Review the function of large aquatic plants in water pollution treatment

By

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ABSTRACT

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Keyword：water pollution，large aquatic plants，treatment，phytoremediation

Being a worldwide problem, water pollution has a huge impact on the mankind. The world has invested a lot of manpower and material resources after the environmental governance. Environmental pollution control has a new breakthrough with the emergence of phytoremediation technology that has the characteristics of low cost, more ecological and environmental friendly. This paper summarizes the mechanism of large aquatic plants in water pollution treatment, the status of water pollution, and the application of large aquatic plants in order to minimize the content of pollution from water. Moreover, the discussion is also based on the selection principle of aquatic plants to decrease the water pollution and safe disposal to used aquatic plants.

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INTRODUCTION

The earth is said to be as a “blue planet”, as 70% of its surface is covered with water. However, in reality, 97.5% of water is salt water and the fresh water accounts for only 2.5%. Moreover, nearly 70% of the fresh water is fixed in the Antarctic and Greenland glaciers, the rest in the soil moisture or deep groundwater, which cannot be used by humans. Hence, less than 1% of the earth's fresh water is there to consume by humans directly (Zhong, 2002). These waters are provided through lakes, rivers, reservoirs and shallow groundwater sources. In other words, water is the most precious and limited resource for mankind. Furthermore, there are numerous activities such as erosion, climatic changes, evaporative cooling, hydropower, promotion of the cycling of inorganic and organic matter and so on. However, with the rapid development of industrialization and urbanization, many toxic substances like pesticide and some organic pollution have entered the water system. This has made the problem of water pollution the most serious environmental problem that the world is facing today. About 42 billion cubic meters of sewage is discharged into the rivers and lakes every year, polluting 5.5 trillion cubic meters of fresh water, which is equivalent to more than 14 percent of global runoff (Wang 2017). Human activities such as mining, metal smelting, chemical industry, coal combustion, automobile exhaust emissions, domestic wastewater discharge, pesticide and chemical fertilizer application and atmospheric deposition are the main factors causing pollution in the water bodies.

Water pollution can bring some negative effects to the water ecological system function. Some harmful substances, like heavy metal ions and organic pollutants, can keep in water over one hundred years. These toxic substances are consumed by humans through the food chain. For example, the little fishes eat the tiny organic particles; big fishes eat those tiny fishes; and human in turn eats the big fishes. Hence, ultimately the health is getting affected.

Everyone is aware of the fact that water pollution is a serious problem that is effecting the human survival and sustainable development. It is negatively affecting human health, agricultural productivity and the stability of natural ecosystems. The establishment and development of strategies and technologies for the removal of water pollution has become an important area of scientific and technological research. Compared with the physical technology and strategy of mechanical decontamination method, the strategy of using green plants to remove pollutants is an environmentally friendly approach to water pollution.

Phytoremediation is a generic term that uses plants for remediating soils, sludge, sediments and water contaminated with organic and inorganic contaminants. It can be defined as “the efficient use of plants to remove, detoxify or immobilize environmental contaminants in a growth matrix (soil, water or sediments) through the natural biological, chemical or physical activities and processes of the plants”. Plants are unique organisms equipped with remarkable metabolic and absorption capabilities, as well as transport systems that can take up nutrients or contaminants selectively from the growth matrix, soil or water. Phytoremediation involves growing of plants in a contaminated matrix, for a required period of time in order to remove contaminants from the matrix, or facilitate immobilization (binding/containment) or degradation (detoxification) of the pollutants. The plants can be subsequently harvested, processed and disposed (Wang S M, 2006).

Aquatic plants in the ecosystem are primary consumers. They are autotrophic organisms. They play a key role in maintaining a virtuous cycle of aquatic ecosystems. The examples include- aquatic plants can store short-term nutrients such as N P K, which inhibits the growth of lower aquatic plants such as algae, purify contaminants in water, provide habitat for some organisms, as well as to promote water production, nitrogen cycle.

Table 1: Common ecological restoration of aquatic plants

Pollution factor	Phytormediation Plant
Cd	*Iris, Canna, Rushes, Barracude, Ipomoea, Metzyllum*
Pb	*Oriental cattail, Cape health Chara, Canna, Rushes*
Cu	*Reed, Eichhornia crassipes, Algae*
Zn	*Reed, Eichhornia crassipes, Algae*
As	*Eichhornia crassipes, Algae,*
Mn	*Eichhornia crassipes, Algae, Acours calamus*
Hg	*Algae, Progency Chara*
Cr	*Algae, Progency Chara*
Co	*Algae,*
N P	*Eichhornia crassipes, Canna, Calla*
COD	*Eichhornia crassipes, Calamus, Water Iily*
BOD5	*Eichhornia crassipes, Reed, Cat-tail*
Phenol	*Rush,*
Pesticide	*Canna, Chrysanthemum*

Aquatic plants are mainly composed of three major categories: aquatic vascular plants, aquatic mosses and higher algae. However, the vascular plants play the most significant role in the sewage treatment. The plant individuals are relatively tall, usually can be divided into algae, emerged plants, floating leaves plants and submerged species (Chong, Hu and Qian. 2003).

