% ~ 25% of the initial content. This shows that the vitrification technology is stable and reliable for the storage of heavy metal pollution. However, it is worth noting that vitrification technology has the disadvantage of losing all ecological functions of the restored soil.

3. Chemical Remediation Technology

Physical remediation has the problem of engineering cost, which is limited to a small area of highly polluted soil. However, chemical remediation has been widely used because of its low cost, high treatment efficiency, small limitation of polluted area and pollution degree. There are two main ideas for the technology of remediation of heavy metal contaminated soil by chemical methods: (1) enhance the solubility and migration of heavy metals by chemical means to separate heavy metals from the soil, and then use physical means for further treatment. (2) Passivate heavy metals in the soil medium by chemical methods, reduce the dissolution and migration of heavy metals, and reduce the harm of heavy metals to the surrounding environment.

Electrokinetic remediation is a technology that forms an electric field gradient by applying low-voltage direct current on both sides of the contaminated soil, and brings the heavy metal pollutants in the soil to both ends of the electrode through electromigration, electroosmosis or electrophoresis under the action of the electric field to separate out from the soil in the form of solution for appropriate physical and chemical treatment. Good electric field force requires high pollutant concentration and soil permeability and conductivity, which leads to great limitations of electrokinetic remediation. In view of the poor effect of electrokinetic remediation in low pollution soil, fan et al. [9] added citric acid to the cathode, which increased the content of free heavy metal ions in the soil and enhanced the electrokinetic remediation efficiency. Li et al. [10] proposed the solution of adding conductive solution between the cathode and the soil to be treated to solve the problem of metal precipitation caused by the increase of soil pH in electric remediation. In the experiment of removing copper and zinc from sand, the removal efficiency of more than 96% also shows that this solution can effectively improve the treatment efficiency of electric repair technology. At the same time, it is also found that the metal removal efficiency depends on the treatment time and the content of electrolyte in the solution.

Soil leaching method is a soil remediation technology that uses the eluant to clean the soil, makes the pollutants in the soil flow out with the eluent, and then recovers the eluent and soil. Common eluents include acid, salt and high concentration chloride solution, chelating agent, surfactant and redox agent. When the soil contains a variety of heavy metal pollutants, the continuous leaching extraction method can be used. Peter et al. [11] found that the components most easy to remove heavy metals by chemical leaching are: exchangeable, carbonate bound and iron manganese oxide bound heavy metal ions. However, the soil leaching process requires high permeability of the contaminated soil, so that the leaching solution can penetrate into the soil and bring out heavy metals for recycling. In addition to the limitations of soil properties, the leaching agents used for soil leaching may cause secondary damage to the contaminated soil.

Chemical fixation refers to adding a curing agent to the soil, changing the existing forms of heavy metals in the soil through adsorption, ion exchange, surface oxidation / reduction, coprecipitation, solid solution, micro encapsulation, etc., reducing the solubility, mobility, leaching toxicity and bioavailability of heavy metals in the soil environment, so as to achieve the effect of fixing heavy metals in the soil. Chemical fixation can be divided into soil solidification and soil stabilization.

Soil solidification technology is to transform polluted soil into impermeable solid blocks. Wang et al. [12] tested the soil in a place in West Drayton, UK after 17 years of repair with cement-based curing agent. The leachable concentrations of Cu, Ni, Zn, Pb and Cd in the soil are still lower than the standards in the private water supply regulations (UK) in 2009. This research data shows that the cement-based curing agent has a good storage effect on heavy metal pollutants. However, it should be noted that the ecological value of the contaminated soil will be completely lost after the soil solidifies.

Soil stabilization refers to the use of modifiers to transform pollutants into a state and form that is not easy to dissolve, has little migration capacity or toxicity, and reduce the biological effectiveness of pollutants, so as to achieve harmless, or reduce the harm of pollutants to the ecological environment. The remediation effect of soil stabilization is greatly affected by the modifier, which only acts on specific

heavy metals.

Liao Xiaoyong et al. [13] conducted a survey and summary from the aspect of engineering application. In table 2-3, it can be found that the chemical oxidation technology has been applied in many states in the United States, indicating that the technology has a variety of application sites and a mature market. Compared with chemical oxidation, the disadvantages of in-situ leaching, such as less application, high cost and long repair cycle, limit the development of the technology. However, the pollutants treated by the two technologies in the table are volatile pollutants, so it is only a reference for the evaluation of the ability of the two technologies to treat heavy metals, which does not mean that chemical oxidation is completely superior to in-situ leaching in the treatment of heavy metal pollution.

4. Bioremediation Method

Compared with physical and chemical remediation, bioremediation technology has become a new technology in recent years because of its multiple advantages, such as small environmental disturbance, no secondary pollution, and most products are stable and harmless substances.

Bioremediation technology is mainly divided into three categories: phytoremediation technology, animal remediation technology and microbial remediation technology. However, at present, phytoremediation and microbial remediation technology are the main technologies to realize the technical application. At present, only earthworms and other technologies are commonly used in animal remediation technology, and there are few scientific practical applications.

Phytoremediation technology enriches heavy metal elements in soil into plants through biological enrichment of specific plants, and then treats harvested plants to reduce secondary pollution [17]. Plants repair heavy metal contaminated soil mainly through absorption and transportation and Rhizosphere stabilization. Phytoremediation has low cost and technical requirements, simple operation, but it is greatly affected by soil quality and climate, and also has high requirements for plant biomass and tolerance.

