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General Research Paper

Investigation on the Bioremediation of Metal Pollution of Water and Soil Environment in Yongding River

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ABSTRACT

The Yongding River is the mother river of Beijing. However, due to the environmental pollution caused by economic development, the water and coastal environment of this river has suffered from great destruction. The ecological restoration of the Yongding River is imperative. Phytoremediation and microbial remediation have made certain achievements in the aspect of river pollution control, but both have their own advantages and disadvantages. How to make best use of their respective advantages depends on the collocation and combination of plants and microbes. Based on field research and former literature, we proposed the method of plant-microbe associated bioremediation to restore the water environment and remove heavy metal pollution in soil of the Yongding River. This attempt provides new ideas and methods for the restoration of the ecological environment of the Yongding River.

INTRODUCTION

Yongding River is the largest one in Haihe river drainage basin, with a total area of 4.7×10^4 km^2. The area of Yongding River, which flows through Beijing, is about 3200 km^2, accounting for 6.7% of the total watershed area. The length of Yongding River is about 747 km, and the part which flows through Beijing is about 170 km long, flowing from five districts: Mentougou, Shijingshan, Fengtai, daxing and Fangshan. According to the longitudinal slope and section of different characteristics, and the characteristics of the flood control, Yongding River is divided into the Guanting gorge section, plain city section, together with their pasture lands (Wen et al. 2012).

In recent 30 years, because that the rapid development of social economy did not coordinate well with ecological environment, the water resources of Yongding River basin were over developed. Moreover, from the late 1970s, human factors such as a large number of sand-excavating, too much pollution, etc., caused the Sanjiadian channel segment setting off, environment degeneration, serious sand blowing and even the river had dried up for a long time. Now the broad river is covered with thick sand; the bare riverbed is covered with continuous wild grass, becoming bleak. Especially in the late 80s, in the area of city from Sanjiadian to south loop six, the riverway is setting off; sand blows frequently; the ecological system becomes extremely fragile (Zhu & Deng 2012).

On October 22, 2010, the city is buzzing, because "city environmental protection the first major" finally settled. Beijing Mentougou court made the first-instance judgment, Beijing Huanxingyuan Environmental Protection Technology Corporation who contracted harmless sewage treatment plant sludge disposa of Qinghe and Jiuxianqiao, was found guilty by the court of major environmental pollution crime. Previously, the company poured 6500t sludge containing a variety of heavy metals and a large number of bacteria from Beijing Qinghe, Jiuxianqiao sewage treatment plant into the old bed of Yongding river that belongs to Beijing underground water resource conservation zone, causing the loss of wealth which was up to hundreds of millions of yuan.

In the face of these severe pollution incidents, the ecological environment of the Yongding river basin management is imperative. As a link between southwest regional ecology, Beijing important ecological corridor and the important water source, the development of the Yongding river management not only can greatly improve the ecological environment of Beijing area, but promote the steady development of regional economy, and play an important role on carrying out the strategic plan of building a world city, speeding up the Beijing international livable city construction, comprehensively implementing "Humanistic Beijing, science and technology Beijing, green Beijing" target, etc.

We learnt from the literature, the Beijing municipal government uses the "ecological water type" management mode to deal with the Yongding river management. By optimizing the scheduling of water resources, increasing the river reservoir, formed lakes and wetlands connected by stream, restored the natural morphology of river, and formed good urban landscape river (Li et al. 2006). And it associated both sides of the green land construction planning to achieve mutual fusion between river and city by repairing bottomland, closing river and growing grass, and restoring vegetation, etc. in the flood land and sand urban riverside zone.

According to current situation of Yongding river water environment and soil pollution as well as Beijing municipal government for the Yongding river governance mode, we believe that in the process of curbing pollution we should pay more attention to the Yongding river ecological benefit, rather than using the simple way of "have means to resist" to manage the heavy metal pollution in Yongding river. On the basis of governance, combining with the actual situation of Yongding river, we pay attention to reflecting certain ecological and economic values in the process of governance. Therefore, on the basis of predecessors' practice and research results, we put forward using plant microbes joint repair technology to restore the Yongding river ecological environment.

HEAVY METAL POLLUTION SITUATION

From the aspect of environmental pollution, heavy metals refers to mercury, cadmium, lead, arsenic, chromium and metals that have significant biological toxicity. Heavy metal pollution mainly consists of the water pollution and soil pollution. The wastewater containing heavy metal which is produced by modern industrial facts (such as mining, metallurgy, mechanical processing, surface treatment, heavy industry, etc.) will cause serious pollution to the environment, even threatening human life.