Table 2：Four kinds of life type of aquatic plants （source：Chong，Hu and Qian. 2003）

Life type	Growth characteristic	Represent plants
Garden Greenland plants	Rhizome was born in the sediment	*Reed, cattails*
Potted flowers	The plant body is completely floating on the surface of the water, with a specialized adapt to the floating life of the organizational structure	*Eichhorniacrassipes, Duckweed*
Cut flowers	Rhizome was born in the mud, the leaves floating in the water	*Water Lily, Nymphoides*
Indoor water tank	Soil or muddy water interface following the services	*Cryptomeria*

OBJECTIVE AND HYPOTHESIS

Due to its cheap and environment friendly nature, phytoremediation technology is a widely used technology in recent years. With the discovery of some aquatic plants, the control treatment of heavy metals and organic pollutants in water environment system has been a top most research topic in the world. Due to this, the aquatic plants have the same characteristic of hyperaccumulation plants. In this paper, some normal aquatic plants will be discussed, and aquatic plants mechanism analysis, practical application, control treatment effectiveness and developing prospect will be explored. Furthermore, some factors that influence the ability of aquatic plants to clean water pollution will be listed down and discussed.

LITERATURE REVIEW

1. THE CURRENT SITUATION OF WATER POLLUTION IN CHINA

The information was published by the National Environmental Protection Agency which is related to water pollution.There is an outline about surface water quality in the seven major rivers of china from the published data. For example, the organic pollution is the most urgent problem in the Songhua River and the Liaohe River systems. The polluted river that reached accounted for about 50 percent of the evaluated river reaches in length in 1986. In the Haihe River basin, water quality is the worst. There are many published researches consequences to support the fact. For example, in a comprehensive pollution index, the organic pollution and heavy metal pollution of the Haihe River basin are the first and second most serious respectively among the seven major river basins. In the Huanghe River basin, natural water quality is terrible. There are many suspended matter content at all monitoring cross-sections which exceeds the standard. As we all know, heavy metal ion and chloride contents were at high levels in the past. Currently, organic pollution is rather serious; N content is growing, while arsenic content is reducing. Comprehensive water pollution index of the Huaihe River basin is the second most serious which is only below than that of the Haihe River, but heavy metal pollution of the Huaihe River basin is the most serious. Organic chemical is the major pollution, and the 55.8 percent of the evaluated river reaches was polluted. Further, water quality of the Huaihe River is getting worse in recent year, especially during the low-flow periods. The concentration of ammonia N, phenol, nitrite N and lead, mercury, cadmium and chromium is becoming higher. In the Changjiang (Yangtze) River basin, the major pollution appear on some tributaries, lakes and urban river have been polluted seriously. The main pollutants are suspended matter the ammonia N pollution. In the Pear River basin, water quality is not bad, the main water pollution is from organic pollutants. Furthermore, the pollution from ammonia N, organic chemicals nitrite N is becoming heavier in specific river reaches.

DEVELOPMENT HISTORY OF CLEANING POLLUTION BY AQUATIC PLANTS IN CHINA.

The ecological function of aquatic plants in the water body makes it a very useful component in the prevention and control of water pollution. Due to the increase of water pollution, an efficient and environmentally friendly treatment technology had started to grab people’s attention towards itself. Many of the substances resistance to pollution and purification capabilities of these aquatic plants studies have founded that water pollution restoration of ecological engineering technology has been developed, and the technology is an as the core of large-scale aquatic plants to clean pollution.

In the1990s, scientists used floating island in order to carry out repairing work in Wuli Lake in Wuxi City, and they founded that N, P removal efficiency is high. Then in 2002, using the technology of phytoremediation to clean the Yongding River and other polluted water bodies in Beijing has gained excellent phytoremediation results. Further, in 2002, the study of Jianjun Shi showed that those aquatic plants were used to accumulate the radioactive elements in the water. In 2005, the study of Yi Wang showed that there was a positive function for reducing the toxicity of heavy metal pollutants through the aquatic plants system, thus lower the water toxicity and repair the water body.

