International Journal of Earth, Energy and Environmental Sciences
ISSN: 2517-942X
Vol:4, No:7, 2010

Treatment of Eutrophic-lake Water by Free Water Surface Wetland

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***Abstract*—**In China, with the rapid urbanization and industrialization, and highly accelerated economic development have resulted in degradation of water resource. The water quality deterioration usual result from eutrophication in most cases, so how to dispose this type pollution water higher efficiently is an urgent task. Hower, different with traditional technology, constructed wetlands are effective treatment systems that can be very useful because they are simple technology and low operational cost. A pilot-scale treatment including constructed wetlands was constructed at XingYun Lake, Yuxi, China, and operated as primary treatment measure before eutrophic-lake water draining to riverine landscape. Water quality indices were determined during the experiment, the results indicated that treatment removal efficiencies were high for Nitrate nitrogen, Chlorophyll–a and Algae, the final removal efficiency reached to 95.20%, 93.33% and 99.87% respectively, but the removal efficiency of Total phosphorous and Total nitrogen only reach to 68.83% and 50.00% respectively.

***Keywords*—**Constructed wetland, Eutrophic-lake water, Nutrient removal, Removal efficiency

I. Introduction

THE growth of industry and agriculture to supply the human demands from their increasing population causes an nnihilation of water ecosystems and an augmentation of water pollutions[1, 2]. During the last decades, constructed wetlands (CWs) were very successful when used for artificial treatment of wastewater and low-quality water from different sources. This approach is based on natural processes for the removal of different pollutants with the aid of different water plants including floating or submerged [3]. CWs are effective treatment systems which can be very useful in developing countries since they are simple technology and involve low operational costs [4-6], particularly suited for treating diffuse sources of pollution, such as urban and agricultural runoff [2]. Most of the time, CWs can be constructed with local materials which lowers the construction cost significantly [6, 7], they also can operate under a wide range of hydraulic loads, in most cases, CWs are designed based on hydrological and sizing conditions [8]. This work is the bigger successful application of this technology to convert eutrophic-lake into landscape water at this scale in China, the aim of this paper is to evaluate the respective treatment efficiency and draw a conclusion of potential use about this technology.

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II. Materials and Mtehod

A. Study Area

This study was carried out in XingYun Lake, Yuxi, China, located in the southwest of China (E: 102°46', N: 24°19'), where the climate is classified as warm and wet with rainfall in summer.

B. Description of the Treatment

The treatment system consisted of primary biology treatment, primary crushed stone wetland treatment, secondary biology strengthen treatment and secondary crushed stone wetland treatment, their areas were 145.5, 313.6, 125.1 and 348.7 square meter respectively corresponding to HRT of 7.0, 2.5, 7.6 and 2.5 hours. All of the flow system adopted gravitational flow for operating conveniently and economically, and through cascading measure providing with necessary dissolved oxygen (DO).

A schematic overview of the treatment is depicted in Fig. 1

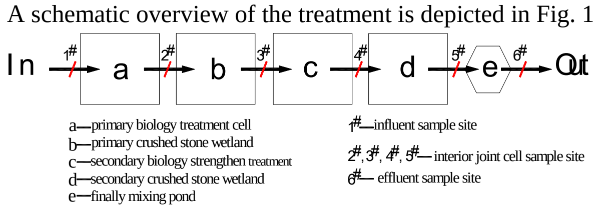

Fig. 1 Schematic representation of the treatment including six sample sites

C. Measurement of Water Quality Parameters

The treatment system operated from Sep, 2001 to Mar, 2003. All samples were determined by Yuxi environment monitoring station. The samples were taken monthly at six sites (1#—6#) in this system as shown in Fig. 1: at the inlet of the system and at the outlet of each cell. The water samples were collected using protocol described in the Standard Method (State Environmental Protection Administration of China, 2002) [9].

D. Water Analyses

The pH, DO and temperature (T) were determined immediately by a pH meter, a DO meter and a temperature meter in situ. TN and TP concentrations were determined after acid digestion. Water samples were also determined colorimetrically for ammoniacal nitrogen (NH_3–N) and nitrate nitrogen (NO_3–N). Chl-a was determined using a spectrophotometer at 645 nm and 665nm light lever. Algae were determined by the biological monitoring method.