The water containing heavy metals mainly comes from mine pit drainage, electroplating factory plated parts washing water, drainage concentrator tailings, waste rock field rain flooding, non-ferrous metals processing factory, steel pickling water drainage, as well as paint, electrolysis, pesticide, pigment and other industrial sewage. Because heavy metals have enrichment and cannot be biodegraded, so in order to reduce their harm to the environment, we can only transfer their position or change their physical and chemical form in the practical management (Wang & Jiang 1993).

There were mainly two kinds of heavy metal wastewater treatment technologies around the world previously. One is to change dissolved state of heavy metal into insoluble metal deposits, thus we can get rid of the heavy metal from wastewater through precipitation and flotation. Such as neutralization precipitation, sulfide precipitation, the float, electrolysis, precipitation, etc. The other is to concentrate and separate the heavy metals in wastewater without changing their chemical forms, such as reverse osmosis, electrodialysis, ion exchange methods, etc. According to the effluent water quality, water quantity and other factors, these methods can be used alone or in combination (Hu 2008).

However, the effect of these two kinds of processing methods is unitary with limited ecological benefits. In recent years, the technology of plant united with microbe repairing the polluted environment becomes more and more popular, and it also creates a new situation for controlling water pollution.

CURRENT RESEARCH STATUS OF BIOREMEDIATION

Restoration of heavy metals pollution by plants: Phytoremediation technology is a way that can fix, absorb, transfer, transform and degrade pollutants through green plants, finally making them into harmless substances to the environment (Tang 2006). According to the mode of plants removing heavy metal pollutants, phytoremediation technology mainly contains plant extract, plant fixed and plant volatile, etc. Its principle is as given in Table 1 (Luo et al. 2007).

According to the several types of phytoremediation of heavy metal pollution, along with consulting relevant literature, we found the following several kinds of plants which can repair heavy metal pollution better.

Barit (*Leersia hexandra* Swartz) is suitable to grow in the wet environment. It is able to generate a lot of enrichment of heavy metals such as Cr, Cu, Ni and so on. Barit is the first chromium hyperaccumulation plants found in China (Zhang et al. 2006). Hyperaccumulator refers to plants that can accumulate heavy metals excessively. Brooks firstly put forward the concept of the hyperaccumulator (Liu 2010) in 1977. It seems to be a kind of extreme metal hyperaccumulation plants (Xue et al. 2004), which can absorb and accumulate large amounts of heavy metals from the growing

Table 1: The type and principle of phytoremediation of heavy metal pollution.

The type of phytoremediation	The principle
Phytoextraction	Using hyperaccumulation plant absorption of heavy metals in the soil, through harvest to achieve the goal of clear.
Phytostabilzation	Plants by changing the soil chemical, biological, physical condition to make the precipitation of heavy metals.
Phytovolatilization	Plants absorb easily volatile elements, such as, Hg, Se, turning them into a gaseous substance, which was released into the atmosphere through leaf transpiration, thereby eliminating pollution of water and soil environment.

medium, and will not cause any damage. In the process of studying barit repair of heavy metals (Cr, Cu, Ni) from polluted water, Zhang et al. (2008) and others found that barit has strong ability of tolerance to Cr, Cu and Ni. In harvest barit's root, stem and leaves, the content of Cr, Cu and Ni were higher. What is more, the heavy metal content in root was significantly higher than the other two parts.

Beijing's climate belongs to the temperate zone monsoon climate, where rainfall is more. Barit is suitable to grow in the Yongding river basin. Meanwhile, because the plant's absorption of heavy metals is relatively more, and it will not affect surrounding biological environment, so we can try to use the aggregation of the plant to achieve the effect of preliminary treatment of Yongding river heavy metal pollution. Of course, we need valid test to validate its feasibility.

So far, there have been many scholars and experts at home and abroad studying this subject that makes use of phytoremediation of heavy metal pollution of water bodies, and they have made a lot of progress. Liang junmei, etc. (Liang et al. 2008) took *Pistia stratiotes* L. as test material, using hydroponic method, studied the *Pistia stratiotes*'s repairing effects on copper polluted water. The test results showed that the *Pistia stratiotes* had good repairing effects on low copper polluted water. *Pistia stratiotes*'s repairment for copper relies mainly on the absorption and accumulation in root. The root's accumulation of Cu^{2+} is much higher than that of leaf part accumulation. And the test results also showed that *Pistia stratiotes*'s enrichment ability of Cu^{2+} has something to do with Cu^{2+} water mass concentration and pH. Tang et al. (2010) examined duckweed's potential in the application of heavy metal pollution of water body restoration, and found that duckweed has good repair and absorption effect on Zn. Dai Quanyu's (Dai et al. 1998) study shows that, the effect of *Lolium multiflorum* treatment for wastewater containing gold (Au) is very obvious, and the root of *Lolium multiflorum* (dry weight) contains Au whose purity will be up to 784 g/t. *Thlapi carulescens* is a common material to study phytoremediation of soil heavy metal pollution at present. *Thlapi carulescens* is a kind of wild herb. It has great potential for absorption of Zn and Cd (Liu et al. 2003). *Pteris vittata* is firstly discovered arsenic hyperaccumulation plant, its content of As is up to 5070 mg/kg (Liu et al. 2003). In addition, there is a kind of commonly used plants as resources-*Brassica juncea*. *Brassica juncea* can endure and normally grow in the environment containing Zn, Pn, Cu and Cd (Jiang et al. 2000), and has good repair effect on Zn, Pn, Cu and Cd pollution.