China began to improve the environment by focusing the research work of aquatic plants purification abilities, and hence developed Tai Lake, Dianchi Lake, and the East Lake’s eutrophication control and ecological restoration demonstration research in the early 1990s. The study found that the disappearance of the Donghu Lake’s cyano-bacteria populations was related to the stocking filter-feeding fishes. The later researches and tests were based on using silver carps such as predatory fish, as filters to control the eutrophication for lake water’s phytoplankton (algae) quantity and improve water quality. Chinese Academy of Sciences, Nanjing Lakes Geography, set up a pilot area of the demonstration project in Wuli Lake Shore, for establishing the associations among emergent aquatic plants, floating-leaved plants and submerged plants. During the project, the aquatic plants’ diversity index reached up to 40%, and the dominant plant in lake water was changed from algae to large aquatic plants. The area later on found improvement on its water quality and became clear water.

SOME INFORMATION ABOUT AQUATIC PLANTS

Plant adsorption is the direct occurrence of roots (or stems and leaves) surface which is considered to be the most rapid removal of heavy metals, N, P and organic ion from the water. These aquatic plants can absorb pollutant by chelation ion exchange, selective absorption and other physical and chemical processes (Reddy and Debusk, 1987), that plants can be used for cleaning water pollution and they must have the following characteristics (Yan 2003）:

(1) Plants also have a higher rate of accumulation even in the lower concentration of pollutants.

(2) Plants can be enriched in high concentrations of pollutants in their body.

(3) They can absorb the accumulation of several heavy metals, N P and the organic ion pollution (Samecka and Kemper. 2004).

(4) They can contribute to fast growth, large biomass (height), along with insect resistance

Table 3: Upper limit of tolerance of some aquatic plants to heavy metals (mg/L)（source：He，Geng and Luo. 2008）

Heavy metal ion	Hg	Cu	Cd	Zn	Pb
Ottelia	-	15.4	0.10	4.00	40.3
Hornwort	1.00	7.80	5.00	-	-
Water hyacinth	0.06	20.0	5.00	10.0	30.2
Nymphoides Levin	-	-	0.20	0.50	-
scirpus tabernaem-ontani	-	-	30.0	-	-
Algae	-	5.00	10.0	-	-

It is to be mentioned that aquatic plants can clean water pollution as they can absorb the heavy metal ion and N, P from the water bodies. However, these aquatic plants will die when the heavy metal ion, N, P and the organic pollution content in the water are out the upper limit of tolerance for some of the aquatic plants. In the table 3, the upper limit of tolerance of some aquatic plants to the heavy metals are listed, the highest upper limit of tolerance to Pb is *Ottelia*, it can live in the water whose Pb content is 40.3mg/L. Most aquatic plants can live in the water which is polluted by Cd, and the *scirpus tabernaemontan* even can live in the 30mg/L Cd of polluted water.

However, a quite large amount of aquatic plants cannot live in the Hg polluted water as the Hg ions are able to destroy the cell structure of the aquatic plants（Jia. 2005).

Table 4: Upper limit of tolerance of some aquatic plants to N P (mg/L) （source：Chen et al 2008）

Plant name	Maximum height （m）	Nitrogen content	Phosphorus Content
Coix	2	24.1-25.6	4.2-5.6
Reed	3	18-21	2.0-3.0
Mosaic reed	2	17.2-35.1	1.7-6.2
Trapa incisa var. sieb.	1	10.9-25.1	1.3-6.9
Incisa var. sieb	1.8	16.8-27.9	4.4-5.3
Chrysanthemum	0.8	12.3-29.9	1.61-5.94
cat-tail	2	5.0-24	0.5-4.0
Rush	1	15	2
Iris	0.5	4.7-25.3	2.3-4.7
Calamus	1.2	11-35	2.3-5.7
Algae	-	12.0-48	1.5-11.5
Duckweed	-	25-50	4.0-15.0
Eichhornia crassipes	-	10-40	1.4-12
Salvinia	-	20-48	1.8-9.0

Vallisneria	0.5	16.9-30.5	2.2-4.7
Spruce	-	1-38	1.2-6.4

In table 4, the Maximum height and the upper limit of tolerance of some aquatic plants to N, P are listed. The highest upper limit of tolerance of N and P are the Duckweed, in which the nitrogen content is 25-50 mg/L and the Phosphorus content is 4.0-15.0mg/L

CURRENT ISSUES ABOUT CLEANING WATER POLLUTION BY USING AQUATIC PLANTS.

. There are many studies on the remediation of the soil pollution by using plants, but it is not sufficient. Lots of applications of plant pollution remediation, such as heavy metal remediation in water, the absorption and accumulation of pollutants in plants, the tolerance of different concentrations of pollutants, and strong pollutant-tolerance aquatic plants selection， are also need to be further take into the account. In addition, due to geographical and market factors, aquatic plants market factors and aquatic plants market demand, the aquatic ecological restoration still has many potential problems. Therefore, this field of plant ecological restoration needs to carry out a wide range of work and analysis-.

