ISSN: 2414-1895 DOI: 10.6919/ICJE.202210_8(10).0025

A Review of the Research Status and Remediation Technology of Heavy Metal Pollution in Soil in China

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Abstract

Soil is an essential geological resource on which human beings depend for their survival. However, with the development of industry, soil pollution has become one of the most significant environmental pollution problems in China. Heavy metals are pollutants that can cause serious damage to soil, have the potential to be easily degraded by microorganisms. With the increasingly serious problem of heavy metal pollution in farmland soil pollution, the yield and quality of crop products are also declining, which has caused great harm to human health. In order to effectively solve the above problems, this article starts from the analysis of the current situation of heavy metal pollution in China and expounds on the biochemical remediation technology and physical remediation technology possessed by China, and then serves as a reference for the research work of heavy metal pollution in China.

Keywords

Heavy Mental Pollutant; Soil Remediation Technology; Research Status.

1. Introduction

According to the National Soil Pollution Survey Communiqué (2017), the rate of soil pollution exceeding the regular standard in China is 16.1%, and the rate of exceeding the standard for land use by heavily polluted enterprises is as high as 36.3% [1]. Heavy metals are the main pollutants that lead to the degradation of the environmental quality of agricultural soils, among which heavy metals that have a serious impact on soil mainly include chromium (Cr), arsenic (As), nickel (Ni), mercury (Hg), lead (Pb), cadmium (Cd) and other elements. Excess heavy metals in the soil can cause direct damage to crops, leading to plant deaths and reduced agricultural yields. At the same time, because pollutants stay in the soil, these heavy metals can endanger human health through the food chains and biomagnification. At the same time, these pollutants can also indirectly threaten humans by polluting water bodies and the atmosphere. Therefore, considering that soil remediation technology can effectively improve the current soil environment and ensure the safety of agricultural production, it is of practical significance to discuss the current situation of heavy metal contaminated soil and its remediation technology.

2. The Current Situation and Harm of Heavy Metal Pollution Soil in China

The causes of heavy metal pollution of soil are very extensive, basically divided into natural causes and man-made causes. Natural causes are mainly influenced by the matrix and soil formation processes. Anthropogenic causes are the main reasons of heavy metal soils, which involve sewage irrigation, the heavy use of pesticides and fertilizers, atmospheric settlement, transportation, and waste accumulation [2]. According to the survey of the relevant agricultural departments in China, the irrigation area of soil sewage in China's farmland is about 1.4 million hectares, the soil area polluted by heavy metals accounts for about 64.8% of the total irrigation area, and the annual grain production reduced by heavy metal pollution is about 10 million tons [3].

3. The Remediation Technology of Heavy Metal Soil

The remediation technology of heavy metal pollution soil is to degrade, absorb or transfer the heavy metal and other pollutants contained in the soil. Eventually this approach will reduce the pollution concentration and transmit the harmful substances into harmless substances. Most soil remediation technologies for large multiple metal pollution are classified as three types: physical remediation, chemical remediation and biological remediation.

3.1 Physical Remediation

3.1.1 Soil Dressing, Soil Replacement and Excavation and Transportation Method

Soil dressing method introduces cleaning soil to certain degree into contaminated soil in terms of varied soil contamination degree, to achieve the effective reduction of heavy metal components and the direct contact area between plants roots and pollutants. The soil replacement method removes the contaminated soil and retreads the new contaminated soil [4]. Both methods show the advantages of quick response and good effect but with high remediation costs and large construction quantities, only suitable for the soil with small area and shallow contamination. The similar method, the excavation and transportation technology, takes the principles of excavating the contaminated soil and transporting it to the landfill site with landfill certificate for treatment. The obstacles in transportation emissions constitutes the restrictions in the technology applicability, for instance, the contaminated area and the nearest landfill site could be farther apart. The factors that limit the applicability of this technology are obstacles in the process of transport emissions, such as the polluted area and the nearest landfill site may be very long. In addition, there could be odor and pests once the landfill is not properly designed and maintained [5].

3.1.2 Electrokinetic Remediation Technology

Electrokinetic remediation technology inserts electrodes on both sides of the soil to form the voltage gradient, by which under the electric field, heavy metal ions in the soil will migrate to both ends of the electrode by means of electromigration and electroosmosis, then being removed from the soil to enable the soil decontamination. In general, the following factors would pose impacts on remediation effect: soil, electric field strength, electrode material, pH value, electrolyte, operation time, etc[5]. Electrokinetic remediation and other typical technologies (such as leaching, plants, microorganisms, etc.) have also been extensively explored [6]. Additionally, the utility of a single traditional electrokinetic remediation technology can no longer satisfy the current demand for heavy metal soil remediation. To this point, electrokinetic remediation technology has been taken into consideration for further improvement both at home and overseas, such as polarity exchange technique, anode approximation method, etc. [7]. Electrokinetic remediation technology is characterized by simple operation, little environmental impact, and extensive applicability. When it comes to the actual application, it is necessary to take the change of soil pH value, possible secondary contamination, remediation cost rise, and vulnerabilities to electrode polarization or electrode corrosion into consideration [8].