E. Data Analysis

Statistical analysis and variance analyses were performed using Excel 2003 and SPSS 17.0 respectively, Data were transformed into natural logarithms to approximate a normal distribution when needed, normality and homogeneity of variance was checked with a Kolmogorov-Smirnov test. Pearson's corrlelation were performed to find cross-correlation among variable and significant differences were determined by an analysis of variance (ANOVA). A P–value of 0.05 and 0.01 can be interpreted to declare that the correlation matrix was statistically significant.

III. Results

In this paper, after discussed different treatment cell removal efficiency, we found that the effects of different HRT were contributed to the result of treatment, so respective eutrophic-lake treatment cell was monitored to discern the removal efficiency under hydraulic loading conditions.

A. Total Nitrogen (TN) Removal Analysis

The TN removal mechanisms in CWs systems are very complex, in general which include nitrification, denitrification, plant and microbial uptake, *et al* [1, 10-12]. Denitrification refers to the reduction of NO_3 (or NO_2) to N_2 and other gaseous products such as N_2O and NO, this process is carried out by a large number of heterotrophic, facultative anaerobes. Several experimental studies on N removal in CWs treatment confirmed that unplanted treatment had a lower N removal compared with planted treatment for many cases [1, 11, 12]. With plant grew, dissolved inorganic nitrogen is taken up and incorporated into biomass, however, for plant respiration and death, biomass was recycled to nonliving organic and inorganic matter.

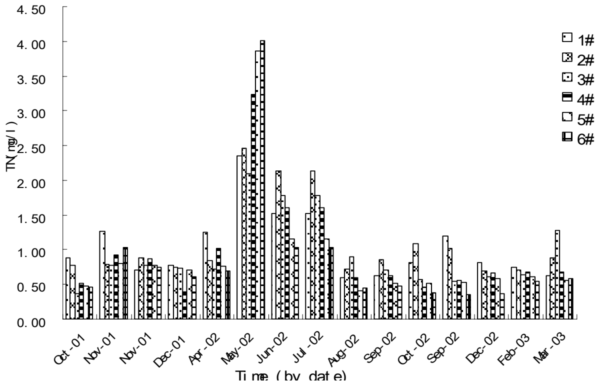

Fig. 2 Determined value of TN from Oct, 2001 to Jan, 2003

Majority determined value of average TN concentration of succedent treatment cell was higher than 1# except from May, 2002 to July, 2002 as shown in Fig. 2.

B. Ammoniacal Nitrogen (NH_3-N) Removal Analysis

NH_3-N is taken as one of important sources resulted in eutrophication, in the presence of nitrifying bacteria and oxygen, it can be converted to nitrate nitrogen, and the process was named as nitrification. Determined value of NH_3-N in all sampling sites from Oct, 2001 to Mar, 2003 as shown in Fig. 3. During the sample period, its concentration increased suddenly from May to July, 2002, at the same time other sample sites concentration raised correspondingly, because this period is rainstorm high frequency to happened, and the surface runoff carried a lot of pollutant into the water body .

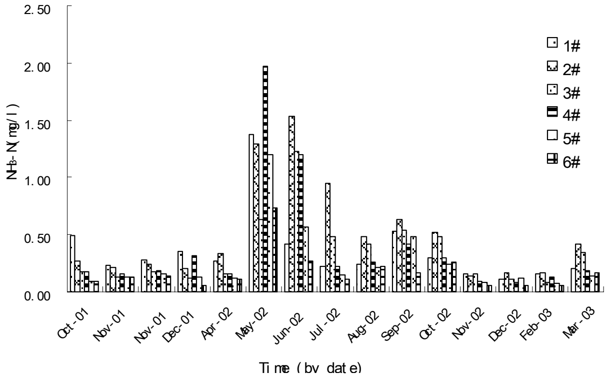

Fig. 3 Determined value of NH_3-N from Oct, 2001 to Mar, 2003

C. Nitrate Nitrogen (NO_3-N) Removal Analysis

NO_3-N is also taken as one of important sources which result in eutrophication. There were not monitor data before April in 2002, so the curve was only from that time. Every sample concentration trended to below 0.50mg/l from July in 2002 to Mar in 2003, the final outlet removal efficiency reached to 95.20% during the whole sampling period as shown in Fig. 4.