The above are some cases which can be referred to the use of phytoremediation of heavy metal pollution. From the disposal methods of heavy metal pollution, we get some enlightenment. First of all, there are some local existences in heavy metal pollution. Different places may have different sources of heavy metal pollution, mining, ore washing dust, ore dressing, smelting, steel rolling, electroplating industries will cause heavy metal pollution. Therefore, the priority is to find out pollution sources when controlling heavy metal pollution, so as to suit the remedy to the case. And then target the pollution by the selection of plants; there should be systematic experiments. We can choose targeted guardians "pollution defender" through detailed accurate experimental data. Last but not least, although the plant repair in the treatment of heavy metal pollution has great potential to develop, but there are several deficiencies, such as plant repair is very slow, repair cycle is long, plants' tolerance is limited, etc.

Restoration of heavy metal pollution by microorganisms: Methods of microbial technology applied to the control of soil heavy metal pollution mainly have two kinds: one kind is the transformation of heavy metals by microbes, and another kind is the adsorption of heavy metals by them.

Microbial transformation of heavy metals refers to its metabolites using microbial or some reduction cells themselves by microbial oxidation and reduction, and methylation or demethylation effect will transform toxic metal ions into non-toxic or low toxic precipitation. Under anaerobic conditions, S^{2-} produced by the hydrolysis of sulphate reducing bacteria (SRB) produce H_2S, and metal ions Zn^{2+}, Cd^{2+}, Pb^{2+}, Cu^{2+}, etc. form their sulphides and get reduced by precipitation reaction (Tao et al. 2003).

The adsorption of heavy metals by microbes mainly has two forms: active adsorption and passive adsorption, which is given priority to passive absorption. Passive absorption means all types of microbes on the surface of the active group, such as extracellular polysaccharide, chemical genes, react with heavy metal ions via complexation, chelation, ion exchange etc. (Tao et al. 2003). Zhou Ming and others (Zhou et al. 2006) researched using *Bacillus licheniformis* dead bacteria to adsorb Cr^{6+} in water, the research results showed that *Bacillus licheniformis* dead bacteria have good adsorption effect for Cr^{6+} under optimized conditions, namely the temperature of 50°C, table speed of 140 r/min, solution pH of 2.5, adsorption time of 2 h, bacteria concentration of 1 g/L, Cr^{6+} initial concentration of 300 mg/L, the bacteria of Cr^{6+} had the maximum adsorption capacity of 60.5 mg/g. *Bacillus licheniformis* R08 dead bacteria Pd^{2+} adsorption, adsorption capacity can reach 224.8mg Pd^{2+} per gram mycelium (Tang et al. 2008).

So far, there have been many studies of the microbial treatment of heavy metal, involved in genetic engineering and immobilized microorganism technology. Such as γglutamine cysteine (γ-glu-cys) is synthesize by glutamic acid and cysteine through the catalysis effect of glutamine cysteine synthetase (γ-glutamyl cysteine synthetase γ-ECS), and the further synthesis is GSH. These compounds all contain -SH, and they can be combined with Cd (II), Pb (II) and As (III), reduce the poison to the plant, and promote their absorption and accumulation. Expression of γ-ECS genes in arabidopsis and Indian mustard GSH and γ-glu-cys content is significantly higher than reference (Li et al. 2010). We can assemble aim genes or make use of the mutational gene which controls a certain feature of human body, in order to make the microbe adapt to the water flow rate, temperature, concentration of metal ions, pH, etc. better and improve the effect of treatment to heavy metal pollution, meanwhile extend the time of the action. Immobilized microorganisms technology is a way that can limit free microbes to a specific space by chemical or physical methods. It can keep microbes active, and we can use the microbes repeatedly by this new technology. For example, Iqbal et al. (2004) used a new type of porous low-cost carrier-*Phanerochaete chysosporium*, and studied the adsorption of Pb^{2+}, Cu^{2+} and Zn^{2+}. Finally, results showed that the immobilized bacteria remove Pb^{2+}, Cu^{2+}, Zn^{2+} in water better, reaching levels of 14.6%, 12.8% and 16.1%.