Firstly, in order to study the combination multiple types of plant clean effect, the systematic absorption and tolerance of aquatic plants need to be researched. Secondly, to study the ability of aquatic plants to clean multiple pollutants, further, some factors need to solve which reduce the clean capacity of aquatic plants, such as competition, microbial invasion and so on. Thirdly, to understand the current aquatic plants market on the scale of water treatment and water pollution, ecological restoration required aquatic plants species and quantity. And to deal with the different aquatic plants that live in different depth water level and the different types of pollution.

MATERIALS AND METHODS

There are many information which has been compiled from Chinese publications stemming mostly from the last decade, to show the research results on the role of aquatic plants in cleaning water pollution, and to provide a general outlook of phytoremediation in China. Related references from scientific journals and university journals are searched and summarized in sections concerning the accumulation of heavy metals, organic ions, N P ions in plants, aquatic plants for these toxic ion purification techniques.

By analyzing these data, the application status of phytoremediation in China and current status of water pollution could be found out. According to the severity of different water pollution and related researches in China, this paper mainly classifies and summarizes the relevant research progress of three different types of water pollution and the mechanism of action of aquatic plants to clean this pollution. Finally, the restrictions on the development of aquatic plants applications are discussed.

RESULT

It is to be noted that the normal water pollution can be divided into: heavy metal pollution, organic pollution and N P pollution. The mechanism of action of aquatic plants was introduced to clean the heavy metal pollution, N P pollution and organic pollution. Furthermore, there are seven aquatic plants that are listed for introducing the ability of aquatic plants to clean these pollution and they are:

Figure 1. *Typha latifolia*

Figure 2. Cyperus al ternifolius L.

Figure 3. *Phragmites communis Trirn*

Figure 4. Scirpus validus

Figure 5. Acorus Camumus L.

Figure 6. Juncus ohwianus Kao

Figure 7. Zizaniacaducif]ora Hand. Mazz （Z.latifolia Turcz)

After the sewage enters the artificial wetland, the plants can remove the pollutants in the sewage through absorption, and adsorption including the absorption and utilization of nitrogen and phosphorus, and the adsorption and accumulation of heavy metals. In 1997, Copper found that the contents of nitrogen and phosphorus in constructed wetlands planted with *Typhaangustifolia* and *Juncus effuses* were 18% -28% and 20% -31%, which were lower than those in the non-vegetative control substrate. This means that *Typhaangustifolia* and *Juncus effuses* absorbs and use some part of the sewage nitrogen and phosphorus. In 2001 , Cheng demonstrated that *Cyperus alternifolius* could consume 30% of the copper and manganese in the polluted water, and absorb the zinc, cadmium, and lead from 5% to 15%.

- Adsorption and enrichment of heavy metals by plants

A large number of studies have found out that planted wetlands system has higher removal capacity of heavy metals in sewage than that of no plant system (Kantawanichkafl et al., 1999; Ansola et al., 2003). This indicated that the aquatic plants have great ability to absorb heavy metals. Plants can directly absorb water-soluble heavy metals through the roots, and can also change the chemical form of pollutants by changing the rhizosphere environment (pH, Eh), to reduce or eliminate the chemical toxicity and biotoxicity of heavy metal pollutants (He et al., 2003). Chengsheng Yang et al. further explain the adsorption of heavy metals in four species of *Typha, Reed, Cyperus malaccensis and Cynodondactylon(Linn.)*. The study results showed that all these four species have strong adsorption ability to heavy metals, and heavy metals are mainly concentrated in the underground part of the plant.

Mays et al. (2001) explained the treatment of low concentrations of heavy metal wastewater with constructed wetlands and found that the most heavy metal elements such as Pb and Cd can be accumulated by wetland plants.

Table 5. The different bioconcentration factor (BF) and traslocation factor (TF) to Cd and Pb from different plants stem part and root part （source：Yang et al，2004）

Plant Name	Stem part BF		Root Part BF		TraslocationFactor (TF)	
	Cd	Pb	Cd	Pb	Cd	Pb
Typha orientalis Presl	0.087	0.035	0.25	0.16	0.34	0.2
Cyperus alternifolius	0.029	0.029	0.13	0.082	0.21	0.35
Phragmites communis	0.058	0.066	0.12	0.2	0.46	0.31
Scirpus validus Vahl	0.15	0.021	0.36	0.07	0.42	0.29
Juncus effusus L.	0.31	0.044	0.22	0.14	1.39	0.31
Sorghum	0.13	0.048	0.345	0.11	0.38	0.41
Acorus calamus L	0.2	0.094	0.47	0.19	0.42	0.48

According to the table,*Juncus effusus L.* has the highest BF to Cd in the stem part as compared to the other plants which is 0.31. However, the lowest BF to Cd is 0.029 which is from *Cyperus alternifolius* stem part. In the part of root, *Acorus calamus L* has the highest BF to Cd, which is up to 0.47, but the *Phragmites communis* has the lowest BF to Cd of 0.12.