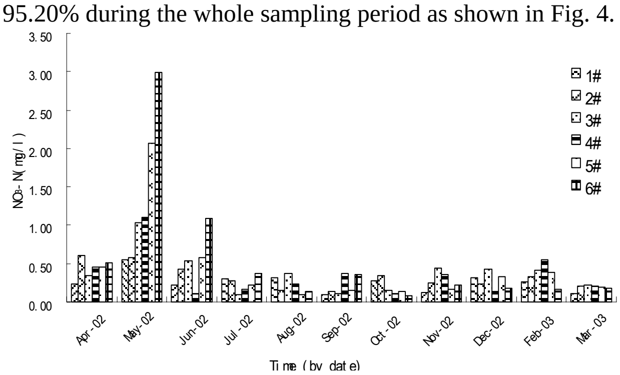

Fig. 4 Determined value of NO_3-N from Apr, 2002 to Mar, 2003

D. Total Phosphorous (TP) Removal Analysis

The TP removal mechanisms from wastewater including sorption on substrates, storage in biomass and the formation of new sediments [11], most P removal is effected by the media bed [14], and associated with the physical-chemical and hydrological properties of the filter media [11, 15]. However, biological P removal was also taking place [1], plants, algae, and microorganisms all utilized P as an essential nutrient [16-18]. The determined concentration value of TP transition was differing from the above result such as TN or NO_3-N as shown in Fig. 5. For accompany with plant respiration and death, biomass is recycled to nonliving organic and inorganic matter, so the harvest has the advantage to accelerate pollutant removal phosphorus and keeping removal sustainability of this system, also could also gain considerable economic benefits.

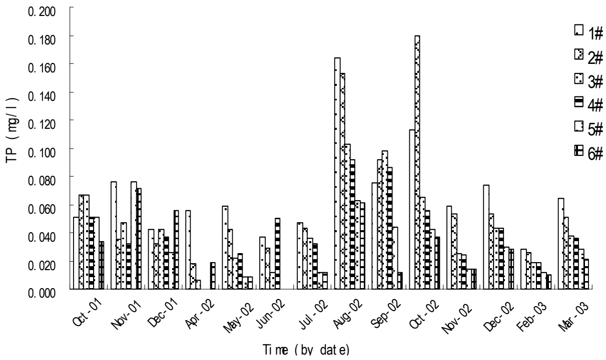

Fig. 5 Determined value of TP from Oct, 2001 to Mar, 2003

E. Chlorophyll –a (Chl-a) Removal Analysis

During the sampling period, the Chl-a concentration variation graph was similar to TN in all of the time, and the majority concentrations of Chl-a kept lower level especially the 6# sampling site as shown in Fig. 6. When the algae booming, the Chl-a concentration raised correspondingly. But concentration value of final outlet reached to a minute value though the concentration of inlet was high as shown in Fig. 6. The high removal efficiency indicated the treatment was available to the Chl-a removal.

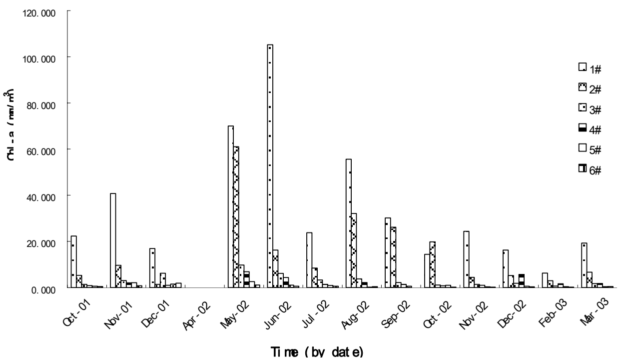

Fig. 6 Determined value of Chl-a from Oct, 2001 to Mar, 2003

F. Algae Removal Analysis

The effects of algae have been a matter since eutrophication problems continue to intensify in many reigons of the world [19]. An algal booming is a rapid increase or accumulation in the population of algae in an aquatic system, toxins from the booming can damage to other organisms, such as kill fish and other aquatic life by decreasing sunlight available to the water and by using up all of the available oxygen in the water. The algae concentration variation graph was similar to Chl-a during the whole sampling period, the most algae concentrations of subsequent treatment cell kept lower level, especially in the 6# sampling site, it even reached to naught as shown in Fig. 7. The final outlet removal efficiency reached to 99.87%, which indicated high efficiency of the treatment in the algae removal.

