Theory and Practices of Water Pollution Control by Wetland
— a Case Study of Reed Wetland in Baiyangdian Lake

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ABSTRACT: Wetland is an important eco-system on the earth and can effectively control agricultural non-point source pollution. Reed is a typical wetland plant for land/inland water ecotone in north China. The studies indicated that reed had a underground rooted-stem, which formed a "high speeded-connecting vessels" i.e. reed root channel (RRC) in Baiyangdian lake of Hebei province. It spread predominantly along horizontal direction underground and are mainly distributed at 18-75 cm. The results of field work from healthy reed-wetland (HRW) and regarded reed-wetland (RRW) showed that the reed, averagely, in HRW is 4.2 m height, 1 cm diameter, 65/m2 density; in RRW is 2.4 m height, 3 mm diameter, 86/m2 density. These results indicated the regradation of the function of RRC in RRW. The results of laboratory work of sewage purification from reed soil column (RSC) (0 ~ 100 cm) and wheat soil column (WSC) showed that the efficiency of purification to sewage, in RSC, is high than in WSC, especially for phosphorus. The efficiency of purification, in RSC, is 92.6% for total phosphorus, 43.5% for total nitrogen, 54.1% for COD, respectively; in WSC, is 86.0% for total phosphorus, 241.3% for total nitrogen, 29.8 % for COD, respectively.
Keywords: wetland, reed root channel, water pollution control

1 INTRODUCTION

The contradiction between development and environment protection has been an unavoidable issue in developing countries. This problem is especially serious in areas where economic growth is fast. In China, the water eutrophication of lake and reservoir has become one of the biggest hazards in the last two decades. Whenever it happens, great damage is caused in fishing, aquaculture, tourism and many related industries. How to reduce the potential risks of algae blooming is one of the key topics among researchers and policy makers.

The wetland system in the Baiyangdian lake is a multi-functional landscape that should be rationally used for environment protection. It belongs to land/inland-water ecotones wetland (LWEW), which has received home and abroad attention from environment academe in recent years[1-3]. There is about 100,000 km^2 of LWEW in our country, 38.5% of the whole area of the natural wetland. The degradation of LWEW is serious since it is often neglected by people. The result is reduction of water quality, eutrophication of water body, erosion and collapse of bank, reduction of bio-diversity and aggravation of flood[4].

Reed root channel (RRC) is one of the important part of the LWEW system, which is a high speeded-connecting vessels conducting substance transportation in the ecosystem. Some change of water and nutrient in the ecosystem can quickly affect other part of the ecosystem through root channels system. Plant root channels is an important type of soil macropore, whose structure, formation and space distributing and function in wetland ecosystem have been rarely studied. Study of RRC has not almost been reported[5-8].

Baiyangdian lake has been famous for the title “a bright pearl in north China”, a kind of typical LWEW ecosystem, which is predominated by reed community. As local “number one of plant”, reed has huge underground rooted-stem which forms “highway” in reed wetland. It has been found that the root zone soil system of reed community had obviously a retention role to pollutants such as nitrogen and phosphorus flowing into the region of Baiyangdian lake through underground flow[9-10]. Study of structure, space distribution and purification of pollutants of the underground channel system that characterizes LWEW is highly significant in theory and practice.

2 STUDY SITE AND METHOD

The field experimental sites were located in Baiyangdian lake, the largest natural freshwater body in North China Plain. It is located 130 km south of Beijing and covers a surface area of 366 km^2. Baiyangdian lake is a decaying lake with the water area being reduced due to local land till activity, and is in a eutrophic state. The lake depth is usually less than 2 m, but variable depending on the hydrologic conditions. During certain dry years, the lake only retains a small amount of water and typically exhibits swamp-like conditions. The dominant macrophyte vegetation is the common reed *Phragmites australis* with a height of roughly 3 m. *Nymphoides peltatum, Lemna minor* are distributed in the marginal waters around the reed community. In addition, other vegetation such as *Scirpus yagara, Scirpus juncoides, Butomus umbellatus, and Juncellus serotinus* coexist with the dominant reed. In Baiyangdian lake, reed fields occupy 8000 hectares, accounting for 22 % of the lake area. These vegetation constitute the emerging community with a biomass density of 3-5 kg/m^2. More than 3700 artificial ditches divide the reed fields into multiple beds. The reed beds usually have a width of 30-40 m and the ditches of 5-10 m. During moderate flow conditions, water moves freely in the ditches; these ditches act as multiple corridors in the reed bed landscape. The edge area of reed beds and ditches is easily influenced by the undulation of water flow and provides a good exchange of water and matter between the reed bed soil and ditch water.

The study of experiment consists of two parts.

