Purification function of the natural wetland in the Liaohe Delta*

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Abstract—The estuary wetland is the last barrier for inland pollutants flowing into the sea. The possibility to use the natural wetland, mainly reed marsh and Suaeda heteroptera community as land treatment system to polluted river water was studied. Experimental results indicated that the reed march has a high retention rate to pollutants like COD, N, P and oil. The canal system has high a purification rate to these elements as well. There is also a big potential to use the Suaeda community as a treatment system to exchange water from prawn and crab breeding ponds along the coast. As the pollution problem of coastal seawater has become more and more serious in Eastern China, and Liaohe is among the most seriously polluted 7 rivers in China, this study will greatly contribute to the strategy makers to take suitable reactions.

Keywords: purification function; wetland; reed marsh; canal; Suaeda community.

1 Introduction

Structure, function and change are three important aspects of landscape ecology (Forman, 1986). Landscape function means the interactions among spatial elements, such as the flows of energy, materials, and species among the component ecosystems. A lot of research has been done on the purification function of wetlands (AMBIO, 1994; 1995, Pride, 1990; Hammer, 1989; Mulamootti, 1989; Teal, 1982; Whigham, 1982; Cruz, 1982). But different research projects focus on different aspects.

The Liaohe Delta is situated in Northeastern China, to the north of Liaohe Bay. The climate here is temperate monsoon, with a frozen period of about 150 days. It has the world second largest reed marsh, with an area of 917 km^2. Several rivers flow into the sea here, with large amount of pollutants from upstream (Table 1), many of which are nutritious elements that can cause eutrophication problems in the coastal seawater. If those elements, such as N, P, COD, BOD etc., are retained in the wetland, they can nourish the plants and improve the bio-production, while the water quality can be improved simultaneously. This paper will mainly focus on the purification function of reed (Phragmite communis) marsh for these nutritous elements. The purification ability of canals will also be studied.

Table 1 Runoff and main pollutants release into the Liaodong Gulf of main rivers in Liaohe Delta

River name	Run off, $\times 10^9 m^3/a$	COD, t/a	NH_4^+-N, mg/L	NO_2^--N, mg/L	NO_3^--N, mg/L
Shuangtaizi River (Liaohe)	2.1	21697	0.37-4.23	0.002-0.04	0.11-1.4
Daliaohe River	4.0	53903	2.3-104	0.0-0.088	0.0-2.38
Daling River	2.0	49432			
Xiaoling River	0.4	2245			

The oil field distributed all over the delta is another pollution source. The wastes such as drilling mud, drilling water and spiller oil often cause pollution near the oil drilling station and pipe lines. The possibility to use the natural wetland as a treatment system for oil pollutants is also studied in this paper.

In addition, the prawn-crab breeding ponds are developing very fast along the coast. The

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exchanged water from these ponds has a high content of nutrient elements like N and P, especially from June to September (Table 1). If no measure is taken, the out-broken of "red tide" will be unavoidable. The pioneer community of Suaeda heteroptera provides a possible solution to solve this problem.

2 The purification function of reed marsh

2.1 Comparison of reed productivity between irrigated and non-irrigated fileds

Irrigation can improved production, according to the experiment done in the 1960s (Sun, 1981). The productivity of irrigation reed fields can be 40%-70% higher than that of the non-irrigated fields. This is due to better growth condition evoked irrigation (Table 2; Su, 1983).

The average diameter of above ground stems reaches the higher under the irrigated situation. However, excessive water will cause decrease of productivity, like in the situation of flooded filed (Table 2). Irrigation can also remove some weed species, such as hordeum jubatum, from the pure reed community.

Table 2 Comparison of reed growth among dry, irrigated and flooded reed field

	Dry field	Irrigated field	Flooded field
Distribution depth of underground roots, cm	1—120	0—80	0—60
Irrigation depth of underground stems, cm	40—80	20—40	15—30
Average diameter of underground stems, cm	2.1	1.6	1.2
Average height of above ground stem, cm	180	192.2	157.8
Diameter of above ground stem, cm	0.64	4.6	3.9
Density of above ground stems, stem/m^2	21.5	77.5	376
Productivity of above ground stems, t/hm^2	4.40	9.58	7.03

Normally the reed marsh needs 3 times of irrigation-drainage during the growth period (Sun, 1981).