3.1.3 Heat Treatment Technology

Heat treatment technology, also known as thermal desorption technology, falls into in-situ thermal desorption and ectopic thermal desorption, both of which heat the contaminated soil by steam, microwave, and infrared radiation according to the volatility of pollutants, to get the pollutants to be volatilized, thus removing the heavy metal pollutants in the soil [9]. Moreover, in-situ thermal desorption is superior to ectopic thermal desorption in terms of environmental protection, cost efficiency, and the prospect of sustainable development, leading to the gradual decline of ectopic thermal desorption technology [10].

ISSN: 2414-1895
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3.2 Chemical Remediation

3.2.1 Solidification / Stabilization Technology

Solidification / stabilization technology receives extensive application due to it being one of the most effective and least risky remediation methods. The remediation method introduces solidification / stabilizer into the soil, to change the active state of heavy metals in the soil, enabling the stabilization and preventing the diffusion and transformation of heavy metals. Frequently used solidification / stabilization agents contain ordinary Portland cement, quicklime, ground granulated blast furnace slag, phosphate, red mud, etc. [11]. However, the solidification / stabilization technology is incapable of removing the pollutants in the soil, thus leading to a certain probability that the pollutants will be further released after the soil is weathered. The application of this technology should be thus gravely considered.

3.2.2 Leaching Technology

The leaching technology injects the leaching agent into the soil, followed by pressurization and sedimentation to immerse the leaching solution into the soil, for the separation of the pollutants from the soil surface to enter the leaching solution, enabling the effect of soil decontamination. Leaching technology can be classified into in-situ soil leaching technology and ectopic soil leaching technology. Additionally, the concentration of leaching agent, leaching duration, pH, etc. constitute influencing factors for the effect of leaching technology. Leaching technology exhibits its flexibility in application, enabling its frequent combination with other technologies (such as thermal desorption technology, solidification / stabilization technology, electrokinetic remediation technology, etc.) [12]. Also, the leaching process applies large amounts of chemicals, constituting its shortcoming. In addition, China has a vast territory and abundant resources, for which leaching technology varies with soil type, raising the demand for widely applicable, environmentally friendly leaching solution, which is the top priority for this technology.

3.3 Bioremediation

3.3.1 Microbial Immobilization Technology

Microorganisms is unable to degrade and destroy heavy metals, while microorganisms, a kind of metal immobilizing agent, enables the transformation of the physicochemical properties or valence of heavy metals through biosorption, bioaccumulation and biomineralization to affect the migration, transformation, or redox precipitation reaction of heavy metals, and thus the reduction of their toxicity. In terms of the combination mode between microorganism and carrier, the existing immobilization methods mainly include adsorption method, embedding method, cross-linking method, surface combination method, flocculation method and composite immobilization method, showing the characteristics of small secondary pollution, low cost, high treatment efficiency, strong stability, and strong load resistance. This method remains in the stage of laboratory research. Compared with the traditional physical and chemical remediation methods, the microbial immobilization technology has a longer cycle [13].

3.3.2 Phytoremediation Technology

Phytoremediation technology, compared with physicochemical remediation, would not produce secondary pollution, showing the feature of environmental protection. Phytoremediation is defined as applying plant specific functions to remove heavy metal pollutants from soil. Owing to the continuous secretion of various organic compounds into the external environment by plant roots after the plant settles down, the physical and chemical properties of heavy metal contaminated soil will conduct migration and transformation, to achieve the function of soil decontamination [14]. There is a great variety of plants in nature, which falls into hyperaccumulator plants, heavy metal resistant plants and other types (i.e., vulnerable to heavy metals) by their ability to absorb heavy metals in soil from high to low [15]. Nowadays, the research of hyperaccumulation plants has attracted increasing attention at home and abroad. Unfortunately, there are few successful cases up to now. What limits the application of hyperaccumulation plants is an efficiency problem, while it is undeniable that phytoremediation technology shows irreplaceable functions in controlling water and soil loss, restoring plant landscape, and improving land use value [16].

4. Conclusion

Soil is an important non-renewable resource in human production and life. Hence, the study of remediation technology and rational use of soil contaminated by heavy metals is crucial for the future development of mankind. Therefore, relevant personnel should take different countermeasures according to the soil conditions in different areas, continuously improve the remediation mechanism of heavy metal pollution in the soil, and continuously optimize the remediation technology of heavy metal contaminated soil.

Acknowledgments

Thank for Professor Sun Keqin of China University of Geosciences (Beijing) for his guidance to this article.

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