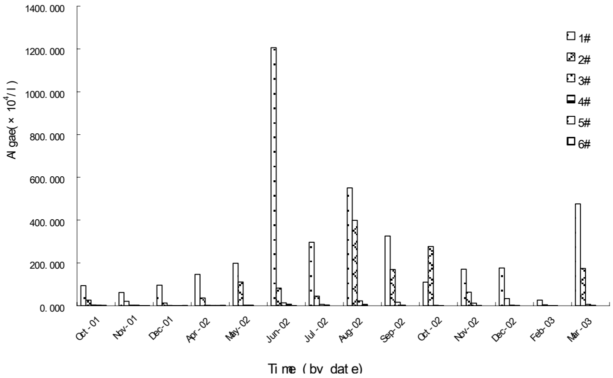

Fig. 7 Determined value of Algae from Oct, 2001 to Mar, 2003

IV. Discussion and Conclusion

A. Removal Efficiency Analysis

The application of eutrophic-lake water treatment to illustrate removal efficiency of CW, the water flow regime in the system increased the hydraulic loading efficiency and removal rate of nutrient. The study results indicated six sample sites along this system: influent (1# site) and subsequent treatment effluent (2# to 6# site), concentration of 6# site was the most important role for it was the final effluent site. From the above results, we could conclude that the treatment removal efficiency was high for NO_3-N, Chl-a and algae, the final removal efficiency reached to 95.20%, 93.33%, and 99.87% respectively. The removal of N occurred by plant uptake, microbial assimilation, and denitrification process [11], several experiments confirmed that unplanted treatment had a lower N removal compared with planted for many cases [1, 13]. The removal efficiency of TN and TP approximately maintained 50% during the experiment period. In order to maintain the sustainability of removal efficiency, these plants which uptake phosphorus and nitrogen were harvested before decay would become efficient measure to enhance the removal efficiency. It had been found that the proper vegetation management not only improves treatment effect but also improves substantially wildlife value of the constructed wetland [20].

B. Cross-correlation Analysis

Cross-correlation coefficients between every varialbe were evaluated, the cross-correlation coefficients were calculated with the use of following Eq.(1).

$$r = \frac{\sum_{i=1}^{N}(x_i - \overline{x})(y_i - \overline{y})}{\sqrt{\sum_{i=1}^{N}(x_i - \overline{x})^2}\sqrt{\sum_{i=1}^{N}(y_i - \overline{y})^2}} \tag{1}$$

where x_i and y_i were the parameter values, $\overline{x}$ and $\overline{y}$ were the mean values of the two parameters. Values of the cross-correlation coefficients range from -1 to +1, where -1 impling perfectly inversely correlated variable and +1 impling perfectly correlated variable, thus the absolute value of the cross-correlation coefficient was used in the following discussions.

Cross-correlation coefficients values between each variable as shown in Table 1, we could draw the conclusion that between different removal efficiencies have significant correlation values in this treatment, for example, TN value showed a positive strong correlation with the NH_3-N and TP, and Chl-a showed strong correlation with algae. This was probably due to better algae removal which contributed to improve Chl-a removal processes, in general, each sampling index have good cross-correlation with other, and the value was great than 0.50.

TABLE I
SIGNIFICANT (P<0.05) AND HIGH SIGNIFICANT (P<0.01) VALUES OF CORRELATION MATRIX BETWEEN MUTUAL REMOVAL EFFICIENCIES IN CWS FROM SEP 2001 TO MAR 2003

	TN	NH_3-N	NO_3-N	TP	Chl-a	Algae
TN	1.00					
NH_3-N	0.92**	1.00				
NO_3-N	0.80	0.79	1.00			
TP	0.95**	0.86*	0.90*	1.00		
Chl-a	0.75	0.58	0.86*	0.90*		
Algae	0.68	0.49	0.81*	0.85*	0.99**	1.00

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

This is a basic necessity for the removal of nutrient such as TN and TP from eutrophic-lake water, but people also should pay attention to some indices such as NO_3-N, Chl-a and algae, because their high concentrations also may caused eutrophication in open water body when draining off to another water body such as landscape river water. Further more studies on optimizing process in CWs is still going on with field-scale experiments, research will conduct to possibilities for recycling the treatment water, reach to colorless, odorless, lower concentrations of nutrients and organic pollutant discharge, and the aesthetic appreciation will also become significant interest.

V. CONCLUSION

In this pilot-scale study, a surface flow constructed wetland located in XinYun lake was used for treating heavy eutrophic pollutant water for the first time in China. The results demonstrated that CWs could remove most amounts of chl-a and algae, and the effluent quality of the system remained minute value. At the same time, the results also indicated that TP and TN could be removed more than 50% and the CWs system could be operated for a long time. The finding could be used to provide useful information on design and operation of CWs technology in treating eutrophic lake water.

ACKNOWLEDGMENT

The author would like to grateful to members of my office for their support, especially for the constructive comments of Ph. D. X. Y. Wang., M. W. Song., S. T. Li and Y. N. Li.

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