Research Progress of Artificial Forest in the Remediation of Heavy Metal Contaminated Soils

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Abstract. (1) Remediation of soil contaminated by heavy metals has become a hot topic in the world, and phytoremediation technology is the most widely used. (2) In addition to traditional economic benefits, ecological benefits of artificial forest have been more and more important, which are very helpful to soil polluted with heavy metals in the environment. (3) The characteristics of heavy metal pollution of soil and plantations of repair mechanism have been reviewed, and the current mining areas, wetlands, urban plantations on heavy metal elements have enriched the research results. The purpose is to find a new path for governance of heavy metal soil pollution.

1. Introduction
With the social development, a large number of metal materials are used. At the same time, serious pollution has also occurred. Heavy metal pollution has become a serious environmental problem. Many researchers are focused on a series of control technologies. At present, the best response is the phytoremediation technology, which is a biological treatment method. This technology features low cost and small disturbance to the environment. It has important significance in the treatment of heavy metal pollution of soil. Many plants have been studied as repair materials, including herbs, shrubs and woody plants. Much attention has been paid to research reports regarding the remediation of many woody plants contaminated by heavy metals, gradually mature woody repair mechanism, and artificial forest as a special community of woody plants. So this paper reviews the current research progress in remediation of heavy metal pollution on artificial forest soils, to provide more references for future related research.

2. Heavy Metal Pollution of Soil and Remediation Technologies
These heavy metals, including Cu, Zn, Pb, Mn, Cd, Hg, Ni, As, would cause soil pollution. According to reports, in 1950 there were 2.2 million tons of cadmium (Cd) emitted to air globally, 93.9 million tons of copper (Cu), 78.3 million tons of plumumb (Pb) and 1.35 million tons of zinc (Zn)[1]. For example, Cu^{2+} is a necessary element for plants[2], but excessive Cu^{2+} would cause serious harm to plants, thus leading to intracellular biological metabolism, and ultimately inhibiting plant growth[3].
Soil suffers the most serious heavy metal contamination. These metals eventually enter into the soil through ecological cycles, causing heavy metal pollution of soil to different degrees. For example, according to preliminary statistics, China currently has 26.67 million ha\(^2\) farmland subjecting to different degrees of heavy metal pollution, and the contaminative farmland accounts for 20% of the total farmland; Pb, Cd, Hg, Cu and combined pollution are most prominent[4]. Meanwhile, crops and other plants are grown in contaminated soil through the food chain cycle. Ultimately heavy metal elements in crops and other plants will enter the body, and eventually pose hazards to human body because of its biodegradable, highly toxic, significantly cumulative effect. So, prevention of heavy metal pollution of soil is extremely important.

Now remediation techniques are mainly around the physical, chemical, biological methods. To repair soil contaminated with heavy metals, physical methods are commonly used. New soil is used to replace old soil. Later, a heat-treatment is used for electric repair. The chemical treatment method is mainly based on soil chemical properties. It adds soil improvers, surfactants, inhibitors and other chemical reagents, in order to reduce the activity of heavy metals. The bioremediation method uses biological metabolic activity to reduce the concentration from harmful substances in the environment[5]. To treat heavy metal pollution, the physical and chemical methods were mainly adopted in the past, but physical and chemical methods are complex, costly, and likely to cause secondary pollution, so bioremediation is at the forefront of research. The most commonly used biological method is phytoremediation, which uses plants to absorb heavy metals. It is efficient and economical. In recent years, as the repair material plant has been used more and more, we find that the use of heavy metals and Hyperaccumulators tolerant plants is the key to phytoremediation.

3. Repair of artificial forest polluted by heavy metals

3.1 Restoration mechanism of artificial forest

The artificial forest is a special forest resource. Compared to natural forests, it has some advantages, such as fast growth and ease to use. Initially, planting artificial forest aims to meet the social demand for timber products, but due to ecological construction, artificial forest not only brings economic benefits, but also has more application areas, such as large quantities having been planted on the mining area, coastal wetlands, urban green land, desert, greenbelt and protected zones.

Many hyperaccumulators are herbaceous, but with phytoremediation technology development and discovery of hyperaccumulators[6], research shifted focus to woody plants[7]. So, in recent years, artificial forest has begun to play the role of phytoremediation for soils polluted with heavy metals. Artificial forest is woody plants, especially trees, which have large biomass, roots, stems, leaves, and dry areas having greater exposure to the environment. It can absorb, transform and degrade pollutants, and does not easily spread pollutants to the environment. Most artificial forest mainly aims at producing timber and the green environment. Even if the trees have enriched some heavy metal elements, it will not easily enter the food chain and cause harm to human health. Because of this reason, woody repair industry has emerged in many countries[8]. In China, over the past ten years, more and more studies showed that many trees play a special role in repairing heavy metal pollution.

3.2 Heavy metal pollution repair of the mining artificial forest

Mineral exploitation, especially some metal mining areas, can cause heavy metal pollution problems. Many studies have been focused on vegetation restoration mine. From 1999 the arsenic (As) hyperaccumulators[9], Sedum alfredii Hance and zinc (Zn) hyperaccumulators[10] were found in China; a variety of hyperaccumulators were planted, and artificial forest has been widely used in many mining areas.