March 15 to April 10: Unfrozen water from nearby rivers. This kind of water usually has a low salt content, but accumulated with nutrients from upstream cities during the winter and early spring. The water temperature is usually higher than that of the soil and thus helps it to get unfrozen. The fresh water also washed the salt down from the soil so that the new reed can sprout earlier and faster. In the relatively higher area, water is often irrigated without drainage, while in the lower area, drainage is needed to cut down the soil content.

April 20 to May 15: Water drained from paddy fields and upstream rivers, as well as salty water from the sea. Whether or not to drain are irrigation is dependent on the quantity of water from upstream. The concentration of nutrients is lower than that of March. In this period the reed is about 40—50 cm high, and the growth speed can be 4 cm/day. This time of irrigation must be conducted carefully so that the salty water would not kill the new reeds.

Early June: It is dependent on the precipitation and the water quantity from upstream. The reed comes to the flourishing period. There is a high demanding for water from both reed and soil, thus a thicker water layer (10—15 cm) is needed. But if the groundwater level is too high for along period, there will be too many underground roots, and the reed stem will be very slim, leading to a low production.

July and August are the rainy season in the Liaohe Delta, normally no irrigation is needed. September and October are the ripe period for the reed, and little water is needed for the growth.

On account of the shortage of water resource for industrial and agricultural use in the Liaohe Delta, it is almost impossible to irrigate the reed fields according to the growth needs. One strategy that can be taken is to extend the irrigation period, and accept a wider range for water quality, so as to enlarge the total irrigation area and get a higher production of reed.

2.2 The advantage irrigating the reed with wastewater

2.2.1 More production increase than irrigated by normal water

According to a field experiment done in the 1980s, the height of reed irrigated with waste water are 45 50 cm higher than that irrigated by normal water (Song, 1984), while the productivity is about 17%—26% higher. In the field, the reed irrigated with wastewater has strong stems and dark green leaves, with an optimal stem density. The reason for the production increase is that, wastewater has a higher nutrient content than normal water. The deposition of organic matters from the wastewater can improve the soil structure and provide more nutrients to reed growth. Moreover, the wastewater usually has a low salt content, and thus helps the desalinization procedure of soil.

Table 3 Comparison of growth indicator between reeds irrigated by wastewater and normal water

Year	Irrigated by	Height, cm	Diameter, cm	Number of gnarls	Productivity, t/hm^2	% of production increase
1981	Wastewater	320	0.8	22	10.6	26.3
	Normal water	270	0.7	18	8.6	-
1982	Wastewater	310	0.85	21	10.4	16.8
	Normal water	275	0.75	20	8.9	-
1983	Wastewater	337	0.75	24	15.0	26.0
	Normal water	297	0.7	22	11.0	-

The wastewater often has a high COD (chemical oxygen demand) content (Table 1), which decreases the DO (diluted oxygen) value in water and impedes the growth of plants. But reed is rarely affected by this oxygen shortage, since the oxygen for root respiration mainly comes from the photosynthesis of the leaves, and transported down through a kind of ventilation tissue in the plant body. During the 3 years' experiment, no growth impedance was observed.

2.2.2 Relax the water shortage problem in spring

Spring (March to May) is the dry period in the Liaohe Delta. The evaporation is 17 times higher than the precipitation in March, while the highest evaporation occurs in May(281.5 mm). The average spring precipitation here is only 96.5 mm, about 15.5% of the annual rainfall. It is quite far from the actual need of natural vegetation growth, not to say the local industrial and agricultural needs. If the reed fields are irrigated with waste water from upstream factories, no heavy damage can be done to the reed growth, while much better qualified water can be saved for agriculture and industry.

2.2.3 Prevent coastal seawater pollution

If the wastewater with high pollutant content is discharged directly into the sea, coupled with suitable conditions for some algae species, it may cause great problems in the long run. Actually the general quality of Chinese ocean environment has been decreasing in the years, according to the Report the Chinese Ocean Environment, year 1997, published by the Chinese Bureau of Ocean. In the Bohai Sea, the concentration of nitrogen above the National Standard increased from 16% in 1996 to 68% in 1997. The problem is especially serious near the large river mouths and large cities. As a result, a large area of "red tide" broke out along the coast of Bohai Sea in September 1998, covering thousands of square kilometers sea surface. Great damage has been caused to the local fishing and aquaculture.

