Effect of Plants Combination in Purifying Farmland Drainage

Songmin Li[1,2(✉)], Qingyun Zhou[1], Nana Han[1], Shuhong Sun[1]

[1] Department of water conservancy engineering, Tianjin Agriculture University, Tianjin 300384, China. lisongmin228@126.com
[2]State Key Laboratory of Hydraulic Engineering Simulation and Safety, Tianjin University, Tianjin 300072, China. lisongmin228@126.com

Abstract. Drainage from farmland contains a lot of nitrogen and phosphorus, it is one of the important causes of water eutrophication. In order to reduce the concentration of nutrients before it discharged into receiving waters, 7 aquatic plants were selected to plant in outdoor planting box in the experiment, 5 different aquatic plant combinations were constructed, the removal effect of different combination was studied under same conditions，the reduction rule was researched，and the nitrogen and phosphorus in sediment were investigated. The results showed：after 49 days，the purifying effect of aquatic plants was significantly higher than that with no plant. Among them，the combination with Lythrum salicaria、Reed、Canna has the best effect in TN and TP removal, the removal rate reach：90.98%、95.95%、98.46% respectively. Reductive process of total nitrogen, ammonia nitrogen and total phosphorus in water are accord with polynomial regression, the concentration decreased along with time increasing. When initial nitrogen and phosphorus content in sediment is higher，nitrogen and phosphorus in the sediment will decrease because of plants absorbing; whereas the initial sediment nitrogen and phosphorus content is low，nitrogen and phosphorus in the water can transfer into the sediment, at the same time, the water was purified.

Keywords: Aquatic plants combination, Farmland drainage, Nitrogen and phosphorus, Reduction, Sediment

1 Introduction

Large amounts of nitrogen and phosphorus in farmland drainage has become an important source of eutrophication pollution. More and more experts and scholars concerned about the water plant treatment method [1-3]. It can not only play the role of water purification, but also improve the ecological environment and promote ecological restoration of degraded water. Currently, research on aquatic plants used to water purification mainly focused on a single plant individual or community, the tests have shown that the purification role of aquatic plants is efficient or effective [4-6]. But whether in natural conditions or artificial habitats, there are not only applicable to one kind of plant, but a complex system composed of various plants, especially in the pond or wetland system, plants is an important part. Different plants have different oxygen transfer rate, the effects on soil microbial activity is different, so the purification efficiency is also different. The combination of two or more kinds of aquatic plants can form a complementary effect of water purification to different pollution elements. It will produce more significant purifying effect. Studies have shown that: purification effect of a rational combination of aquatic plants is better than a single plant [7-8]. Whether aquatic plants can play it’s maximize purifying effect and utilization potentiality, the key lies in effective and appropriate selection of plant species and scientific collocation. Experimental research on the removal of nitrogen, phosphorus and other pollution elements by aquatic combination systems, analyzing its removal efficiency of nitrogen and phosphorus in water and soil, and compare it with the treatment with no plant to study the contribution rate of plants on nitrogen and phosphorus removal, and to determine the best combination. It can provide a theoretical basis for the comprehensive management of water environment.

2 Materials and Methods

2.1 Aquatic Plants

Aquatic plants with wide range of applications, good adaptability, developed plant root system and good purifying effect of specie were selected in the experiment, including Typha, Reeds, Lythrum salicaria, Zizania aquatica, Canna, Iris wilsonii, Water lily.

2.2 Test Water

Farmland drainage used in the test was prepared by artificial preparation methods, urea, and potassium dihydrogen phosphate were used to simulate the farmland drainage in Taihu Lake Basin. The initial concentrations of N and P were set as that TN concentration is about 15mg/L, TP concentration is about 0.8mg/L.