We are inspired by some biological symbiosis principle that whether we can use biological collocated with plants to control the ecological environment pollution?

YONGDING RIVER ECOLOGICAL ENVIRONMENT RESTORATION SITUATION AT PRESENT

Development of Yongding river ecological restoration: At present, the "four lakes-one line" engineering in southwest five regions has made some achievements in the management of Yongding river. Upstream, for example, Sanjiadian's reservoir has formed the water storage, while the downstream Lugouqiao in Fengtai has restored the landscape named Lugouxiaoyue. The Yongding river in Shijingshan section, which is 13.8 km long, has formed green land and wetland, with no bare surface. It has changed greatly compared with before. The green ecological development zone called "four lakes-one line" project which connects Mentougou's Mencheng lake, Shijingshan's Lianshi lake, Fengtai's Xiaoyue lake and Wanping lake, is the important achievement of the western ecological conservation zone construction of Beijing, and it has become a new engine to promote the development of southwest five area economic society.

By constructing Mencheng lake, Mentougou district has made great contributions to ecological management of the Circumjacent area and the upper 5 branches, especially in the field of construction of ecological clean small watershed. The constructions has managed the Yongding river's gorge section and its main tributaries ecologically, and the effect is remarkable. The Shijingshan district through the existing Shekwu construction, promoted the Shougang demolition and reconstruction and emerging industry base construction, at the same time focus on mining along the banks of the Yongding river historical and cultural resources, cultivation of special tourism brand, to develop "water bank" drive the adjustment of industrial structure transformation, and creating new economic growth point. Fengtai through ecological zone construction, integration of a bridge (Lugou bridge), a city (Wanping city), an island (Xiaoyue island), a town (Changxindian old town), a park (Fair park), three lakes (Fair Park lake, Xiaoyue lake and Xiao Wan Ping lake) and other resources, unified planning of 50 km^2 industry development area, and committed the Yongding river ecological district, further promoting the industry gathered themselves together, and raising the overall strength of the industry.

Plant-microbial joint repair in Yongding river governance remains a blank: We have investigated and studied the present pollution and repair situation of Yongding river, reaching the conclusion that there is no governance, which applies the technology on soil heavy metal pollution of rivers.

According to relevant data, we know that using plant-microbial joint repair, not only can fix the soil heavy metal pollutants, but can also play a certain degradation and restoration on the organic pollution. Different processing has a definite effect on the degradation of soil total hydrocarbon content, which makes the effect of bioremediation and scope of application further improved (Ma et al. 2005).

But, there are corresponding disadvantages with plant and microbial remediation, such as phytoremediation has a longer period, tolerance is limited, the more stringent requirements on the living environment and microbes in the repair process, and easy disturbance by indigenous microorganisms controlled by surrounding environment and so on. The joint repair of plants and microbes, especially the cooperative action of plant roots and rhizosphere microorganisms, has achieved good effect in small repair (Chen et al. 2002). Plants and microorganisms joint repair is mainly manifested in the following aspects: a. Plants provide superior survival environment for microbes, which increases microbial chances of survival, and is conducive to restoration of microbial activity. b. Rhizosphere microbial communities can reverse enhanced plants to absorb nutrients. Thus, improving survivability of the plants in the environment. c. Through microbial nitrogen fixation and mineralization of element, the soil fertility has increased.

Plant-microbial joint repair is an effective way of bioremediation. We should study more about the joint repair function between them. The key to plant-microbial joint repair contaminated soil is to find a suitable matching combination of plants and microbes according to the actual situation of soil pollution

CONCLUSIONS

Through the comparison and reference of the existing literature, it is not difficult to find that plant-microbes joint repair method combines the advantages of two single methods to strengthen the effect of heavy metal pollution control. The chosen plants and microbes possess extensive source and high selectivity. The technology is easy for experimental investigation and argumentation, and its methods are simple and practical. Meanwhile, it is simple and costs little, and will not bring secondary pollution. What is more, we can adjust the proportion of the chosen plants and microbes flexibly in the process of governance, in order to apply the technology in different areas of the river. According to the characteristics and the actual situation of each section of the river, we can choose distinct plants and microorganisms to work together, thus, achieving the goal of reasonable management of water pollution. We hope that plant-microbes joint repair method can offer a reference to ecological environment repair of Yongding river, and provide new ideas and methods for ecological corridor construction of Yongding river.

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