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Study on the Effect of Sewage Concentration on Treatment Efficiency of Artificial Wetland of Plateau Lake

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Abstract: Contrast experiments on the effect of concentration of the total phosphorus(TP) on treatment efficiency of artificial wetland are carried out through changing TP concentration of influent water into surface flow(SF) and subsurface flow(SSF) wetlands and growing six plants (purple-leaf canna, water onion, water hyacinth, oenanthe javanica, calamus, reed). Treatment efficiencies of SF and SSF wetlands with the six plants varying with TP concentration change are analyzed, and some indexes of purifying function of SF and SSF wetlands with six plants including theoretically optimum treatment concentrations and removal efficiencies, actual optimum treatment concentrations and removal efficiencies, and TP maximum daily treatment loads, are obtained. The experimental results show that, TP removal efficiencies of SF and SSF wetlands with the six plants decrease with the increases of TP concentrations, different plants have different levels of treatment efficiency reduction, and the reduction of removal efficiency of SSF wetland is smaller than that of SF wetland. Removal efficiency of water hyacinth is little changed with the increase of TP concentration, and treatment efficiencies of SF and SSF wetlands decrease by 1.61% and 1.12% respectively. Removal efficiency of Canna is obvious changed, and treatment efficiencies of SF and SSF wetlands decrease by 2.94% and 2.55% respectively. Purple leaf cama had the least changes in the decrease of removal rate, and the table stream processing rate decreased by 17.07%, and subsurface flow by 15.9[illegible]%. The decrease in the removal rate of reed was clear and its table stream processing rate decreased by [illegible]0.86% and wubsurface flow by 18.2%. The actual optimum removal efficiency of SF wetland with water hyacinth is the largest of these SF wetlands' and reaches 85.2%, and its corresponding maximum daily treatment load of TP is 81g /(d • m^2). But the actual optimal removal efficiency of SF wetland with oenanthe javanica is the smallest of these SF wetlands' and is 76.88%, and its corresponding maximum daily treatment load of TP is 51.84g/(d • m^2). The actual optimum removal efficiency of SSF wetland with water hyacinth is also the largest of these SSF wetlands' and is just 88.31%, and its corresponding maximum daily treatment load of TP is 102.6g/(d • m^2). The actual optimum removal efficiency of SSF wetland with cama is the smallest of these SSF wetlands' and is only 78.32%, and its corresponding maximum daily treatment load is 55.2g/(d • m^2).

Artifical wetland is widely accepted as an efficient, low consumption and new sewage treatment technology, especially in the cases of nitrogen and phosphorus removal. Study finds that many factors affect the removal efficiencies of nitrogen and phosphorus of artifical wetland, such as the substrate of wetland, plant species, microbes, sewage load, residence time, the concentrations of nitrogen and phosphorus in sewage and water distribution ways[1]. To the effect of sewage load on the treatment efficiency of artifical wetland, Zhou Yaohua et al think that, wetland flora as a whole, its removal efficiency of low concentration domestic sewage (20%) is higher than that of high concentration domestic sewage(100%) [2]. In the sutdy of the effect of residence time on the treatment efficiency of wetland, Cui Fang finds that CODcr, TP, NH3-N concentrations of influent water have little effect on the removal efficiency of wetland with reed, but TN concentration has significant effect on the removal, and its removal efficiency is only 27% [3], Yuan Donghai et al find that purification efficiency of artifical wetland has a certain requirements about the initial concentration of pollutants in sewage, which is better in lower concentration of pollutants cases, and which drops in higher concentration of pollutants cases [4]. Sewage concentration has certain impact on decontamination effect of wetland, and we have found that present the domestic and international research are most about single species of plant and single type of wetland, but contrastive study of consideration of different plants and types of wetlands is very few. In this paper, contrast experiments on the effect of concentration of the total phosphorus(TP) on treatment efficiency of artificial wetland are carried out through changing TP concentration of influent water into surface flow(SF) and subsurface flow(SSF) wetlands and growing six plants (purple-leaf canna, water onion, water hyacinth, oenanthe javanica, calamus, reed). Treatment efficiencies of SF and SSF wetlands with the six plants varying with TP concentrations change are analyzed, and some indexes of purifying function of SF and SSF wetlands with six plants including theoretically optimum treatment concentrations and removal efficiencies, actual optimum treatment concentrations and removal efficiencies, and TP maximum daily treatment loads, are obtained, and hydraulic conditions of wetlands are optimized too. These results have certain significance in promoting the further development of the artificial wetland technique and restoring ecological environment.