China is a large agricultural country. The heavy metal pollution of farmland soil directly affects the national food security. Many scholars have studied Intercropping between crops and hyper accumulative plants in order to achieve the effect of not only repairing heavy metals in soil, but also protecting crops, reducing heavy metal pollution, and improving crop quality. At present, many studies have confirmed the feasibility of intercropping and interplanting hyperaccumulating plants. The relevant contents are shown in Table 2-5.

As for the problem that most phytoremediation only plays a role in single heavy metal pollution. Yang Qifeng et al [22] carried out research on Phytoremediation of complex heavy metal pollution. They used the herb Robina pseudo acacia and woody flower Viola fargesii to intercrop to repair the polluted soil. After intercropping, the degradation rates of Cd, as, Pb, Cu and Zn in farmland were 96.37%, 72.56%, 75.45%, 46.28% and 50.59% respectively, In addition, the experiment of intercropping dachshund tree and Chrysanthemum indicum was also carried out. The experimental data showed that the degradation rate of heavy metal elements in soil was significantly improved. Therefore, it is speculated that the remediation method of intercropping hyper accumulative herbs and woody flowers can not only reduce the metal content in soil, but also have certain economic benefits. In the case of small land and large population in China, intercropping of hyperaccumulation plants with crops and cash crops can not only achieve the purpose of restoration, but also harvest safe crops. Such a treatment method can not only meet the needs of the people and bring practical benefits, but also alleviate the contradiction between soil remediation and land use to a certain extent.

General Secretary Xi put forward "accelerating the reform of the ecological civilization system and building a beautiful China" in the 19th national university. The proposal and continuous implementation of the construction of the ecological 7 civilization in China means the planning and construction of large areas of landscape green space. For the heavy metal pollution of such sites, the purpose of repairing the soil can be achieved by planting ornamental hyper accumulative plants. Chinese scholars have also done some research in this area. For example, Zhou Ruiren and others [23] used the ornamental plant Ligustrum malongense B.S. Sun) to repair the soil polluted by heavy metals. The experimental data show that sijichun has a certain repair effect on the soil polluted by CD, Pb and as, and also has a certain landscape effect. Wei Chaodan et al. [24] used the ornamental plant Tradesantia sillamontana to repair the soil polluted by heavy metal Pb. The experiment found that Tradesantia sillamontana showed strong tolerance and good enrichment to Pb pollution. At the same time, the plant itself also had a certain ornamental and beautifying effect. In conclusion, the promotion of ornamental hyperaccumulating plants for the remediation of heavy metal contaminated soil has guiding significance for alleviating the contradiction between soil remediation and land use.

In order to reduce the dependence of phytoremediation technology on Soil and climate, many scholars, starting from the direction of joint remediation, put forward such methods as plant microbial joint remediation technology, modifier plant joint remediation, chelator plant joint remediation, voltage plant joint remediation, genetic engineering plant joint remediation technology, and achieved the goal of reducing the dependence of phytoremediation technology on Soil and climate.

Microorganisms mainly repair heavy metal contaminated soil through adsorption, precipitation, leaching, transformation and volatilization. It is affected by the characteristics and concentration of pollutants, local climatic conditions, site hydrogeological conditions and the type of bioremediation technology [14]. Xu Yanbo et al. [25] used the urease produced during the growth and metabolism of carbonate mineralizing bacteria to decompose the substrate urea, and then played the role of producing carbonate ions and consolidating heavy metal ions. Finally, the exchangeable concentration of as, Pb, Cd, Zn and Cu in polluted soil was reduced by 16.9% to 49.8%. Yu Tianhong et al. [26] summarized the previous views and proposed that the efficiency of bioremediation can be effectively improved by adding nutrient elements, screening microbial strains with strong tolerance / resistance, improving strains by means of molecular biology technology and genetic engineering, physical chemistry and plant microbial joint remediation.

5. Conclusions

Soil is an important part of the ecological environment and one of the main resources for human survival. Once the soil is polluted by heavy metals, it is difficult to eliminate, and soil

pollution has a strong concealment compared with air pollution and water pollution. Although it is difficult to detect in daily life, soil pollution causes harmful substances to accumulate in plants and endanger human health through the food chain, affecting the quality of groundwater, surface water and atmospheric environment. Because heavy metals are difficult to be degraded and easy to be enriched, it is difficult for heavy metals contaminated soil to be purified naturally and treated manually. Therefore, it is necessary to study the remediation technology of heavy metal contaminated soil.

In this paper, the advantages and disadvantages of several common remediation technologies for heavy metal soil pollution are analyzed, and the research progress in the field of heavy metal pollution is briefly summarized: the physical remediation technology first studied has the advantages of simple equipment and easy popularization, but it is limited to a small area of highly polluted soil. The chemical remediation technology has avoided the shortcomings of the physical remediation technology. It has been widely studied and applied in 2010 and the following ten years due to its low cost, high treatment efficiency, and small limitations on the polluted area and pollution degree. In recent years, the emerging bioremediation technology has the advantages of small environmental disturbance, no secondary pollution, stable and harmless products, avoiding the ecological damage of physical and chemical remediation, and has become a research hotspot in recent years.

The research on the remediation of heavy metal contaminated soil will help to have a comprehensive understanding of this field, and provide a solution for the current ecological civilization construction of the government and other departments from the aspect of remediation of heavy metal contaminated soil ecological environment. However, the feasibility of the remediation technology is not considered from the aspects of ecology and toxicology. In the actual soil remediation project, it is necessary to further investigate and supplement the data of contaminated soil practice. Moreover, the advantages and disadvantages of the specific technology are also related to site conditions, pollution conditions and other factors, and cannot be completely copied.

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