In the stem part, the *Juncus effusus L*. has the highest BF to Pb which is 0.094, the lowest BF to Pb is 0.021 which is from the *Scirpus validus Vahl*. In the root part, *Phragmites communis* provide highest BF to Pb (0.20). The *Scirpus validus Vahl* has the lowest BF to Pb (0.07).

The *Juncus effusus L* has most significant TF to Cd which is up to 1.39. This means that the *Juncus effusus* can efficiently remove the heavy metal from root part to the stem part. The TF is an essential factor which influences the purifying ability of aquatic plants.

Table 6. The concentration of different plants stems part and root part to Cd (mg/kg）（source：He，2003）

Plant Name	Stem part of concentration	Root part of concentration
Typha orientalis Presl	0.08	0.26
Cyperus alternifolius	0.03	0.16
Phragmites communis	0.06	0.13
Scirpus validus Vahl	0.15	0.38
Juncus effusus L.	0.32	0.22
Sorghum	0.12	0.36
Acorus calamus L	0.3	0.49

From the above table, it is to be concluded that, in the stem part group, the highest Cd concentration is from the *Juncus effusus L,* which is 0.32 mg/kg, and the lowest Cd concentration is from the *Cyperus alternifolius*, which is 0.03mg/kg. Whereas, in the root part, the highest Cd concentration is from the *Acorus calamus*

L(0.49 mg/kg) and the *Phragmites communis* has lowest concentration to Cd and it is about 0.13 mg/kg. Moreover, in the same plant, the root part concentration to Cd is far higher than stem part concentration to Cd.

Table 7. The concentration of different plants stems part and root part to Pb (mg/kg）（source：Wu 1981）

Plant Name	Stem part of concentration	Root part of concentration
Typha orientalis Presl	14	68
Cyperus alternifolius	12	34
Phragmites communis	28	85.3
Scirpus validus Vahl	8.6	28.91
Juncus effusus L.	20	56
Sorghum	22	48
Acorus calamus L	38.62	81

According to the table 7，the *Acorus calamus L* stem part has the highest Pb concentration which is up to 38.62 mg/kg, and the *Phragmites communis* root part has the best concentration ability to Pb which is about 85.3 mg/kg. However，the *Cyperus alternifolius* stem part has the lowest Pb concentration which is 12 mg/kg，and the *Scirpus validus Vahl* root part can absorb lowest Pb which is 28.91 mg/kg. Further，there is still the fact that all aquatic plants root part have more concentration to Pb compared to stem part.

The tolerance of plants to heavy metals depends on the plant species. There is a typical absorption relationship among them: emergent plants> floating plants, floated plants> submerged plants (Hu et al., 1981). The different parts of same plant also have different absorptive capacity, for example, in *Cattail* plants, it absorbs heavy metal in wastewater, the absorptive capacity of *Cattail* body part is root> underground stem> leaf in turn (Qi et al., 1999).

- Absorption of nitrogen by plants

Nitrogen is one of the most indispensable elements of plant growth and is therefore called the life element of plants. Therefore, in order to maintain normal growth and development, wetland plants must absorb nitrogen as their nutrient from the outside environment. The nitrogen in the sewage is in the form of organic nitrogen and inorganic nitrogen. Inorganic nitrogen, as an indispensable nutrient in the process of plant growth, can be absorbed and utilized in the form of ions (NH_4^+ and NO_3^-), and part of the organic nitrogen is decomposed by microorganisms，then it can also be absorbed and utilized by plants. Yuanxiao Jing (2002) conducted an experiment on purification of domestic wastewater from *Cyperus falcipifolius*. The experiment showed that the removal rate of TN is 64% for submerged constructed wetland planted with *Cyperus alternifolia*, and the removal rate is higher 28% than that of artificial wetland without plants, and every gram of dry weight *Cyerus alternifolius* can absorb 2.25 mg of nitrogen in wastewater. Chris (1996) further found out that per gram of dry *Reeds* and *Phragmites communis* in subsurface wetland systems can be used to absorb 15-32 mg of nitrogen from wastewater. This shows that wetland plants have certain absorption of nitrogen, but different plants have different absorption capacities.