Experimental Overview

Experimental Design. Wetland experimental field was built beside the logistics building in Kunming University of Science and Technology Chenggong campus. It has two different types of wetlands: Surface flow and subsurface flow. The SF wetland involves seven plots, in six plots of which are grew purple leaf canna, water onion, water hyacinth, oenanthe javanica, calamus, reed, and one of which is a blank plot. Each plot is 5.0m × 2.0m × 0.50m, whose the original soil backfill is 0.25meter. For comparison, SSF wetland also involves seven plots, and plants grew are the same as that of SF wetland. SSF wetland is divided into two parts, and each part is 5m×2.0m. There is a pool of 1.0m × 2.0m at the front end of wetland, grave base of 25cm, and original soil backfill of 35cm. The hydraulic gradient of experiment field is 2%. The specific arrangement is shown in Fig. 1.

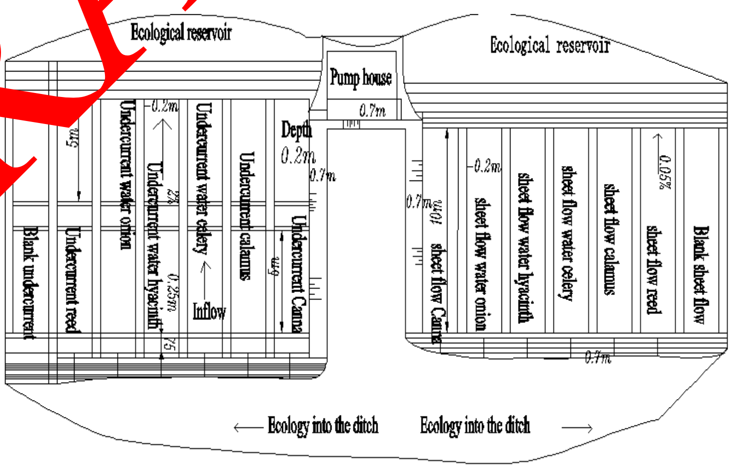

Fig.1. The design of artificial wetlands

Experimental Methods. Artificial wetland experimental field was formally completed on February 20, 2009, and equipped with submersible pumps, water meters, scales, thermometers and other test equipments.

Four experiments with 4 days for one time were carried out from April 6 to May 13, 2010. Experimental contents are as follows: （1）influent water flow: Continuous operation mode with continuous running 3 days and experimental influent water flow 100L / h is applied in the experiment.

（2）measurement items: TP, TN, COD concentrations, PH, temperature of influent and effluent water are measured. TP is determined by digestion-apectrophotometry, using potassium persulphate –as the reducing agent. TN alkaline potassium persulfate digestion - UV spectrophotometry.

（3）experimental program: An experiment needs 10 days including 4 days' experiment , 3 days' concentration analysis, and 3 days'data analysis. Experimental program is shown in Tab. 1.

Tab. 1 Experimental program table

Program	Time	Flow	Influent concentration (mg/L)
Program 1	Apr.6—Apr. 9	100L/h	1.66
Program 2	Apr.16—Apr.19	100L/h	2.52
Program 3	Apr.25—Apr.28	100L/h	4.15
Program 4	May 4 —May 7	100L/h	[illegible]

Experimental results and analysis

Contrast experiment of Six different types of plants in different wetland phosphorus removal when the influent concentration changes

Experimental results. According to the experimental design, experimental were conducted from April 6, 2010 to May 13, 2010. By experimental observations, purple leaf canna, water onion, water hyacinth, iris, reed five wetland plants in two different types of flow , subsurface flow wetland grew well, except water celery. Due to season, temperature and other factors, the water celery appeared withered leaves, dried, and plant density decreased;. The results are shown in Figure 2, Figure 3 and Table 2.

