Review on The Remediation of Heavy Metal Antimony Contaminated Soil

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Abstract. Environmental pollution has long been a hot topic in the world, and soil heavy metal pollution is particularly prominent. In recent years, many scholars have found that the heavy metal antimony (Sb) has been widely found in the soil, which has shown many problems that cannot be ignored and has attracted widespread attention in the academic community. Article summarizes the related accumulator plant of Sb and the physical remediation technology, chemical remediation technology and phytoremediation technology of Sb contaminated soil. It is expected to provide reference for heavy metal soil remediation, and hope to find a hyperaccumulator plant that can efficiently absorb heavy metal antimony, to promote green with permanent governance effect, economical, and completely repair technology application and promotion.

1. Introduction

Sb is a common trace metal, which exists mainly in the form of chemical combination in soil, and it is one of the heavy metal elements that can produce toxic effects on human body. Sb is not a necessary nutrient element for human body and plants, and its compounds are toxic to plants and animals[1]. Sb has different toxicity depending on its valence state and the toxicity of trivalent antimony is 10 times higher than that of pentavalent antimony. SbH₃ and Sb₂O₃ are the most toxic. Antimony trivalent toxicity is also related to the morphology and crystal structure of the compound[2]. Sb and its compounds have potential toxicity and carcinogenic effects. Due to their high toxicity, they have been listed as environmental priority pollutants by the US Environmental Protection Agency and the European Union in the last century. Sb is listed as hazardous waste in the Basel convention on the transboundary movement of hazardous waste [3-5]. Moreover, it is also a global pollutant that is transmitted over long distances [6]. China is the country with the most abundant Sb resources in the world, and about 80% of Sb production in the world comes from China [7-8]. "World Antimony Capital" is located in Lengshui River, Hunan Province.

In recent years, antimony pollution has been paid more and more attention by many experts at home and abroad. For the problem of heavy metal pollution in the environment, phytoremediation technology has performed well and has been well developed. Moreover, the phytoremediation of
heavy metals in soil has great potential and less secondary pollution, which can also maintain the fertility of the soil and keep the soil structure and fauna communities from being destroyed. Based on the existing research, this paper summarized the technology of heavy metal antimony accumulator plant and soil pollution remediation, in order to provide some suggestions for the pollution control of antimony in the environment in the future, and provide some scientific basis for reducing the content of antimony in the soil.

2. Heavy Metal Antimony Enrichment Plant

Baker et al. [9] showed that plant Alpine pennycress was transplanted into contaminated soil, and the results showed that the content of heavy metals in soil was greatly reduced, which proved that plants could be used for remediation of heavy metal contaminated soil. Brooks [10] research finding in 1977 that some plants in nature had a much higher ability to enrich heavy metals than other plants, and tried to use these plants to enrich some heavy metals. Therefore, the concept of hyperaccumulative plants was put forward, which referred to a group of plants growing in natural environment with dry weight of more than 1000 mg·kg⁻¹ of Ni as hyperaccumulative plants. More than 500 species of hyperaccumulative plants have been found nowadays, at the same time, the related literature reports of new hyperaccumulative plants were also emerging [12-13].

For a phytoremediation method, suitable hyperaccumulative plants are the prerequisite for this method. Finding a plant that can enrich one or more heavy metals has been an important part of soil pollution control. The study of antimony accumulator plant at home and abroad has just started. So far, several potential accumulator plants have been reported, most of which have not reached the level of hyperenrichment. Li Ling et al [14] studied Nephrolepis cordifolia growing on antimony slag. The results showed that the content of antimony in Nephrolepis cordifolia was relatively high, far higher than that in reference area, and Sb showed high tolerance. Wang Xiaoli [15] studied the enrichment effect of Pteris cretica 'albo-lineata' on trivalent antimony, pentavalent antimony and methyl antimony. The results showed that Pteris cretica cv 'Albolineata' showed significant enrichment effect on three forms of antimony, in which the aboveground and root contents showed high concentration, reached the standard of ultra-enrichment plants. Baroni et al [16] studied three species of Achillea ageratum, Plantago lanceolata, and Silene vulgaris grown on abandoned antimony ore. When the content of the extractable antimony reached a certain range, the three plants can enrich the antimony in a large amount. The content of antimony in leaves and flowers of Achillea ageratum was 1367 and 1105 mg·kg⁻¹, respectively; the content of root mites in Plantago lanceolata was 1150 mg·kg⁻¹; Silene vulgaris stem antimony content were 1164 mg·kg⁻¹. The results of Zhang Yaping [17] showed that Brassica rapa and Amaranthus mangostanus can be used as remediation plants for remediation heavy and high concentrations of heavy metal antimony in the field. Xue Liang [18] showed that Amaarantus paniculatus and Miscanthussinensis can be used to remediation soil antimony pollution, among which Miscanthussinensis as a kind of energy-producing plant with development value, can still bring huge economic effects while being used for Sb-polluted phytoremediation. It were an ideal Sb pollution repairing material. Feng et al [19] also found that Pteris cretica may be a potential antimony hyper accumulator. Yin zhiyao et al [20] found that rice, wheat and corn, the major grain crops, had strong enrichment capacity and high transport coefficient for heavy metal antimony. The study found that Boehmeria nivea can grow and settle in the soil contaminated by heavy metals and became the dominant plant in the mining area. It will have great research value as a potential plant for ecological restoration of abandoned land in the mining area [21].