2.1 The experiment of field observation on the distribution of RRC

The experiment of field observation on the distribution of RRC was conducted in healthy and regarded reed field in Nanliuzhuang vliiage (NV), Anxin town and Yangmengzhang villige (YV), Zaili town, respectively, Anxin county, Baiyangdian lake, Hebei province. On the two village mentioned above, respectively, select typical site of reed field and examine varieties, diameter, overlay rate, number of the reed and conditions of the grass in the field. Dig 12 soil profile, select 2 typical field-site, then dig soil profile of 2 m× 1.5 m, each marked with gridding (aperture of 5 cm× 5 cm) made of thin iron thread and draw the section on distribution of root system in upright direction (root can be divided into 4 grades according to thickness: <1 mm, 1-2 mm, 2-3 mm, >3 mm; and it can be also partitioned into the dead and the alive.), take photos of them finally.

From up to down, take 8 soil columns (20 cm× 25 cm× 20 cm) from 2 soil profile, choosing one every 20 cm of soil layer, pick out all the root, and carry them in bags back indoor according to the layers they belong to, wash the soil off from the root through sieve with aperture of 0.1 mm, sort the root into 4 grades according to diameter: <1 mm, 1-2 mm, 2-3 mm, >3 mm after air-drying them, then count number, length and fresh weight of each kind of root, according to the layers they belong to. Finally, take some, drying them at 80℃ to a stable weight and calculate their dry weight.

2.2 The laboratory simulative experiment of sewage purification of soil columns

2.2.1 The experiment of large soil columns

A patch of reed field and wheat field were selected. Three soil columns (100 cm in height and 25 cm in diameter) on the reed field (RSC) and 1 soil columns on the wheat field (WSC)were digged, without destroying soil structure. Then put it into prepared column barrels made from tin (25 cm in diameter and 110 cm in height), carry them back indoor. At the same time, the soil of the reed and wheat field is divided into 5 layers from up to down: 0-20 cm, 20-40 cm, 40-60 cm, 60-80 cm, 80-100 cm. Take the soil by soil layer, and carry them back indoor, air-dry and sieve them out; fill the simulative soil columns (25 cm× 100 cm) with the soil according to soil layers and density, totally, 3 simulative soil columns from the reed field (RSCm) and 3 from the wheat field (WSCm). In order to make the columns resume their original structure on the natural condition and enhance authenticity of the simulative experiment, dip the stable columns of soil in tap water.

2.2.2 The experiment of small soil columns

Take air-dried and sieved 1 kg soil, from the reed field of 0-20 cm, 20-40 cm, 40-60 cm, 60-80 cm, 80-100 cm, respectively; then put them into tube made of PVC, 40 cm in length and 7 cm in inner diameter (the bottom enveloped with nylon net of 300 mesh). In order to make the columns resume their original structure on the natural condition and enhance authenticity of the simulative experiment, dip the stable columns of soil in tap water.

2.2.3 The experiment process and measurement

The experimental sewage is from Fuhe river flowing into Baiyangdian lake, in which concentration of total phosphorus is 1.96 mg/L, that of total nitrogen 14.7 mg/L and COD 66 mg/L.

The sewage were poured into the soil columns, maintaining 10 L/d for large soil columns and 1 L/d for small soil columns respectively, in order to observe the capacity of purification of sewage for different soil columns type and for different soil layer of reed field. The water samples were taken once every 10 days from the bottom of columns in order to measuring concentration of total nitrogen, total phosphorus and COD of the water sample.

3 RESULTS AND ANALYSIS

3.1 The experiment of field observation on the distribution of RRC

The studies indicated that reed had an underground rooted-stem, which formed a “high speeded-connecting vessels” i.e. reed root channel (RRC) in Baiyangdian lake of Hebei province. It spread predominantly along horizontal direction underground and can quickly transport water to far distance within ecotones and consequently provide the transport, adsorption and transformation interface for pollutants such as nitrogen and phosphorus. According to the survey results of field profiles, the RRC are mainly distributed above 120 cm along the profile and particularly concentrated at 18 ~ 75 cm.

The results of field work from healthy reed-wetland (HRW) and regarded reed-wetland (RRW) showed that the reed, averagely, in HRW is 4.2 m height, 1 cm diameter, $65/m^2$ density; in RRW is 2.4 m height, 3 mm diameter, $86/m^2$ density. The dry-weight of stem, 0-20 cm, in HRW is more than 15.1% in RRW, 20-40 cm 49.7%; the dry-weight of root, 0-20 cm, in HRW is more than 49.2% in RRW, 20-40 cm 74.2%. The length of root, regardless of less than 1 mm, 1-2 mm and more than 2 mm, in HRW is always more than in RRW (Table 1). These results indicated the regradation of the function of RRC in RRW. The results from field and laboratory work demonstrated that to strengthen the conservation and management of reed wetland and to maintain the ecosystem of the healthy reed wetland, in theory and in practice, is very helpful for purification of water pollutants.

