Effects of Phytoremediation on industrial wastewater

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Abstract: Due to the development of industry, there are different levels of heavy metal pollution in domestic waters, and the treatment of heavy metal pollution is also imminent. As a hot plant for phytoremediation, Leersia hexandra Swartz has a good effect on remediation of chromium, copper and nickel polluted water. The highest removal rates of chromium, copper and nickel are 100%, 93.8% and 89.3% respectively. Leersia hexandra Swartz also has good enrichment characteristics of chromium, copper and nickel in heavy metal contaminated soil. In the soil containing chromium, copper and nickel, Leersia hexandra Swartz can grow normally and has strong tolerance to high concentration of heavy metal contaminated soil, which indicates that Leersia hexandra Swartz has certain research value in the field of remediation of heavy metal contaminated soil or water.

1. Introduction

Industrial wastewater is unavoidable in today's society, and the subsequent pollution problem has become a hot topic. Phytoremediation as the most popular technology to solve heavy metal pollution, more and more super-enriched plants have been found, Leersia hexandra Swartz is one of them. Leersia hexandra Swartz is a wet plant of perennial Gramineae and the only chromium-enriched plant found and reported in China. In recent years, Leersia hexandra Swartz's chromium enrichment ability and its influence on chromium enrichment have attracted much attention. All aspects of exploration have laid a foundation for the research of removing heavy metals and optimizing water body.

2. Production and Classification of Wastewater

Industrial wastewater includes production wastewater, production wastewater and cooling water. It refers to wastewater and waste liquid produced in industrial production process, which contains industrial production materials, intermediate products, by-products and pollutants produced in production process. There are many kinds of industrial wastewater with complex components. Because industrial wastewater often contains many kinds of toxic substances, polluting the environment is very harmful to human health. Therefore, it is necessary to develop comprehensive...
utilization and turn harm into benefit. According to the composition and concentration of pollutants in wastewater, appropriate purification measures can be taken to dispose of them before they are discharged.

3. Current Situation of Soil Pollution

Soil heavy metal pollution in China is mainly caused by the "three wastes" produced by mining, smelting, electroplating, chemical industry and other agricultural measures such as sewage irrigation and unreasonable application of pesticide and chemical fertilizers. Soil heavy metal pollution is one of the main problems affecting human health and environmental quality. It not only affects crop production, but also affects the quality of the atmosphere and water environment, and even endangers human health through the food chain[1].

3.1 Current status of copper, arsenic and chromium pollution in soils

3.1.1 Soil Copper Pollution

The background values of soil copper in China are 7.3-55.1 mg/kg[2], and the background values of copper content in layer A are 7.3-55.1 mg/kg. The median, 75 and 90 values are 20.7, 27.3 and 36.6 mg/kg[3], respectively. The normal copper content in soil is 2-200 mg per kg. The soil copper content in China ranges from 3 to 300 mg per kg, with an average of 22 mg per kg. Copper can be enriched in soil and absorbed by crops. Soils near copper smelters contain high concentrations of copper. Rock weathering and irrigation with copper-containing wastewater can accumulate copper in soil and retain it for a long time. The main sources of soil copper pollution are copper and zinc mining and smelting, metal processing, machinery manufacturing, iron and steel production, sewage irrigation, pesticides and so on[4]. Soil copper contamination has led to copper content in agricultural products in some areas, such as Beijing, Tianjin, Xi'an, Shenyang, Changchun, Wuhan, Chengdu and Shanghai, exceeding national food hygiene standards[5]. The sources of copper in agricultural soils in China are animal manure, atmospheric sedimentation, sewage and sludge in turn[6].

3.1.2 Soil Chromium Pollution

Chromium widely exists in nature and mainly forms chromite. The valence of chromium is divalent, trivalent and hexavalent. The natural source is mainly rock weathering, mostly in trivalent form; the anthropogenic pollution source is mainly the discharge of industrial chromium-containing waste gas and wastewater. Chromium in industrial wastewater is mainly a hexavalent compound, such as chromium ion. The exhaust gas from coal and petroleum combustion contains particulate chromium. Chromium is transferred to chromium with different valences in the environment. For example, trivalent chromium can be adsorbed on solid substances and exists in sediments (sediments); hexavalent chromium is mostly soluble in water and relatively stable; but it can be reduced to trivalent chromium under anaerobic conditions. China stipulates that the standard six-price concentration of drinking water should be less than 0.05 mg/L. The maximum allowable concentration of chromium in surface water is 0.5 mg/L (trivalent chromium) and 0.05 mg/L (hexavalent chromium). The maximum allowable emission standard of hexavalent chromium and its compounds in industrial wastewater is 0.5 mg/L (hexavalent chromium). Fishery water is 0.5 mg/L (trivalent chromium) and 0.05 mg/L (hexavalent chromium). The maximum allowable concentration of hexavalent chromium in the air of residential area is 0.0015mg/m³ (primary determination value) and 0.1mg/m³ (converted into chromium trioxide) in the air of workshop[7].