Tab. 2 Wetland plants in a variety of changes in the concentration of total phosphorus removal rate (%)

Program	Purple leaf canna			Water onion			Water hyacinth		
	SSF	SF	Difference	SSF	SF	Difference	SSF	SF	Difference
1	88.12	[illegible]	7.34	[illegible]	83.43	4.92	90.41	87.08	3.33
2	87.98	[illegible]	[illegible]	[illegible]	83.00	5.18	90.35	86.71	3.63
3	86.78	[illegible]	[illegible]	87.82	82.70	5.11	90.19	86.42	3.78
4	85.57	[illegible]	7.85	86.8	81.48	5.32	89.78	85.47	4.31
Average	[illegible]	[illegible]	7.52	87.79	82.65	5.13	90.18	86.42	3.76
Program	Water celery			Calamus			Reed		
	SSF	SF	Difference	SSF	SF	Difference	SSF	SF	Difference
1	[illegible]	[illegible]	7.29	87.47	78.42	9.05	86.95	78.42	8.52
2	[illegible]	[illegible]	7.54	87.44	78.24	9.20	86.82	78.08	8.74
3	[illegible]	77.02	7.08	86.81	77.53	9.27	86.41	77.51	8.89
4	[illegible]	75.87	6.88	85.85	76.47	9.38	85.76	76.06	9.69
Average	[illegible]	77.10	7.20	86.89	77.67	9.23	86.48	77.52	8.96

According to Figure 2 and Figure 3, six plants SF and SSF constructed wetlands have removed TP, but while concentration increasing, the removal rate decreased. When the influent TP concentrations <4.15 mg / L, the removal efficiency of SF constructed wetlands is an average of 80.59%, subsurface flow is an average of 87.47 %. The removal rate of subsurface flow is 6.88% higher than the SF. When imported water TP concentration> 4.15 mg / L, the removal rate of SF is an average of 78.85%, and SSF is an average of 86.09%, which is 2.35% higher. When the influent concentrations greater than 4.15mg / L, the reduction of removal rate of SFconstructed wetlands is more obvious, down by 1.74%.SSF is down by 1.38% , therefore, the reduction of SF is greater than the SSF down by 0.36%.

Figure 2 and Figure 3 also shows that TP removal efficiency of a six plant SF and SSF constructed wetlands decreases as the concentration increases. Furthermore, different plant have different degrees of reduction. In bothe SF and SSF constructed wetlands, cama wetland sees the biggest reduction in sewage removal while water hyacinth has the smallest. Removal efficiency of canna SF constructed wetland drops to 77.72% from 80.66%, 2.94% lower. Removal rate of SSF wetland drops to 85.75% from 88.12%, 2.55% lower, down 2.75% on average. Water hyacinth removalSFconstructed wetlands down 85.47% from 87.08%, 1.61% lower; and removal rate of subsurface flow constructed wetland removal efficiency dropps to 89.787 % from 90.41% lower by 0.63%, 1.12% lower on average. As the concentration of effleunt iscreaes, the decreasing order of reduction ofSFconstructed wetlands treatment rate is canna, reed, water celery, water onion, iris and water hyacinth, and the decreasing order of reduction of subsurface flow constructed wetland sewage treatment rate is canna, water celery, iris, water onion, reeds and water hyacinth.

Experiments show that, regardless of the SF or SSF constructed wetlands, the removal rate increased as the effluent decreased, but decrease in tremoval in the SF is larger than SSF; and different plants decreased to different degrees. SF reed wetland removal rate decreases by 2.36%, while the removal rate of SSF reed wetland decreases by 1.19%,SSF is 1.17% smaller than the SF. The reduction of SF iris constructed wetland is by 1.95% r, while the SSF iris constructed wetland is down by 1.62%, SSF is 0.33% lower than the SF ..

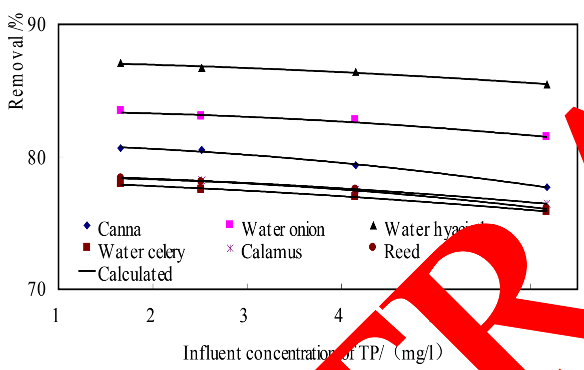

Fig.2. SSF constructed wetland TP concentration in the table to change the removal of the six comparison chart

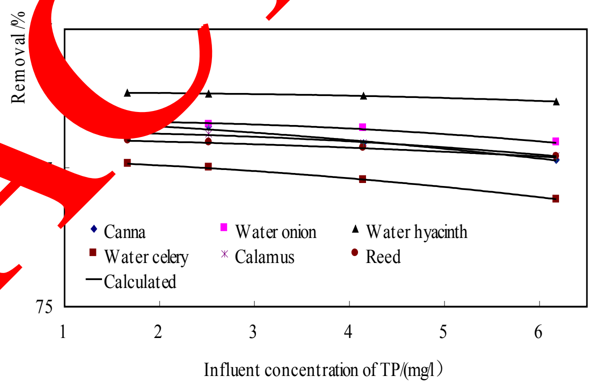

Fig.3. SSF constructed wetland TP concentrations changed wetland removal of the six comparison chart