3. Heavy metal antimony contaminated soil remediation technology

3.1. Physical and chemical remediation technologies

Soil heavy metal pollution is characterized by high risk, high concealment, irreversibility and long-term nature. However, due to the lack of research on soil heavy metal antimony remediation, the conventional remediation methods can be used for reference in general soil heavy metal pollution.
Therefore, heavy metal antimony contaminated soil can be treated by traditional methods for soil heavy metal treatment. Physical remediation technology [22] is based on mechanical physics of soil replacement, topsoil removal and deep tillage, which can effectively control the concentration of heavy metals in soil. However, physical remediation, in most cases, can only temporarily mitigate heavy metal hazards and there is a risk of secondary pollution. This method belongs to the treatment method of palliative treatment and does not fundamentally solve the problem of heavy metal pollution in soil. Physical remediation techniques can be used as a supplement to phytoremediation in soil remediation when contaminants pose an imminent danger to human health or the environment [23].

Soil leaching in chemical remediation technology [24] refers to the technique of leaching contaminated soil by eluent to achieve the purpose of transferring heavy metals in the solid phase of the soil to liquid phase fluids. The contaminated soil is excavated, sieved to remove surface residue and large soil, and mixed with the eluent. After sufficient leaching, the heavy metals in the soil are removed with the eluent, and then rinsed with water to remove residual eluent from the soil. Heavy metal-rich wastewater can be treated to recover heavy metals and extractants [25].

3.2. Phytoremediation
Chaney[26] first proposed the idea of phytoremediation of heavy metals in soil in 1983, which referred to the process of directly using green plants to absorb heavy metals in the soil, so as to reduce the content of heavy metals in the soil to the standard value. The toxicity of low-content heavy metals in the food chain and the migration and transformation of the food network was minimized, and finally it was harmless to the environment.

At present, there are relatively few engineering cases of antimony pollution remediation in soil, which mainly focus on indoor research. Now, Miscanthus sinensis, Boehmerianivea, Pteris cretica 'albo-lineata' have been studied more and the enrichment effect is better. Miscanthus sinensis has the characteristics of fast growth, high yield and easy reproduction. It can quickly cover the ground after sowing, which has certain promotion effect on soil retention and water conservation and improvement of surrounding environment [27]. Yin zhiyao et al [20] found that the root and overground parts of Miscanthus sinensis had strong enrichment capacity for the heavy metal antimony. Ku wenzhen et al[28] attempted to remediation antimony in soil with Miscanthus sinensis, and found that the average content of roots was 264.09 mg·kg⁻¹ in the laboratory pot experiment. The average content of aboveground was 414.21 mg·kg⁻¹, and the enrichment capacity of aboveground was greater than that of roots, and the average transfer coefficient was 1.66. She wei [29] used Boehmerianivea to remediation antimony in soil, and found that Boehmerianivea also had a good enrichment effect on antimony. The enrichment sites were mainly concentrated in the upper part, and the content reached 64.18~744.44 mg·kg⁻¹. The transfer coefficient was 5.85. Ku Wenzhen et al.[28] also showed that the Boehmerianivea enrichment coefficient and transport coefficient of antimony were greater than 1, satisfying the basic characteristics of antimony accumulator plant, and can be used as a pioneer plant for antimony pollution remediation. Feng et al[30]found that the arsenic accumulator plant Pteris cretica 'albo-lineata' was an antimony tolerant plant. Wang xiaoli et al[15] showed that Pteris cretica 'albo-lineata' showed significant enrichment effect on antimony, including the aboveground antimony content of 816 mg·kg⁻¹ and root antimony content of 6065 mg·kg⁻¹, which had reached the standard of hyper accumulator.

In summary, among the three kinds of antimony enrichment plants that have been studied more, the three kinds of antimony enrichment plants have better effect on antimony enrichment. The enrichment effect of Miscanthus sinensis and Boehmerianivea plants is far from reaching the standard of hyper accumulator plants, and Pteris cretica 'albo-lineata' can meet the standard. Studies have shown that the removal effect of Miscanthus sinensis and Boehmerianivea plants in soil pollution remediation is not practical, especially in the short-term farmland soil remediation[31]. At present, Pteris cretica 'albo-lineata' is one of the best plants for phytoremediation of soil contaminated
4. Concluding remarks and future research needs.
As a global pollutant, Sb is one of the most toxic metal elements in the world. Compared with other toxic metals (such as As and Hg), there are relatively few international studies on Sb, but the excessive content of Sb in soil is a fact and has potential harm to human health. According to the research status, in order to remedy the soil pollution of heavy metals, further research is needed in the following aspects:

(1) It is suggested that in the prevention and control of soil antimony pollution, publicity and management of antimony pollution prevention and control should be strengthened to strengthen people's understanding of antimony pollution hazards, starting from the source control to reduce the occurrence of man-made pollution; the relevant policies of government departments have been put into place. Secondly, more experts and scholars are needed to study antimony contaminated soil to solve the existing pollution problems.

(2) Increase the research on heavy metal Sb hyperenrichment plants, break through the bottleneck problem, find a plant that can enrich the heavy metal Sb in the soil, and expand the practical application of enriched plants to the prevention and control of soil Sb pollution.

(3) More efforts should be made to develop an efficient, economical, pollution-free and low-consumption plant joint remediation technology that can deal with more complex and various pollutants.

Acknowledgements
Sponsored by the Natural Science Foundation of China (51868010 and 51638006), the Natural Science Foundation of Guangxi (2018GXNSFAA138202), the National Key Research and Development Program of China(2016YFD0800800) and the Guilin Science and Technology Major Project (2016012004).

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