4. Phytoremediation Technology

Phytoremediation is an environmental pollution control technology based on the theory of plant tolerance and excessive accumulation of certain or some chemical elements, which uses plants and their coexisting microbial systems to remove pollutants in the environment[8, 9]. At present, physical and chemical methods are commonly used in the remediation of environmental contaminated soils,
such as soil drainage, dilution, leaching, physical separation, stabilization and chemical methods. High cost, difficult to manage, easy to cause secondary pollution, and environmental disturbance. In recent years, bioremediation technology has attracted wide public and scientific interest because of its low cost, suitable for large-scale application, beneficial to the maintenance of soil ecosystem, aesthetic value to the landscape of polluted land and little damage to the environment. Bioremediation technology includes phytoremediation technology, microbial remediation technology and microbial-phytoremediation technology[10]. Phytoremediation technology belongs to in-situ remediation technology. Its cost is low and secondary pollution is easy to control. After vegetation formation, it has the effect of protecting topsoil, reducing erosion and soil erosion. It can be widely applied to vegetation and landscape restoration of mine reclamation and heavy metal contaminated sites[11].Phytoremediation technology relies mainly on biological processes, which are slow and time-consuming compared with some common engineering measures[12]. The remediation of deep pollution is difficult. Because of the limitation of plant growth due to climate and geology, there is the possibility of pollutants entering the nature through the "plant-animal" food chain.

There are many reviews on phytoremediation[1, 8, 9, 11, 13-15], but there are still many limitations on the use of phytoremediation alone. For example, the low growth rate and quantity of phytoremediation plants, the low transfer rate of heavy metals and the high or low concentration of heavy metal pollution will affect the efficiency of phytoremediation, which limits the practical application of phytoremediation[16]. Some studies have shown that Leersia hexandra Swartz constructed wetland still has a good effect on the water remediation of chromium (VI) exceeding 150 times the standard (7.50 mg/L)[17], but the contribution rate of direct absorption and removal of chromium by Leersia hexandra Swartz is less than 10%[18]. How to improve the enrichment efficiency of Leersia hexandra Swartz to chromium environmental pollution is the key point of applying Leersia hexandra Swartz to control the environment.

5.Discovery of Leersia hexandra Swartz
Leersia hexandra Swartz is a wet plant of perennial Gramineae and the only chromium-enriched plant found and reported in China[19]. In wet environment, the rapid reproduction and high density growth of Poa littoralis make the biomass per unit area large, which improves the efficiency of remediation of heavy metal contaminated environment. At first, Leersia hexandra Swartz was concerned as a kind of weed harming rice fields, and relevant agricultural scholars began to study it[20, 21]. After that, it was found that Leersia hexandra Swartz had the biological characteristics of drought tolerance and waterlogging tolerance, and some scholars explored its potential in the field of soil and water conservation and vegetation restoration[22, 23]. Because Leersia hexandra Swartz also has a good absorption effect on other heavy metals, many scholars have also applied Leersia hexandra Swartz to heavy metal contaminated soil, constructed wetland to remediate heavy metal contaminated water and mixed domestic sewage water[24-26].

6.Characteristics of Chromium Superconcentration by Leersia hexandra Swartz
Based on the study of wet plants near an electroplating plant in northern Guangxi, it was found that Leersia hexandra Swartz had the characteristics of super-enrichment of chromium. The average content of chromium absorbed by leaves was 1787 mg/L. The ratio of chromium content in leaves to chromium content in rhizomes was 12, the ratio of chromium content in soil was 57, and the ratio of chromium content in water was 518[27]. Leersia hexandra Swartz also has a high removal rate of chromium, copper and nickel in mixed polluted water. Table 1 shows the removal effect of Leersia hexandra Swartz on different concentrations of chromium, copper and nickel in 10 days[28].