Overall TP removal rate of SSF constructed wetland wastewater is higher than the SF the TP removal rate of SF and SSF constructed wetlan with different plants decreases as increasing concentration of wastewater increases. TP removal rate of iris SSF constructed wetland wastewater is down by [illegible]89%, SF is 77.67% . The iris SSF constructed wetland has the largest difference, 9.23%. TP removal rate of water hyacinth SSF constructed wetland was down by 90.18%, SSF is 86.42% , and water hyacinth SSF constructed wetland has the minimum difference, 3.76%. The difference in average TP removal efficiency of six plants SSF and SF wetland in decreasing order is calamus, reed, canna, water celery, water onion and water hyacinth.

Optimal concentration, optimal removal and TP load to determine the maximum daily processing. Using least squares method, the experimental results, functions return handling, removal and water are a function of concentration in Table 3.

Tab. 3. SF and SSF removal and influent concentration of the functional relation table

Wetland	Wetland plants	Theory of optimal concentration （mg/L）	Theory of optimal concentration （%）	Actual optimal concentration （mg/L）	Actual optimal removal（%）	Maximum load of the influent TP concentration $g/(d•m^2)$
SF	Purple leaf canna	18.46	53.61	4.75	79.00	57.00
	Water onion	22.65	55.54	5.48	81.77	65.76
	Water hyacinth	29.03	57.36	6.75	85.2	81
	Water celery	26.03	50.63	4.32	76.88	51.84
	Calamus	24.42	51.54	4.43	77.45	[illegible]
	Reed	19.20	52.11	4.35	77.03	52.2
SSF	Purple leaf canna	27.74	55.95	6.72	78.32	[illegible]
	Water onion	21.77	57.98	6.63	84.94	[illegible]
	Water hyacinth	35.22	60.20	8.55	[illegible]	[illegible]
	Water celery	22.14	56.07	5.87	82.99	70.44
	Calamus	21.62	55.96	6.09	83.61	73.08
	Reed	33.75	57.24	6.89	[illegible]	82.68

From Table 3, removal and influent concentration of the functional relationship can be seen from Table 3, removal and influent concentration of the functional relationship also can be seen, treatment rate and influent concentration into the quadratic curve.

Tab.4 SF and SSF TP concentration of the plant and removal of the optimal treatment table

We use optimization theory, influent concentration X, Y concentration and removal product removal to establish optimal function, and then the establishment of the function:

$$S=\alpha \cdot X \cdot Y \quad (13)$$

Wetlands	Wetland plants	Fitting formula	R^2	
SF	Purple leaf canna	[illegible] （1）	0.9951	Y is TP removal efficiency X isInfluent concentration of TP,R^2 is Correlation coefficient
	Water onion	[illegible] （2）	0.9781	
	Water hyacinth	[illegible] （3）	0.9834	
	Water celery	[illegible] （4）	0.9946	
	Calamus	$Y=-0.026x^2-0.0092x+78.30$ （5）	0.9988	
	Reed	$Y=-0.0697x^2-0.0365x+78.51$ （6）	0.9967	
SSF	Purple leaf canna	$Y=-0.0299x^2-0.3585x+88.89$ （7）	0.9872	
	Water onion	$Y=-0.058x^2-0.121x+88.29$ （8）	0.9973	
	Water hyacinth	$Y=-0.023x^2-0.047x+90.39$ （9）	0.9984	
	Water celery	$Y=-0.054x^2-0.142x+85.68$ （10）	0.9959	
	Calamus	$Y=-0.052x^2-0.339x+87.60$ （11）	0.9939	
	[illegible]	$Y=-0.024x^2-0.076x+87.15$ （12）	0.9994	

Where: S is the maximum daily processing load, X is the concentration of effluent, Y is removal removal.α=([illegible] L/h×24h/d)/$20m^2$ =0.12t/($d•m^2$)is coefficient.

Eq (1) - (12) generation (13), and let S derivative is zero, ie：

$$S'=0 \quad (14)$$

By (14), the best available wetland influent concentrations X concentration values, the results shown in Table 4.