2.3 Experimental Methods

Test was done in Tianjin University from June to August in 2013 as shown in Fig. 1. Based on the principle of combination of floating leaf plants and emergent aquatic plants, to adapt to different depths of water, also taking landscape effect into account, five combinations were determined, as shown in Table 1, and one treatment with no plant as a contrast. Test was done to simulate ecological pond. Opaque gray plastic box was selected as a test container for low-light conditions, the size was length × width × height = 800mm × 400mm × 500mm, 25cm soil was paved in the bottom of the box to simulated ecological pond sediment conditions.

Table 1. Plants combinations

numbers	plants species
#1	Typha, Zizania aquatica, Water lily
#2	Reeds, Iris wilsonii, Water lily
#3	Typha, Lythrum salicaria, Water lily
#4	Typha, Iris wilsonii, Water lily
#5	Lythrum salicaria, Reeds, Canna

Fig. 1. Plant combinations experiment

The tests was done under normal outdoor light intensity, taking the large evaporation into account, the water was diluted to the scribed line 30L with tap water with no nitrogen, phosphorus and organic matters before sampling, the sampling points are located at 10 cm below the surface, each sampling 50mL. After the system is stable over time, nitrogen and phosphorus in water was measured in 1d, 3d, 7d, 10d, 16d, 26d, 31d, 42d, 49d. Total nitrogen (TN) determined by alkaline potassium persulfate digestion-spectrophotometry, ammonia nitrogen (AN) was determined by nessler's reagents spectrophotometer, total phosphorus (TP) was determined by antimony molybdenum anti-spectrophotometry.

3 Results and Discussion

3.1 Removal Effect of Nitrogen and Phosphorus in Water by Aquatic Combination

TN Removal Effect in Water

In wetland system, absorption of rhizosphere microorganisms, plant tissue and root retention and nitrification and denitrification around rhizosphere are the main way to remove nitrogen. Wetland plants can effectively strengthen the internal soil microbial activity, promoting rhizosphere microorganisms' absorption, retention, nitrification and denitrification and etc., which can improve the wetland nitrogen removal. TN concentrations in test water are shown in Fig. 2.

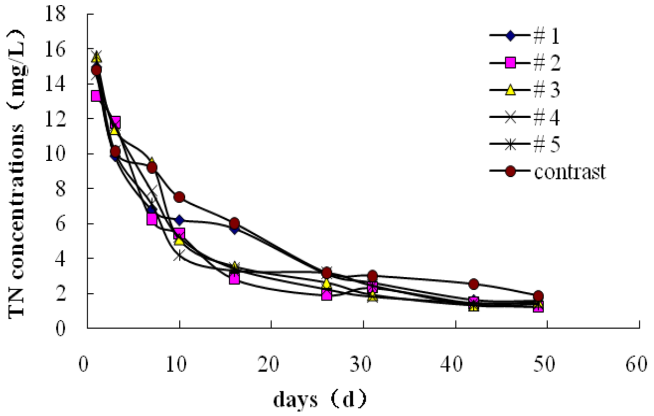

Fig. 2. TN concentration changes in water

5 plants combinations all had a good water TN removal efficiency, and the trend is basically the same, they all showed a good purification effect. At the beginning of the test (first 7d), TN concentrations decreased rapidly. At the Mid-term (10-31d), changes of TN concentrations in water is small, the average removal rate decreased, TN concentrations in each combination has been low and stable when the 42nd. Therefore, it is considered that TN removal in water mainly focused on the first 7 days.

Ammonia Nitrogen Removal Effect in Water

Ammonia nitrogen changes in water were shown in Fig 3. Due to urea is unstable after it dissolved in water, easily converted to ammonia nitrogen, so the ammonia nitrogen in the first 3 appeared a brief rise. Then the ammonia nitrogen concentrations in the treatments all declined stably.