Table 8. The clean ability of seven aquatic plants for nitrogen（source：Zhang et al., 1999）

Plant Name	Orginal Concentration(mg/L)	The last concentration after cleaning		
		3d	5d	7d
Typha orientalis Presl	11.85	2.73	1.8	1.21
Cyperus alternifolius		4.12	1.92	1.78
Phragmites communis		2.68	1.39	0.95
Scirpus validus Vahl		2.98	1.75	1.06
Juncus effusus L.		2.25	1.31	0.69
Sorghum		1.89	0.98	0.54
Acorus calamus L		2.88	1.42	0.56
NO plant		8.18	6.96	6.78

According to the table 8，there are seven aquatic plants cleaning ability were listed for nitrogen. They all have different abilities for removing the nitrogen. In the 5d， the removal rate of *Typha orientalis Presl*，*Cyperus alternifolius*，*Phragmites communis*，*Scirpus validus Vahl*，*Juncus effusus L.Sorghum* and *Acorus calamus L* are 84.8%, 83.7%, 88.2%, 85.2%, 88.9%, 91.7% and 88.1% respectively. However, the removal rate of no plant group is only 41.2%. This shows that seven aquatic plants have strong adsorption ability for nitrogen. During those 3 days, the concentrations of nitrogen have great decrease in the all seven group compared to the no plant group because of the plants nitrification and denitrification. This means that the plants can absorb a huge amount of nitrogen in a short period of time.

- Absorption of phosphorus by plants

Phosphorus, like nitrogen, is an essential element of plants. Energy is required for plant life activities， and the transmission and storage of energy depend on phosphate compounds. The existence of phosphorus in sewage depends on the type of phosphorus in the sewage. The most common ones are phosphates, polyphosphates, and organic phosphates. The phosphorus that can be directly absorbed by plant roots is mainly mono-valent phosphate ions ($H_2PO_4^-$). Polyphosphates and organic phosphates are not or hardly absorbed by plant roots such as divalent phosphate ions (HPO_4^{2-}), trivalent phosphate ions (PO_4^{3-}). The absorption of roots by mono-valent phosphate ($H_2PO_4^-$) and bivalent phosphate (HPO_4^{2-}) is a physiological process that depends on the energy obtained by the plant through respiration (Stottmeister et al., 2003). The study by Mcjarmet et al. (1995) using the constructed wetland method to treat municipal wastewater, showed that about 5% of the phosphorus in the wastewater can be absorbed and utilized by wetland plants. In 1996，Jianwei Liu et al. conducted a comparative study on the removal of phosphorus in sewage from eight kinds of wetland plants such as rice, imperial grass，and corn. The results showed that all eight wetland plants could absorb part of the phosphorus in the sewage. Phosphorus in the sewage is absorbed by the plant roots and can become organic compounds such as ATP, DNA, and RNA through assimilation and is removed by harvesting the plant (Zhang et al., 1999).

Table 9. The clean ability of seven aquatic plants for phosporus

Plant Name	Orginal Concentration(mg/L)	The last concentration after cleaning		
		3d	5d	7d
Typha orientalis Presl	0.88	0.41	0.21	0.18
Cyperus alternifolius		0.48	0.24	0.16
Phragmites communis		0.35	0.27	0.24
Scirpus validus Vahl		0.45	0.29	0.18
Juncus effusus L.		0.39	0.28	0.16
Sorghum		0.31	0.17	0.09
Acorus calamus L		0.36	0.22	0.16
NO plant		0.78	0.72	0.6

The table 9 clearly shows the capacity of these seven aquatic plants is higher than that of no plants group. The removal rate of *Sorghum, Juncus effusus L.Acorus calamus L, Scirpus validus Vahl, Phragmites communis, Cyperus alternifolius* and

Typha orientalis Presl are 79.5%, 81.8%, 72.7%, 79.5%, 81.8%, 89.7% and 81.8% respectively. However, the removal rate of no plant group is only 31.8%. According to this information, there is no denying that the aquatic plants have great contribution on cleaning the phosphorus from the water bodies.

Table 10. The different plant parts to the N and P concentration（mg/kg）（source：Liu，2003）

Plant Name	Plant Part	N concentration (mg/kg)	P concentration (mg/kg)
Typha orientalis Presl	Leaf	31.28	7.36
	Stem	6.64	3.98
	Root	18.54	6.2
Cyperus alternifolius	Leaf	20.12	4.85
	Stem	6.34	2.98
	Root	9.77	3.13
Phragmites communis	Leaf	14.68	4.81
	Stem	18.4	3.21
	Root	10.44	2.96
Scirpus validus Vahl	Leaf	9.66	3.68
	Stem	6.32	2.54
	Root	6.56	2.12
Juncus effusus L.	Leaf	16.88	8.87
	Stem	8.88	6.78
	Root	9.88	6.18
Sorghum	Leaf	29.36	7.87
	Stem	16.26	6.78
	Root	8.52	6.18
Acorus calamus L	Leaf	23.88	4.23
	Stem	14.06	2.84
	Root	5.16	2.36

This table 10 shows the concentration of N and P in the leaf, stem and root part from the seven aquatic plants. According to the table, the highest N concentration is from *Sorghum* which is up to 31.28mg/kg. The N concentration level is leaf> stem>

root, whereas the P concentration level is leaf> root> stem. So the leaf has the highest ability to concentrate the N P. Above all, these seven aquatic plants have great ability to absorb N and P, they all are excellent aquatic plant species for cleaning N and P pollution.