If the river water flows through the natural wetland in the delta first, after sedimentation, dilution, oxidation, dissolve, evaporation, and soil absorption in the canals and the reed fields, the wastewater will become cleaner when discharged into the sea.

2.2.4 Improve soil fertility

Wastewater usually has higher nutrient contents than normal water. After several years of irrigation with wastewater, the peat soil in the reed marsh often becomes more fertile. At least no production decrease is observed, though large amount of dry material is taken out to paper factories from the system every year. Wastewater irrigation should be encouraged for the sake of reed and paper production.

2.3 Purification ability of the reed to wastewater from paper factory

From 1997—1998, the working group made an experiment in the Liaohe Delta to measure the purification function of reed marsh and canal system. The field is irrigated with wastewater from paper factories upstream. In the reed field, ground water is sampled 3 days after irrigation, at 0, 40, 60 and 80 centimeter depths with Lysimeter system. Table 4 and Fig. 1 show the results.

Table 4 Purification ability of reed marsh system to wastewater from paper factories

Depth, cm	COD	TN	organic N	NH_4^+ N	NO_3^- N	NO_2^--N	TP	SRP
0	82.69	3.129	2.676	1.36	0.069	ND	0.15	0.0432
40	69.63	1.922	1.212	1.33	0.142	ND	0.082	0.0469
60	73.98	1.204	0.861	1.23	0.054	ND	0.067	0.0243
80	60.93	1.255	0.811	1.32	0.105	ND	0.08	0.0279
Retention rate, %	26.3	59.9	69.7	2.9			46.7	35.4

Notes: NT. total nitrogen; TP. total phosphorous; SRP. soluble reactive phosphorous

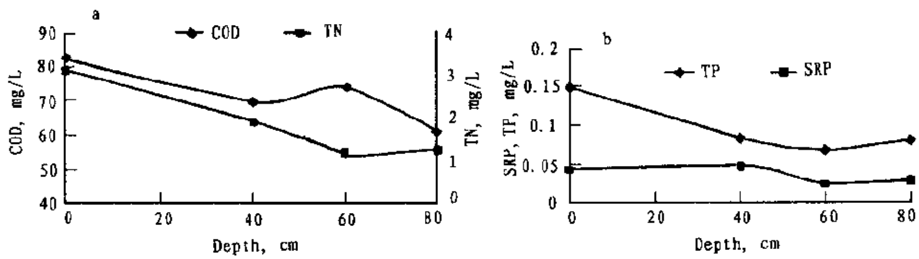

Fig. 1 Purification of reed marsh system to wastewater from paper factory

It is clear in Table 4 and Fig. 1 that the concentration of COD, TN and TP decrease obviously in the profile. The retention rate for organic nitrogen is especially high(about 70%). It is mainly because of the strong root system, and the peat soil like a sponge that can absorb nearly everything. The experiment done in the reed fields is mainly measuring the vertical retention rate of the reed-soil system to polluted water. But the horizontal subsurface flow in the rhizosphere soil also has a high retention rate to some nutrients like nitrogen and SRP (Yin, 1995). In combination, the retention rate of the reed-soil system for nutritious elements is very high.

The ground water output from the reed marsh system into the sea will be mostly cleaned up, if all the wastewater flows through the reed field first. Now the reed field covers an area of more than 900 km^2, large enough to treat all the wastewater from upstream cities and factories during dry season. How to make full use of this precious land resources is under concern.

2.4 Purification function of reed marsh to oil-drilling water

The Liaohe Delta has the third largest oil filed in China. Thousands of oil drilling stations are distributed all over the delta. Due to technological reasons, not all the oil spiller near the oil drilling station can be recycled. This kind of oil often causes pollution to the soil, and impedes vegetation growth nearby. The reed marsh was tested as a kind of treatment system for oil drilling wastes, such as drilling mud, drilling water and spilled oil, in early 1990s(Sun, 1994). Table 5, 6 and 7 show the results.

According to Table 5—7, the flooding system with a yearly water load of 5.64 meter thick (treatment No. 5) has the highest purification ability for oil drilling water. More than 15 tons of

COD and 1 ton of oil can be removed from 1 hectare of this system each year. But the oil drilling stations are scattered, sometimes in the paddy fields and dry land. This experiment only provided a possibility for the reed marsh as treatment system. No practical measures have been taken yet since then.