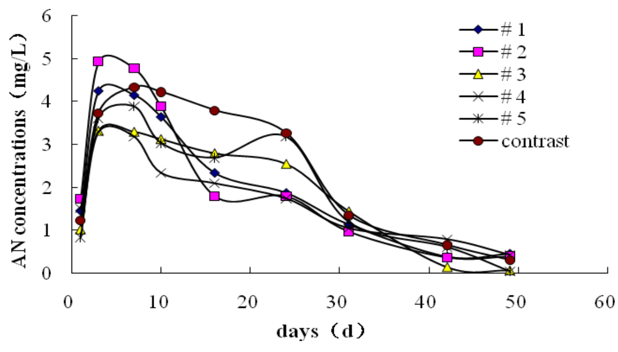

Fig. 3. Ammonia nitrogen changes in water

TP Removal Effect in Water

For phosphorus removal, partly because plants absorption, and partly Settled and consolidated on the substrate in the form of phosphate. There is very few amount of phosphorus is absorbed by plants directly.

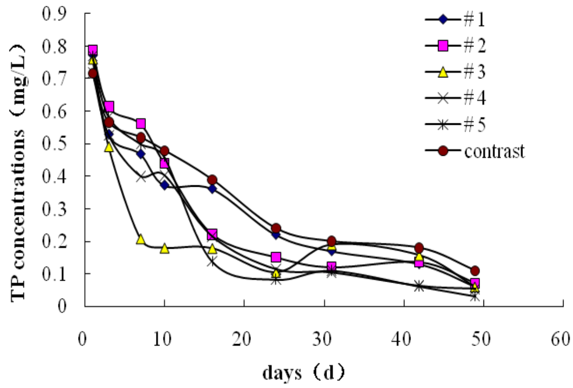

Fig. 4. TP concentration changes in water

TP in water also have a good removal effect for all the combinations, the general trend of TP concentration is substantially the same as the TN as shown in Fig. 4. In the first 7 days of test, TP concentrations decreased rapidly, and then the removal rate gradually decreased. On the 42rd day of combination 2, 31st day of combination, 10th day of combination4, 31st day of combination 5, TP concentration appeared a small recovery. The reason may be that phosphorus was absorbed by sediment, when the water was stirred, a small amount of phosphorus would release from the sediment.TP concentration in the contrast treatment also appeared a downward trend, it indicates that the water body itself has a certain self-purification capacity in the absence plant.

Nitrogen and Phosphorus Removal Rate

TN removal rate of different plant combinations sorted as combination 5> combination 2> combination 4> combination 3> combination 1> contrast, as shown in Fig. 5. The TN removal rate were 90.98%, 90.92%, 90.24%, 90.14%, 89.58%, 87.54% respectively. Ammonia nitrogen removal rate of different plant combinations sorted as combination 5> combination > combination 2 > contrast> combination 1> combination 4, except for combination 1 and combination 4, ammonia nitrogen removal rate were above 90%, they were 98.47%, 98.17%, 92.03%, 91.78%, 89.45%, 86.70% respectively. TP removal rate of different plant combinations sorted as combination 5> combination 4> combination 3> combination 1> 2 combination> contrast, the removal rates were: 95.93%, 92.42%, 92.17%, 92.12%, 90.89%, and 84.67% respectively. As above, combination 5 had the best removal effect for both nitrogen and phosphorus.

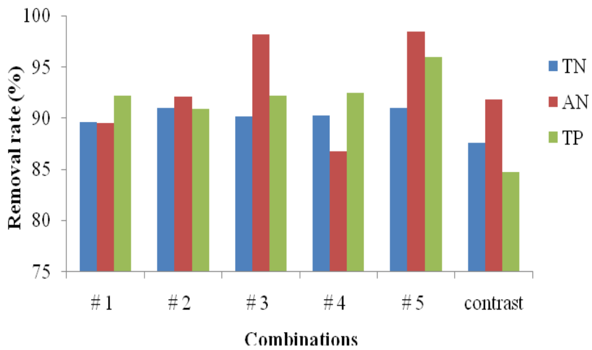

Fig. 5. Nitrogen and phosphorus removal rate

3.2 Reduction Law of Nitrogen and Phosphorus in Water

TN reduction in water

TN concentration in water of combination 5 decreased rapidly from 15.56mg/L at the beginning of test, down to 1.40mg/L at the 49th day. There was an obviously purification effect of TN in water. Polynomial function and exponential function were selected to fit the TN concentration change of the whole process. The fitting results are shown in Fig 6 and Fig 7. Fitting results of other combinations of TN reduction process were shown in Table 2.