- Absorption of organic pollution by plants

Aquatic plants can absorb phenol and cyanide pollutants in the water and do not accumulate these pollutants in the body after absorption. And these phenol and cyanide pollutants are converted and decomposed through the action of enzymes and biochemical to make them lose their toxicity. Phenol and cyanide are gradually decomposed and transformed due to the effect of rhizosphere microorganisms (Wu 1981; Zheng, 1987, 1988). The role of the root system is to oxidize and decompose the sediments around the roots by releasing O2. On the other hand, many anaerobic and aerobic bacterial communities are formed at the bottom of the water body and in the matrix soil to create conditions for microbial activity and thus form a "rhizosphere zone."In this way, plant metabolites and residues and dissolved organic carbon provide a food source for colonies in the wetland. The organic pollution material is removed by microbial decomposition or biodegradation. In eutrophic water bodies, it is also possible to rely on microorganisms on the basis of rhizomes of aquatic plants to make denitrifying bacteria and ammoniated bacteria accelerate transform NH3-N to N02， N and N03. The transformation process of N facilitates the absorption and utilization to N of aquatic plants and reduces the release of nutrients from the sediment into the water (Liu, 2003). Scientists found that *Eichhornia crassipes* can absorb pollutants such as phenols, menylamine and aniline, lignin, detergents, BHC, and DDT (Tan, 1986; Tao, 1998; Dai, 1986). The primary mechanism of removal is the microbial action of roots (McKinlay etal., 1990).

Table 11. Normal aquatic plants for cleaning the DDT and Dimethoate （source：Dai, 1986）

Plant Name	Herbicides Type	Original Concentration	Removal effect
Potamogeton distinctus A.Benn.	DDT	0.445-1.0ug/L	Bioconcentration Factor:2220-3500
Scirpus validus Vahl	Dimethoate	5 mg/L	Removal rate: 78.6%

According to the table 11, there are different aquatic plants for cleaning herbicides pollution, the *Potamogeton distinctus A.Benn* have great cleaning ability for the DDT. When the DDT initial concentration is 0.445-1.0 ug/L, the bioconcentration factor of *Potamogeton distinctus A.Benn* is up to 2220-3500. Furthermore, the *Scirpus validus Vahl* has a substantial capacity for cleaning the Dimethoate which is up to 78.6%.

DISCUSSION

The results show the mechanism of action of aquatic plants to clean heavy metal，N P and organic pollution, and the high capacity of purifying of listed seven aquatic plants to heavy metal, N, P and organic pollution. Although these aquatic plants have a great contribution to clean water pollution, yet it is also clear that the phytoremediation technology is not the main technology used in water remediation projects now. There are two reasons for this phenomenon- Firstly, a few aquatic plants meet the principle which is a requirement for aquatic plants to clean water pollution; and secondly, there is not still a perfect way to dispose the used aquatic plants. So the selection principle of plants in the constructed wetland and the current disposal way to use the aquatic plants were discussed in this part.

1. Selection principle of plants in constructed wetlands

Aquatic plants in wetlands have a significant influence on the treatment effect of pollution. Generally, when the main object of removal is only P and N, the selected plants need to have a large root system that can provide an attachment interface for microorganisms and strong oxygen transmission ability; and when the main pollution type are N, P, heavy metals and certain organic substances, it is essential to select the species that have better absorption capacity and grow faster. If there are numerous pollutant removal targets, it is necessary to find species that can effectively play a variety of ecological functions. Besides, the adaptation to the local climate, plant resistance and resistance to pests and diseases, plant management, and died plant reprocessing should be taken into consideration. Therefore, how to choose the appropriate plant species to improve the treatment efficiency is an essential aspect of the design of constructed wetlands.

