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# Review in Strengthening Technology for Phytoremediation of Soil Contaminated by Heavy Metals

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**Abstract.** In view of current problems of phytoremediation technology, this paper summarizes research progress for phytoremediation technology of heavy metal contaminated soil. When the efficiency of phytoremediation may not meet the demand in practice of contaminated soil or water. Effective measures should be taken to improve the plant uptake and translocation. This paper focuses on strengthening technology mechanism, which can not only increase the biomass of plant and hyperaccumulators, but also enhance the tolerance and resistance to heavy metals, and application effect of phytoremediation, including agronomic methods, earthworm bioremediation and chemical induction technology. In the end of paper, deficiencies of each methods also be discussed, methods of strengthening technology for phytoremediation need further research.

## 1. Introduction

Recent years had witnessed the expanding area of soil contaminated by heavy metal,owing to rapidly increasing of population, the unreasonable development and utilization of mineral resources, the rapid development of pesticide and applying chemical fertilizers, sewage irrigation and industrialization and so on[1].Toxic heavy metal can poses a serious threat to human health, due to bioaccumulation in humans and it can not be easily degraded , so the remediation of heavy metal contaminated soil is particularly important.

Phytoremediation is an environmentally-friendly technology, using plants to remove heavy metal from contaminated soil[2]. It has advantages over physical and chemical remediation,such as permanent effect, cost-effective and secondary pollutant is easy to control. However, many factors limited the remediation efficiency in practice, such as :1)The majority of hyperaccumulating species discovered so far have low biomass ,restrict to region or have a long remediation cycle. 2) They might be good at hyperaccumulating one metal, but be sensitive to other contaminant. 3)The roots of hyperaccumulator plants are generally shallow, and the ability to repair the deep soil is limited.

Thus, it's a important direction to enhance the efficiency of phytoremediation by strengthening technology. This paper mainly discusses how to improve plant biomass and accumulation of heavy metals from physical, chemical and agronomic measures.

## 2. Agronomic Practices

### *2.1. Use of Fertilization*

Fertilization can promote plant growth and biomass, and then increase the total amount of heavy metals accumulated in plants. It can change the form and activity of heavy metals, and then affect the absorption and accumulation of heavy metals in plants. In the study on fertilization of phytoremediation, nitrogen, phosphorus, potash, compound organic fertilizer and $CO_2$ gas fertilizer are the most commonly used.

Robinson[3] found that the application of nitrogen fertilizer could increase the biomass of Alyssumbertolonii ,which was nickel hyperaccumulator, by two times without decreasing its aboveground nickel content. However, the amount of fertilizer should be within a suitable range. Excessive application of fertilizer does not necessarily increase the accumulation of heavy metals in plants, but reduces the efficiency of phytoremediation[4]. Field trials conduced by Liao also showed that the soil remediation efficiency decreased from 7.84% to 6.63% when the phosphorus application rate was 340 $kg/hm^2$ and 600$kg/hm^2$.

Application of $CO_2$ fertilizer in phytoremediation, can not only enhance the resistance of plants to pollutions, improve plant biomass, but also enhance the plant absorption of heavy metals and other pollutants,or even induce the plant turn into hyperaccumulator, furthermore, improve the absolute and relative efficiency of plant extraction technology in heavy metal soil. Study has demonstrated that doubling $CO_2$ fertilizer under drought stress can significantly improve photosynthetic efficiency and antioxidant enzyme activities of wheat to increase heavy metal resistance. The soil test by Tang shown that[5] , elevating $CO_2$ concentration is not only beneficial to improve the ability of India mustard and sunflower to resist copper stress, but also significantly enhance their aboveground biomass, besides, induce the accumulation of copper in these two plants.

### *2.2. Use of other Agronomic Practices*

The mainly agronomic practices that can be employed to maximize phytoremediation potential include tillage, co-cropping, crop rotation and coppicing[6-8]. Tillage is beneficial to turning heavy metals into the rooting zone,where remediation takes place, which promotes the contact between plants and heavy metals, and improves the efficiency of phytoremediation. According to the study[9], rotation, intercropping or interplanting are beneficial to reduce the influence of weeds, diseases and insect pests on plant growth and development. In the study, zinc, cadmium hyperaccumulator S.Alfredii and ordinary plants (maize) were intercropped in remediation of heavy metal contaminated soil.Meanwhile, there was a certain economic output, reducing the cost of soil remediation. Therefore, the application of intercropping or interplanting more than 2 hyperaccumulators can improve the remediation efficiency.