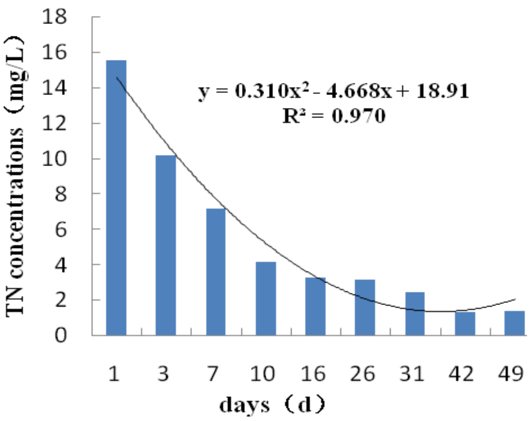

Fig. 6. TN reduction law of combination 5(polynomial fitting)

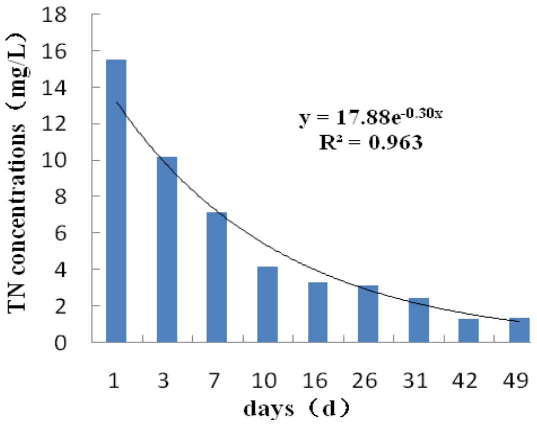

Fig. 7. TN reduction law of combination 5(exponential fitting)

Table 2 TN reduction fitting equation

	Polynomial fitting		Exponential fitting	
	fitted equation	R^2	fitted equation	R^2
#1	$y = 0.212x^2 - 3.623x + 17.22$	0.959	$y = 18.61e^{-0.28x}$	0.973
# 2	$y = 0.270x^2 - 4.214x + 17.65$	0.967	$y = 17.67e^{-0.31x}$	0.951
# 3	$y = 0.297x^2 - 4.710x + 19.95$	0.990	$y = 20.88e^{-0.32x}$	0.965
# 4	$y = 0.286x^2 - 4.500x + 18.92$	0.996	$y = 19.42e^{-0.32x}$	0.970
#5	$y = 0.310x^2 - 4.668x + 18.91$	0.970	$y = 17.88e^{-0.30x}$	0.963
contrast	$y = 0.167x^2 - 3.200x + 17.14$	0.976	$y = 19.08e^{-0.26x}$	0.974

As shown in Table 2, both polynomial functions and exponential functions can fit the TN reduction process in water well, the overall average R^2 value of polynomial fitting is much closer to 1, thus, it is better to fit the TN reduction process with a polynomial function.

TP reduction in water

TP concentration in water of combination 5 decreased rapidly from 0.77mg/L at the beginning of test, down to 0.03mg/L at the 49th day. Polynomial function and exponential function were selected to fit TP concentration change of the whole process. The fitting results are shown in Fig 8 and Fig 9. Fitting results of other combinations of TP reduction process were shown in Table 3.