In Malanzhuang iron ore of Tangshan, such measures as engineering reclamation and biological reclamation are adopted, which have initially established the artificial forest ecosystems[11]. It has not only improved the ecological environment in mining and restored vegetation, but also absorbed heavy metals iron mine (Fe) to one degree or another. In manganese mine wastelands of Xiangtan planted
artificial Koelreuteria paniculata[12], and analyses show that different ages of Koelreuteria paniculata can absorb Mn, Fe, Zn, Pb, Cu; and these heavy metals in Koelreuteria paniculata showed decomposition coefficients greater than migration coefficient. In zinc (Zn) ore area, Leucaena leucocephala (Lam)[13] not only survived, but also enriched 80% zinc in the xylem, which make heavy metal elements fail to migrate to other environments, thus avoiding the surrounding environment from being affected by pollution, and causing no plantations treatment of heavy metals in the mining area.

3.3 Heavy metal pollution repair of artificial mangroves
Mangroves are important coastal vegetation. It has a series of ecological roles, such as cleaning sea and air, protecting banks, dissipating wave, and being habitats and feeding grounds for many birds[14]. So, the coastal wetland system plays an important role. But now as the coastal tidal wetlands are increasingly polluted by heavy metals, the relationship of mangrove ecosystems and heavy metal pollutants has been studied, and these studies show that mangroves have some resistance and tolerance of various pollutants, and the mangrove forest has the ability to absorb pollutants and clean water[15]. By measuring three species of mangrove plants (Aegiceras corniculata, Kandelia candel (Linn) Druce, Acanthusilicifoliu) from Maowei Sea Mangrove Wetland of Guangxi[16], it has been found that the adsorption capacities of metal elements (including: Cu, Zn, Cr, Ni, Pb, Cd, Hg and As) of three plants are different, Aegiceras corniculata: Zn>Cr>As>Pb>Cu>Ni>Cd>Hg; Kandelia candel(Linn)Druce:Zn>Cr>Cu>As>Pb>Ni>Cd>Hg; Acanthusilicifoliu:Zn>Cr>Cu>As>Pb>Ni>Cd>Hg. These studies show that mangroves play an important role of controlling heavy metals. Especially in China's northern part (Fujian Province) there is Kandelia candel (Lin.) Druce ecosystem[17]. By analyzing its heavy metals and pollutant distribution, the artificial forest has great heavy metal adsorption capacities. In 2014, some scholars analyzed seven mangrove plants and their root heavy metal sediments (Cu, Zn, Cd, Pb, As), and the results show that in addition to weak transport capacities, other heavy metals have strong transport capacity. The article recommends introducing strong enrichment plants[18].

3.4 Heavy metal pollution repair of urban artificial forest
Suitable artificial forest is planted in urban areas, which not only play the role of greenbelt, but also prevent heavy metal pollution. There are research data showing that Pinus massoniana Lamb has a 23 years of planting history in urban areas in Guangxi[19]. These artificial trees totally accumulate six heavy metal elements, totaling 39.791kg/hm², where Mn, Zn, Pb, Cu, Cd, Ni elements reserves were 34.047, 3.351, 1.226, 0.874, 0.245, 0.084 kg/hm², reserves of heavy metals in the components of the spatial distribution of dry> bark> root> leaf> branch, indicating that Pinus massoniana Lamb could accumulate heavy metals, especially Mn. The same study also comes from the analysis of the accumulation and migration of Cinnamomum camphora (L) Presl forest of Hunan. Different heavy metal elements have different accumulation capabilities, and the general trend is Cd> Mn> Zn> Cu> Pb> Ni, and dry, bark, root, leaf, branch have different accumulation capabilities: dry>bark>root>branch>leaf. In other words, there are some heavy metals accumulated in the not easy moving parts of artificial forest. In densely populated areas, the human body could contact with heavy metals. Forests planted in many urban areas accumulated heavy metals from air and soil to trunk, and such forest clean the environment and avoid heavy metal elements from entering the food chain.

4. Conclusion
Compared with natural forests, the research applications of artificial forest have some undesirable factors, such as short planting years and unstable forest ecosystem. But now, with the progress of research and construction of artificial forest, the role of artificial forest has been continuously excavated in environmental governance.

So the problem should be studied more in the future:
(1) The plantation ecological benefits in terms of preventing acid rain, and other organic pollutants.
Further screen artificial forest to find more hyperaccumulators.

Technology of repairing heavy metal pollution is characterized by low investment, sustainability and ecological safety, which conform to the concept of ecological construction, but for the artificial forest that accumulates heavy metals, direction to use should be considered after harvest. Woody repair technology should be combined with other techniques, such as woody-herbaceous united phytoremediation, and physico-chemical methods.

Acknowledgements:
This study was supported by the NSFC (Natural Science Foundation of China) "Mechanism of soil quality variation in the process of vegetation restoration area of phosphorite Yunnan mining wasteland" (41361076).

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