Table 1. Distribution of reed root channels and aperture

Site	Soil layer (cm)	Stem				Root				
		Dry Weigh (g)	Length (cm)			No.	Dry Weigh (g)	Length (cm)		
			<1cm	1~2cm	>2cm			<1mm	1~2mm	>2mm
YV	0~20	29.6	124.5	37.5		3	2.59	832.4	149.0	
	20~40	50.3	26.6	48.6	26.9	5	2.27	350.2	91.1	90.9
	40~60	23.5	29.3	22.9	12.8	4	1.61	146.1	48.2	34.6
	60~80	12.3		28.9		3	2.14	121.1	81.2	60.9
NV	0~20	34.8	35.3	60.0		4	5.10	1382.6	334.5	59.0
	20~40	100.1	19.1	123.4	61.8	6	8.81	1027.8	304.7	304.8
	40~60	29.1		39.4		4	5.31	594.6	124.1	230.4
	60~80	19.6		20.6		3	3.27	386.2	86.7	66.7

3.2 The laboratory simulative soil columns experiment of sewage purification

3.2.1 The experiment of large soil columns

The experiment result showed that concentration of phosphorus of the sewage from Fuhe river is very high. The measuring results conducted once every 3 days from 20th October to the 1st December, demonstrated that concentration of total phosphorus is 1.5-2.5 mg/L, of total nitrogen 11-17 mg/L and of COD 66 mg/L.

The efficiency of purification to sewage (Table 2) was RSC > RSCm > WSC, especially for phosphorus. After irrigating sewage 40 days, the concentration of total phosphorus is 0.149 mg/L, 0216 mg/L and 0.280 mg/L for RSC, RSCm and WSC, respectively; the concentration of total nitrogen is 8.31 mg/L, 8.47 mg/L and 8.63 mg/L for RSC, RSCm and WSC, respectively; the concentration of total COD is 30.3 mg/L, 36.0 mg/L and 46.3 mg/L for RSC, RSCm and WSC, respectively. The efficiency of purification, in RSC, is 92.6% for total phosphorus, 43.5% for total nitrogen, 54.1% for COD, respectively; in RSCm, is 89.0% for total phosphorus, 42.4% for total nitrogen, 45.4 % for COD, respectively; in WSC, is 86.0% for total phosphorus, 41.3% for total nitrogen, 29.8 % for COD, respectively.

Table 2. The effect of purification to sewage in different soil columns

Type of soil columns	TP		TN		COD	
	Before treat	After treat.	Before treat	After treat.	Before treat	After treat.
RSC	1.96	0.149	14.7	8.31	66.0	30.3
RSCm		0.216		8.47		36.0
WSC		0.280		8.63		46.3

3.2.2 The experiment of small soil columns

The results of reed small soil columns showed that there was little difference on the capacity of purifying sewage among different reed soil layers. After pouring sewage of 21 L, concentration of total phosphorus is 0.085 mg/L for

0-20 cm, 0.094 mg/L for 20-40 cm, 0.093 mg/L for 40-60 cm, 0.079 mg/L for 60-80 cm, 0.086 mg/L for 80-100 cm, respectively; concentration of total nitrogen is 7.75 mg/L for 0-20 cm, 6.82 mg/L for 20-40 cm, 6.58 mg/L for 40-60 cm, 7.13 mg/L for 60-80 cm, 6.62 mg/L for 80-100 cm , respectively.

The result of preliminary study of above two experiments indicates that sewage was purified after treating through soil for some time. The efficiency of purification to phosphorus is from 86.0% to 92.6%, to N is 41.3-43.5%, to COD is 29.8-54.1%. This suggest that reed wetland ecosystem can act as a very important role in dealing with phosphorus which is a critical factor for eutrophication of lakes and reservoirs. There is little difference among soil layers from the reed wetland to the capacity of dealing with pollutants, as has yet to be further studied and discussed.

4 CONCLUSION

Reed root channel (RRC) spread predominantly along horizontal direction underground. RRC are mainly distributed above 120 cm along the profile and particularly concentrated at 18 ~ 75 cm. The reed of healthy reed-wetland (HRW) has a good reed quality and less dead RRC compared to regarded reed-wetland (RRW). The function of RRC in RRW has been regraded.

The results of laboratory study from soil column showed that the efficiency of purification to sewage, in RSC, is high than in WSC, especially for phosphorus. The efficiency of purification, in RSC, is 92.6% for total phosphorus, 43.5% for total nitrogen, 54.1% for COD, respectively; in WSC, is 86.0% for total phosphorus, 41.3% for total nitrogen, 29.8 % for COD, respectively.

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