Table 5 Purification function experiment for oil drilling water

	Treatment No.	Water flow route	Irrigation period, d	Daily water load, m/d	Yearly water load, m/a
Filter	1	Vertical and horizontal	3	0.033	2.82
system	2	Vertical and horizontal	3	0.020	1.68
	3	Vertical and horizontal	3	0.007	0.60
Flooding	4	Horizontal flooding	1	0.033	2.78
system	5	Horizontal flooding	1	0.067	5.64

Notes: Vegetation: reed; annual working period: 150 days; method of irrigation: water tubes on the ground surface.

Table 6 The effect of wetland purification system to oil drilling water

	Cooling pool		Filter system output			Flooding system output	
Treatment No.	Input	Output	No. 1	No. 2	No. 3	No. 4	No. 5
COD, mg/L	459.2	389.3	144.0	77.3	88.2	77.2	113.9
Total purification rate, %		15.2	68.6	83.2	80.8	83.2	75.2
Wetland purification rate, %	–	–	63.0	80.1	77.3	80.2	70.7
BOD_5, mg/L	33.5	32.1	5.9	3.1	3.4	3.9	7.3
Total purification rate, %	–	4.28	82.3	90.7	90.0	88.4	78.3
Wetland purification rate, %	–	81.6	90.3	89.4	87.9	77.3	
Oil, mg/L	27.65	19.87	4.28	2.26	3.86	1.42	1.78
Total purification rate, %	–	28.1	84.5	91.8	86.1	94.9	93.6
Wetland purification rate, %	–	–	78.5	88.6	80.96	92.9	91.0
TN, mg/L	13.74	11.57	3.80	1.66	1.46	1.60	2.25
Total purification rate, %	–	15.8	72.4	87.9	89.4	88.4	83.6
Wetland purification rate, %	–	–	67.2	85.7	87.4	86.2	80.6
TP, mg/L	0.04	0.07	0.14	0.08	0.13	0.18	0.14

Table 7 Purification ability ($kg/(hm^2 \cdot a)$) of the wetland treatment system for oil drilling water

	Filter system			Flooding system	
	No. 1	No. 2	No. 3	No. 4	No. 5
COD	6917.64	5241.6	1806.6	8676.38	15532.56
BOD_5	738.84	487.2	172.2	783.96	1398.72
Oil	439.638	295.848	96.06	512.91	1020.276
TN	219.114	166.488	60.66	277.166	525.648

3 Purification function of the canal system to waste water from paper factories

As we are measuring the purification rate of the reed marsh system, the retention function of the irrigation canals is also considered. Experimental results (Table 8 and Fig. 2) indicate that the purification ability of the canals is also quite high. Almost half of the pollutants can be removed from the water as it flows through the 6000 meters along canal, before running into the reed fields, either because of bio-chemical decomposition or sedimentation.

The total length of the canal system in the Liaohe Delta is more than 2 million kilometers, about half of which is in the reed field. As the management in the reed fields improves, more canals will be built for water irrigation and discharge. There is also a big potential to use the canal network as a treatment system for polluted water.

Table 8 Purification ability of the canal system to wastewater from paper factories

Sample site	Dist., m	COD	TN	Organic-N	NH_4^+-N	NO_3^--N	NO_2^--N	TP	SRP
Pump stat.	0	152.332	3.224	2.244	2.79	1.97	0.017	0.17	0.0872
Canal 1	500	113.15	2.514	1.996	2.53	1.722	0.015	0.1	0.0519
Canal 2	2000	91.39	2.334	1.715	2.63	0.844	0.008	0.094	0.0534
Canal 3	6000	88.8	0.741	1.167	1.4	0.1	0	0.06	0.0381
Purification rate, %		41.7	46.0	48.0	49.8	94.9		64.7	56.3

Note: "Dist." refers to the distance from pumping station

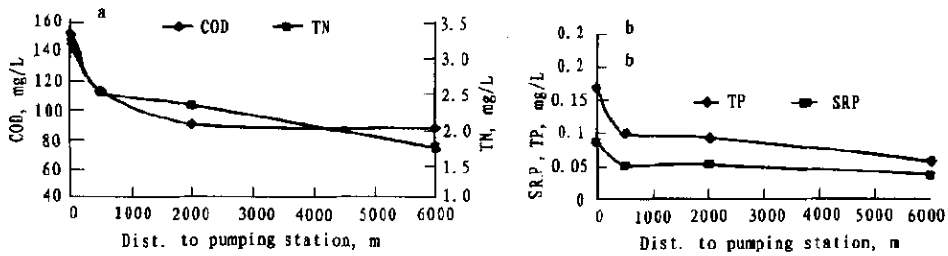

Fig. 2 Purification function of the canal system to wastewater from paper factories