Since the purpose of this study is to be achieved by artificial wetland effluent concentrations of pollutants discharged into the lake, then the standards should be consistent, "Municipal Wastewater Treatment Plant Pollutant Emission Standards" (GB18918-2002) a Class B standard (ie TP <1mg / L) , namely:

$$C_{TPeffluent}=C_{TPinflow}-C_{TPinflow} \cdot Y < 1mg/L \quad (15)$$

By (14) obtained a spreadsheet wetland emission standards in accordance with the actual optimal TP influent concentration, the results are shown in Table 4.

TP influent concentration, the actual value of the optimal generation type (1) - (12), the optimal removal rate by the actual value of the constructed wetland in the optimal removal of different species in the actual calculations in Table 4 .According to the actual optimal TP influent concentration and the best results of actual removal, we get TP total maximum daily load, the results are shown in Table 4.

Seen from the above results, the different types of experiments in which to determine the actual optimal removal of artificial wetlands, TP maximum daily processing load, the actual optimal TP removal rate of water hyacinth wetlands is 85.2%, and the corresponding maximum daily TP processing load is 81g/(d•m^2); water celery TP removal efficiency of the actual optimal is the minimum, which is 76.88%, the maximum daily processing load is 51.84 g/(d•m^2); potential practical optimal TP removal of water hyacinth is the highest(88.31%), and corresponding maximum daily processing load of TP is 102.6 g/(d•m^2), and the SSF cama is the minimum(78.32%), and maximum TP daily processing load is 55.2g/(d • m^2).

Conclusion

According to the comparative experiments on changes of removal rate of 6 species flow and subsurface flow constructed wetland with the change in the influent concentrations, we get the follow conclusions:

(1) The removal rate of constructed wetland decreases as the concentration of TP increases in both SF consrtucted wetlands and SSF constructed wetland. When the TP concentration of influent sewage is smaller than 4.15 mg / L, removal rate of SSF is 6.[illegible]8% higher than that of SF While the TP concentration of influent sewage is bigger than 4.15 mg/L, the reduction in the treatment rate of constructed wetland is obvious, and the decrease of SF is 0.36% bigger than that of SSF. Besides that, the removal rate of SSF is 2.35% higher than that of SF.

(2) The TP removal rate of six plants SF and SSF constructed wetlands decreases as concentration increases. Moreover, different plants have different levels of decrease in the removal rates. The decrease in TP removal rate of cama wetland in both SF wetland and SSF wetland, but water hycinth has the smallest decrease in both wetlands The removal rate of cama SF constructed wetland drops by 2.[illegible]4%, that of SSF wetland decerases by 2.55%, and on average down by 2.75%. The removal rate of SF water hycinth constructed wetlands decreases by 1.61%, that of SSF wetland decerases by0.63%, and on average down by 1.12%. The removal rate of SF reed constructed wetlands decreases by 20.86%, that of SSF wetland decerases by18.2%, and on average down by 1[illegible].53%. At last, the removal rate of SF cama constructed wetlands decreases by [illegible]7.07%, that of SSF wetland decerases by15.94%, and on average down by16.51%.

(3) There are decreases in the treatmetn rate in both SF wetland and SSF wetland as concenn tration of seweage increase, and degrees of reduction vary with plants. However the extents of decrease in SF wetland are larger that in SSF wetland. The TP removal rate of SF reed constructed wetlands reduced by 2.36%, and that of SSF constructed wetland reduced by 1.19%, and the degree of decrease in SSF flow is 1.17%lower than SF. The TP removal rate of SF calamus constructed wetlands reduced by1.95%, that of SSF constructed wetland reduced by 1.62%, and the degree of decrease inSSF is 0.33% lower than SF.

(4) Basing on experients, we get the TP actual optimal removal rate, TP maximum daily treatment load of SF and SSF constructed wetlands. SF water hyacinth has the largest TP actual removal rate, which is 85.2%, and the corresponding TP maximum daily treatment load is 81 g/(d•m^2).The TP actual removal rate of water celeryis 76.88%, which is the smallest, and the

corresponding TP maximum daily treatment load is 51.84 g/(d•m^2).The TP actual optimal removal rate of SSF water hyacinth is 88.31%, which is the largests, and the corresponding TP maximum daily treatment load is 102.6 g/(d•m^2). SSF cama has the smallest rate, which is 78.32%, and the corresponding TP maximum daily treatment load is 55.2 g/(d•m^2).

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