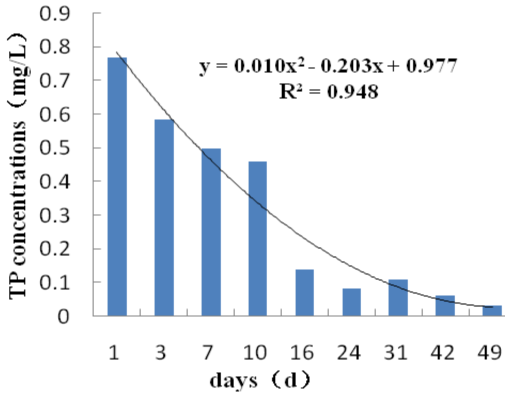

Fig. 8. TP reduction law of combination 5(polynomial fitting)

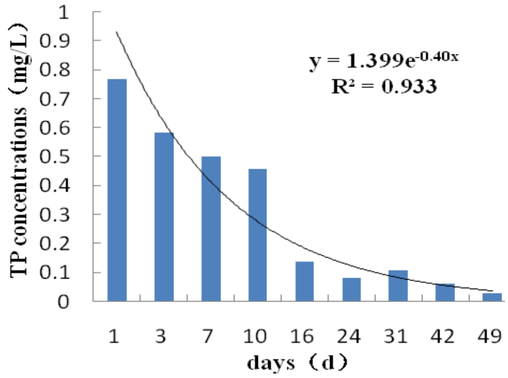

Fig. 9. TP reduction law of combination 5(exponential fitting)

Table 3 TP reduction fitting equation

	Polynomial fitting		Exponential fitting	
	fitted equation	R^2	fitted equation	R^2
#1	$y = 0.006x^2 - 0.140x + 0.852$	0.970	$y = 1.107e^{-0.28x}$	0.944
# 2	$y = 0.010x^2 - 0.192x + 0.986$	0.971	$y = 1.172e^{-0.30x}$	0.953
# 3	$y = 0.017x^2 - 0.238x + 0.902$	0.869	$y = 0.654e^{-0.23x}$	0.750
# 4	$y = 0.009x^2 - 0.175x + 0.871$	0.975	$y = 1.121e^{-0.34x}$	0.971
#5	$y = 0.010x^2 - 0.203x + 0.977$	0.948	$y = 1.399e^{-0.40x}$	0.933
contrast	$y = 0.002x^2 - 0.102x + 0.802$	0.977	$y = 0.996e^{-0.22x}$	0.958

As shown in Table 3, both polynomial functions and exponential functions can fit the TP reduction process well, the overall average R^2 value of polynomial fitting is much closer to 1, the polynomial function can fit the TP reduction process better.

3.3 Changes of Total N and P in Sediment

Sediment samples from each box were taken at the start and the end of the trial. Total nitrogen and total phosphorus in the sediment were measured after drying and grinding, the results were shown in Fig. 10 and Fig.11.