4 The purification function of Suaeda heteroptera community to breeding pond water

4.1 The nutrient content of waste water from breeding ponds

The total area of prawn/crab breeding ponds occupies more than 100 km^2 in the Liaohe delta, most of which is distributed along the beach. As the coast pushed seaward by sedimentation, the area of breeding ponds also expands gradually.

The prawn ponds affect the coastal seawater mainly through the large amount of artificial foodstuff, which has a high content of N(ca. 1%), P(ca.0.75%), BOD and other nutritious elements. The concentration of those elements in the exchanged water is still rather high even after the consumption of prawns and crabs. In case of suitable physical conditions and induced by some bio-chemical factors, red tide will happen inevitable, such as in July of 1991 and September of 1998, when thousands of square kilometers sea surface was infected. On the other hand, red tide can also affect the prawn breeding especially in the densely populated area.

The prawn/crab ponds are a seasonal pollutant source, from June to September generally. The main pollutants are COD, NH_4^+-N, PO_4^{3-} and S^{2-} (Table 9).

Table 9 Average pollutant concentration in the prawn pond(mg/L)

Month	COD	NH_4^+-N	PO_4^{3-}	S^{2-}
June	3.26	0.13	0.013	0.01
July	5.94	0.29	0.018	0.04
August	6.56	0.50	0.030	0.06
September	6.30	0.74	0.021	0.06

According to Table 9, the main problem of prawn ponds comes in August (COD and PO_4^{3-}) and September (COD and NH_4^+-N). Suppose the average water depth in the ponds is 1 meter (June and July) and 1.2 meter (August and September), and the water exchange rate is 10% per day, then the total water exchange rate can be 1000 and 1200 m^3/hm^2 per day, respectively.

The total area of prawn ponds in the study area is more than 100 km^2. In the area where prawn ponds are densely distributed, the output of COD can reach 2 t/(km·d) along the coastline, enough to cause eutrophication problem in the vicinity.

In the recent 2 or 3 years, most of the prawn ponds have stopped breeding, due to the prawn disease expanded all over the coastal area in Eastern China. At the moment only some prawn and crab hatching factories are working. As the reeding ponds come back to work after the diseases are over, like Southern China recently, more serious problem will be caused if no measure is taken to treat the exchanged water.

4.2 The possibility of using Suaeda heteroptera community to cut down nutrient content from breeding pond water.

For the convenient of water exchange, the breeding ponds are usually built in the tidal belts, where Suaeda heteroptera community is situated as pioneer groups. The spatial distribution of these two landscape types is intercrossed with each other. Now the exchanged water from breeding ponds is discharged directly into the sea along tidal ways with ebb. It is quite practical to make use of the Suaeda heteropera community as a land treatment base for the breeding water.

If the Suaeda occupied beach is used as the treatment land for the water drained from prawn ponds, in combination with a well designed distribution pattern, great advantage will be obtained:

The coastal water quality will be improved, and the chances of eutripication caused by prawn/crab breading will be decreased.

The prawn production will be increased, due to better seawater is exchanged into the pond, and the chances for prawn diseases spreading are decreased.

The primary production of Suaeda heteroptera will increase, as a result of improved nutrient condition. More birds and other animals will be accommodated in this community. Thus the biodiversity will be increased.

The total areas of Suaeda community is 744 km^2. The potential for making use of this area is quite high. But, water projects are needed, especially in the area where prawn ponds are densely distributed.

5 Conclusion

The reed marsh has a high retention rate for water pollutants, such as COD, N and P, etc. The large area of reed in Liaohe Delta provides a natural land treatment system to cut down the quantity of eutrophication elements flowing into the sea.

The reed marsh can be used to treat the oil drilling wastes. It is especially important during the oil drilling operation period.

The canal network can also be used as a treatment system for polluted water. The canals are a good assistant system for the reed to retain the pollutants from rivers.

The Suaeda community has a high potential for the purification of exchanged water from prawn/crab breeding ponds.

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