- **Strong stain resistance, decontamination effect**

Strong stain resistance and excellent decontamination effect are the fundamental selection principle of wetland plants. Wetland system should be based on the different types and concentrations of the sewage to choose different wetland plants. For example, when the concentration of nitrogen in sewage reaches 54.5 mg / L, the *Cattail* leaves in the constructed wetlands will be dead and hard to recover in the short term (Gersberg et al., 1990). Shida Huang et al (1995) compared the *Reed, Rushes* and *Iris* three plant pollutant purification capabilities and found that *Rushes* has strongest stripping ability; Jixi Gao et al (1997) selected seven kinds of wetland plants to carry out research, the test results show that *Sagittarius* and *Zizania latifolia (Griseb.) Stapf* has the highest comprehensive purification rate. These studies provide many information to select suitable wetland plants, and people can consider these plants while building constructed wetlands.

- **Roots developed**

Purification of aquatic plants is closely related to the development of their roots. There are two main reasons: Firtly, the developed plant roots can improve the purification ability of aquatic plants by secreting more root exudates, creating favorable conditions for the survival of microorganisms and promoting the biodegradation of the rhizosphere; further, the root system plays an important role in fixing the riverbed surface, covering the soil and maintaining the vigorous vitality of plants and microorganisms. In other word, developed root system has a great contribution for maintaining the stability of wetland ecosystems. In constructed wetlands, pollutants are mainly removed by microorganisms that attach to the aquatic plant root zone. In general, the more developed the root system is, the better the purification effect of wetland systems is (Leveling et al., 2002).

- **Suitable for the local environment**

Plants must adapt to the local soil and climatic conditions which are selected to clean local water pollution; otherwise these aquatic plants will die. For example, some developing countries often copy the model of developed countries, including using aquatic plant species which live in developed countries to clean their own countries pollution, but their treatment effect is not very satisfactory (Denny, 1997; Kivaisi, 2001). Shuiping Cheng (2001) found that cattail and Rushes are the more suitable aquatic plants in Wuhan, especially the rushes are the best thing water-purification plants in the area.

2. Current Disposal of Used Aquatic Plants

As aquatic plants purify heavy metal wastewater, the content of heavy metals in plants is brought up. If they are left untreated or directly returned to the field or compost and biogas, they will easily cause pollution transfer and secondary pollution and will be treated as hazardous waste disposal such as landfill, not only to occupy the land resources, but also a waste of plant resource utilization value. Therefore, it is necessary to adopt a safe and reliable resource utilization strategy. Some researchers put forward the countermeasure of utilization of biological carbon by making use of plant material after purification treatment and conducted preliminary experimental research.

Adding biochar can increase the pH value of heavy metal contaminated soil, and the PH value will increase with the pyrolysis temperature increases. Biochar can reduce the extractable acid content of Pb and Cd, thus reducing the bioavailability of heavy metals and showing a good fixing effect on heavy metals. And the higher the pyrolysis temperature of biochar is, the better the fixation is. We obtained biochar by adding a certain ratio of carbon to soil, and increase the soil organic carbon content, in order to reduce soil and water fertilizer and nutrient lose, so the obtained biochar can be applied to the soil as forest green manure. Further, biochar is extremely stable in the soil, so the absorbed heavy metal is released slowly in the soil after being carbonized and fixed by the plant, and will not cause secondary pollution. Moreover, the biochar long-term carbon fixation in the soil is the potential carrier of carbon fixation.

CONCLUSION

Phytoremediation is a successful project to solve the water and soil pollution by using plants, in this paper， the water pollution is the main topic of discussion. Using large-scale aquatic plant to clean water pollution is an innovative pollution clean technology, and has prefect remediation effects on different sewage bodies. Since it is a brand new research field, there are still many blank fields to be developed and perfected. Firstly, at present, although there are relatively numerous studies on the purification ability of single aquatic plants, the types of plants used are relatively simple. Although there are many aquatic plants resources in China, a few aquatic plants have been put into practice in fact. And there is no denying of the fact that more aquatic plants will be used for cleaning water pollution in the future. Secondly, there is still a few numbers of studies on the interaction of some different types of aquatic plants to purify polluted water. Thirdly, the concentration of pollutants in the water is already too high or too low which will affect the effectiveness of phytoremediation. High levels of contaminants which are over the plant's resistance to toxicity will lead to the death of plants, however it will limit the plant's absorption of pollutants when the concentration of contaminants is too low. Therefore, the different clean methods need to be considered when to clean the various pollutant concentrations. Fourthly, the safe disposal to used aquatic plants is still a problem. When the plant's decontamination ability reaches saturation or reaches the apoptosis season, the residual plant will often become a fresh source of pollution, forming secondary pollution. Therefore, how to timely and adequately dispose of plant debris and resource utilization still needs further study. Using large-scale aquatic plant to clean pollution has significant advantages in purifying polluted water. With further research, those four blank fields of Phytoremediation will be solved. Finally, it will provide a cleaner water ecosystem for the human with the widespread use of the phytoremediation in the future.

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