| Heavy Metal | Initial concentration mg/L | Day 1 concentration mg/L | Day 6 concentration mg/L | Day 10 concentration mg/L |
|-------------|---------------------------|--------------------------|--------------------------|---------------------------|
| Cr          | 10                        | 3                        | 0.9                      | -                         |
It is obvious that Leersia hexandra Swartz has a good effect on remediation of chromium, copper and nickel polluted water. According to the experiment, the highest removal rates of chromium, copper and nickel are 100%, 93.8% and 89.3% respectively. Leersia hexandra Swartz can also enrich chromium, copper and nickel in soils polluted by heavy metals. In soils containing 8516, 3442 and 2992 mg/kg of chromium, copper and nickel, Leersia hexandra Swartz can still grow normally and has strong tolerance to soils polluted by high concentrations of heavy metals[29], which indicates that Leersia hexandra Swartz has research value in the field of remediation of soils polluted by heavy metals or water bodies.

7. Super-enrichment Characteristics of Copper by Leersia hexandra Swartz

The investigation area is located in an electroplating industrial zone in northern Guangxi, about 110 km away from Guilin City. The wastewater produced by the electroplating plant contains heavy metals such as copper, chromium and nickel. After chemical classification, the wastewater is discharged into a nearby pond and then into a nearby river. Heavy metals such as copper, chromium and nickel have been deposited in ponds for a long time, which has a certain impact on the environment around ponds and rivers[30].

Table 2 shows that a certain amount of soil and plant samples with different concentrations were dried, digested and measured before and after transplanting, and their copper content was analyzed.

| Project | Copper addition | 0  | 100  | 200  | 500  | 1000 | 2000  |
|---------|----------------|----|------|------|------|------|-------|
| Transplanted soil |               | 28.61 | 132.06 | 237.63 | 576.43 | 909.74 | 1100.22 |
| Harvesting soil |               | 26.63 | 120.05 | 216.04 | 524.03 | 827.65 | 1000.58 |
| Leaf |               | 46.54 | 52.75 | 80.00 | 150.42 | 163.49 | 307.89 |
| Stem |               | 39.22 | 47.03 | 125.40 | 200.22 | 287.96 | 335.81 |
| Root |               | 49.22 | 60.38 | 84.12 | 277.54 | 341.96 | 500.33 |
| Bioconcentration coefficient | Leaf | 1.75 | 0.88 | 0.74 | 0.58 | 0.40 | 0.62 |
| | Stem | 1.47 | 0.78 | 1.16 | 0.77 | 0.70 | 0.67 |
| | Root | 1.85 | 1.00 | 0.78 | 1.06 | 0.83 | 1.00 |

The results of soil culture showed that the content of copper in leaves of Poa ledeburi was 46.11-308.07 mg/kg, and the bioaccumulation coefficient of copper in leaves was 0.40-1.75. When the concentration of copper in soil was 2 000 mg/kg, the content of copper in leaves reached the maximum (307.89 mg/kg), which was higher than that in other concentrations. When the concentration of copper in soil was 0, the bioaccumulation coefficient of copper in leaves reached the maximum (1.75), which was higher than that in other concentrations.

8. Expectation

On the one hand, the most common weeds in the field have the ability to enrich heavy metals, but now an unavoidable problem is that although Leersia hexandra Swartz has the advantages of fast growth and large biomass, the biomass of individual Leersia hexandra Swartz is relatively small. If we can
start with genetic engineering, we can improve its growth characteristics, increase the biomass of individual plant, and then improve its ability to enrich heavy metals. On the other hand, the current studies on hyper-enriched plants mainly focus on the accumulation of heavy metals, tolerance and accumulation mechanism of plants, and how to improve the metal accumulation of plants. However, little attention has been paid to the late treatment of phytoremediation plants, and the technology is not yet mature.

Acknowledgments
This work was supported by the Programs of National Natural Science of China (51608143), Guangxi science and technology program (GuiKe AD17195023, GuiKe AD18126018), Guangxi Key Laboratory of Environmental Pollution Control Theory and Technology for Science and Education Combined with Science and Technology Innovation Base, Program for High Level Innovation Team and Outstanding Scholar of Universities in Guangxi (Gui Cai Jiao Han [2018] 319), Guangxi special experts funded projects (Beidou Xi) and Special funding for Guangxi ‘BaGui Scholar’ construction projects (Huijuan Liu).

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