## 3. Earthwarm Strengthen Repair

Earthworms play an important role in agricultural production,it can also be used for phytoremediation, which is mainly reflected in two aspects: on the one hand, it can improve the physical and chemical properties of soil, develop soil fertility, and enhance plant biomass; on the other hand, earthworms may have direct or indirect effects on the bioavailability of heavy metals in soil while feeding, site preparation and excretion. Studies also found that earthworm activity in red soil can not only reduce pH value, but also significantly increase the extractable zinc content of DTPA, thus promoting the absorption and accumulation of plants[10].

## 4. Chemical Induction Technology

Most of the heavy metals in soil are difficult to be absorbed by plants. Chemical remediation agents,such as chelating agent, alkali substances, plant nutrients, ions material, plant hormones, humic acid, surface active agent, can increase the tolerance of plants to heavy metals and improve their ability to restore heavy metals[11]. This paper focuses on the chelating agent and pH regulator on Phytoremediation enhancement.

### *4.1. Organic Chelating Agent*

The chelating agent can react with the heavy metal, which can be activated and improved its bioavailability. Further more ,the reaction can increase the uptake and transition of heavy metals by plants. Piechalak[12] reported that with the treatment of EDTA , in the soil content 200 mg/kg Pb,the accumulation of Pb in pea was increased by 67% compared with the control.

Despite the addition of chelating agent can maximize the effect of phytoremediation, there are potential environmental risks and disadvantages.The concentration of chelating agents is too high, which can cause toxicity to soil microorganisms and plants, inhibit the growth of plants, and cause heavy metal leaching and infiltration to groundwater, leading to groundwater pollution[13],[14].Therefore, the practicability and feasibility of chelating agents are still worth further study.

### *4.2. Acid-Base Regulator*

The change of soil pH will directly affect the fraction and activity of heavy metals in soil. The use of pH regulator (elemental sulfur and calcium hydroxide), hyperaccumulator Thlaspicaerulescens at pH 5.84, the zinc and cadmium absorption reached the maximum with the increase of pH, Thlaspi enrichment of zinc and cadmium content decreased .Adding citric acid, malic acid and other low molecular weight organic acids in heavy metal contaminated soil, can promote the accumulation of heavy metal in plants, desorption in soil at the same time. And the degradation of organic acids in the soil as the final product are carbon dioxide and water, which are not prone to residue.

## 5. Other Strengthening Techniques and Measures

With the rapid development of molecular biology, genetic engineering technology, the metal chelating agent, metallothionein (MTs), phytochelatins (PCs) and heavy metal transporter genes can be transfered into hyperaccumulator, which will effectively increase the extraction plant of metal. Besides, the biomass of phytoremediation , tolerance and resistance to heavy metals can be improved simultaneously thanks to the transgenic technology[15]-[17].

In addition, inoculation of rhizosphere micro-organisms in heavy metal soil is also widely used. Soil microbial species, a large number of some rhizosphere microorganisms could change bioavailability of soil heavy metal through metals oxidation-reduction, or by the secretion of biosurfactant, organic acids, amino acids and enzymes to improve the biological availability of heavy metals in the root environment, promoting the growth of plants.

## 6. Perspectives and Suggestion

Though many achievements have been made in strengthening technology for phytoremediation of soil contaminated by heavy metals, in recent years, the study of these technologies needs further expansion. The following aspects should be carried out in the future:

1)The molecular mechanisms of the uptake, translocation, accumulation and detoxification of heavy metals in hyperaccumulator are still to be studied.

2)The specification of hyperaccumulators is having a strong enrichment effect of one kind heavy metal, which was limited to remediate contaminated soil which was usually caused by a variety of heavy metals.We should study on how to create plants that rich in heavy metals at the same time by means of genetic engineering.

3)Use of chelators and chemical surfactants, which have been shown to be toxic and can leach into ground water or soil, may have undesirable environmental consequences.Thus, it is necessary to develop a kind of natural or artificial chelating agent, which is low toxicity, easy degradation, high selectivity and high efficiency. It’s better to combine with other strengthening techniques to maximize the efficiency of chelate induced.

4) Currently, systematic full-scale field studies should be conducted to explore a feasible plant cultivation management measures.Optimizing fertilization technology and applying new fertilizers to improve soil environment, promote plant growth and heavy metal absorption, and improve the efficiency of phytoremediation.

5)Study on the practice application of joint repair should strengthen various strengthening measures to jointly improve the phytoremediation of heavy metal contaminated soils.

6)The recovery process of low content heavy metals in plants still needs further study, so that the biomass of phytoremediation can be properly handled and environmental risks will be reduced.

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