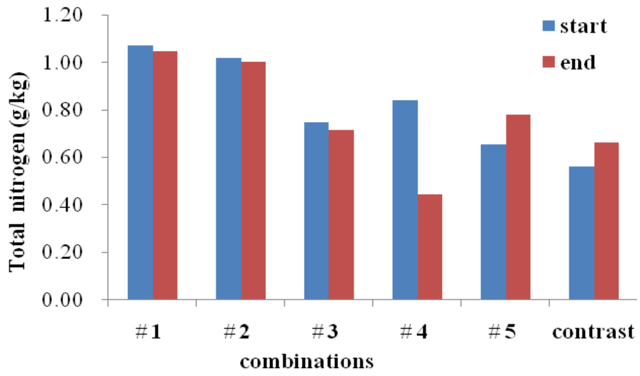

Fig. 10 Total N in sediment at start and end of the test

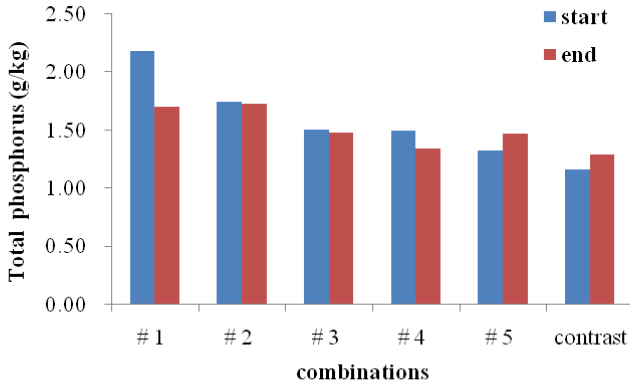

Fig. 11 Total P in sediment at start and end of the test

Except for combination 5 and the contrast, Total N and TP contents in sediment at the end of the test were lower than those at the start, as shown in Fig 10 and Fig 11. This phenomenon indicates that the plants can absorb nitrogen and phosphorus from sediment in the process of growth, the effect is most obviously in combination 4. Total N and P content were higher at the end than at the start of the test in combination 5 and contrast, N and P migrated from water to sediment, fixed by soil colloids, resulting in at the end of the test total N and P contents are higher than at the start of the test. This fully shows that the removal effect of nitrogen and phosphorus and other nutrients in the water, partly due to the absorption of plants, supplying the consumption of plant growth, on the other hand, soil adsorption also played an important role.

4 Conclusions

Aquatic combinations have a good removal effect of nitrogen and phosphorus and other nutrients in water, while the configuration of strewn at random discretion also beautify the environment. The aquatic plants will play an increasingly important role in terms of ecological restoration. Due to the different purification advantages of different aquatic plants, several aquatic plants planted together to be a combination in favor of complementarily between plants, to increase N and P removal rate. The reduction process of TN and TP in water are fitting with a polynomial function, with the extension of time the concentration decreased. When initial total nitrogen and phosphorus in sediment is higher, plants absorption will reduce the total N and P contents in the sediment, whereas at lower initial sediment nitrogen and phosphorus content, nitrogen and phosphorus in water will be migrated to the sediment, leading to total N and P content in sediment increased, at the same time, the water was purified.

Acknowledgment

This research was supported by the Major Science and Technology Program for Water Pollution Control and Treatment (2012ZX07101-008).

References

1. Engelhardt K A M, Ritchie M E. Effects of macmphyte species richness on wetland ecosystem functioning and services. Nature, 12:687-689, (2001)
2. Wu Z B，Qiu D R，He F. Effects of rehabilitation of submerged macrophytes on nutrient level of a eutrophic lake. Chin J Appl Ecol, 14（8）:1351-1353, (2003)
3. LU Q，HE Z L，GRAETZ D A, et al. Phytoremediation to remove nutrients and improve eutrophic stormwaters using water Iettuce （Pistia stratiotes L.). Enuironmental Science and Pollution Reseurch, 17(1): 84-96, (2010)
4. Hu C., Liu Q., Long W.W., et al. Purification of eutrophic water of different degrees with hydrophytes. Environmental Science & Technology, 34(10): 6- 9, (2011)
5. Liu Z.Y., Wang Y.L., Gong D.X. et al. Removal Ability of Common Aquatic Plants on Total N and Total P in Farmland Drainage. Hunan Agricultural Sciences, (03): 59～61, (2012)
6. Yang L.H., Zhuo L. Studies on Purification Abm of Aquatic Plants of the Eutrophication Water . Journal of Jilin Agricultural University, 28(6): 663-666, (2006)
7. Han X.Y., Song Z.W., Li P.Y.. Selection and assembly of macrophyte species in constructed wetland for purification of N and P in wastewater. J. Lake Sci, 20(6): 741-747, (2008)
8. Tian R.N., Zhu M., Sun X.X. et al. Nitrogen and phosphorus removal effects of different hydrophyte combinations under simulated eutrophic conditions. Journal of Beijing Forestry University, 33(6): 191-195 (2011)