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Study on treatment of aquaculture wastewater using a hybrid constructed wetland

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Abstract. This paper reported the pollutant removal performances of a hybrid wetland system for the treatment of aquaculture wastewater. The system consisted of two treatment stages: a subsurface vertical flow (VF) wetland, followed by a horizontal flow (HF). The aquaculture wastewater with the different concentrations such as eutrophy and mesotrophy was treated using hybrid constructed wetland. The experimental results showed that the removal efficiencies of eutrophy aquaculture wastewater achieved 56%, 71%, 73% for nitrite, phosphate and nitrate, respectively. At the same conditions, it can be found that the removal efficiencies of mesotrophy aquaculture wastewater achieved 39%, 74%, 73% for nitrite, phosphate and nitrate, respectively.

1. Introduction

Aquaculture has become the fastest growing food production sector and may be practiced in extensive, semi-intensive or intensive system. Aquaculture has gained prominence due to the stabilization of the fish captures and the increase of fish consumption in the last years.Aquaculture has been a fast-growing industry because of significant increases in demand for fish and seafood throughout the world. Total aquaculture production (including aquatic plants) in 2000 was 45.7 million tonnes by weight and US$ 56.5 billion by value [1]. Aquaculture is growing more rapidly than any other segment of the animal culture industry.

Aquaculture wastewater exerts adverse environmental impacts when the effluents from these systems are discharged to receiving waters. The organic matter loading reduces dissolved oxygen levels and contributes to the buildup of bottom sediments and high nutrient loading impairs water quality by simulating excessive phytoplankton production [2].Aquaculture systems produce large quantities of organic matter and nutrients(nitrogen, phosphorus and other elements) that require treatment and/or disposal. The production if 1 ton (1000kg) of live channel catfish releases 1190 kg of dry matter, 60kg of nitrogen and 12kg of phosphorus to the culture water as metabolic wastes [3]. The major contaminants of in aquaculture wastewater can be broadly classified into three categories: organic carbon, nitrogen and phosphorus. Nitrogen compounds such as ammonium and nitrite can be toxic to aquatic life if present at sufficiently high concentration, while nitrate is known to cause ‘blue babe syndrome’ and is therefore a potential public health threat. Furthermore, nutrients such as nitrogen are well known to stimulate growth of algae and other photosynthetic aquatic life. These nutrients were also found to lead to excessive eutrophication, excessive loss of oxygen resources, and undesirable changes in aquatic ecosystems, which becomes a serious environmental problem [4].Consequently, aquaculture industries look for appropriate and better methods in treating wastewater prior to recirculation or discharge into the receiving water.

Constructed wetlands are the constructed systems which utilize natural processes for treating wastewater that are using soil, vegetation, and microbial communities. They are quite similar to the natural wetlands using natural treatment processes but perform in a controlled environment [5]. Conducted wetland (CW) technology has grown in popularity for wastewater treatment since the early 1970s [6]. The use of constructed wetlands has several advantages over conventional wastewater treatment methods. Initial cost of constructed wetlands for use as primq or secondary treatments is considerably lower than conventional treatments. Annual cost of operation is also considerably less expensive. A paper issued by the Tennessee Valley Authority estimates the savings from constructed wetlands built for small publicly owned treatment works nationwide exceed $2 billion [7]. While constructed wetlands efficiently remove many pollutants from wastewater streams, constructed wetlands also greatly enhance the environment by providing a habitat for vegetation, fish, birds, and other wildlife. Many projects have added nature trails and picnic areas to encourage visitors. Constructed wetland treatment systems are engineered systems that have been designed and constructed to utilize the natural processes but do so within a more controlled environment. Constructed wetlands may be categorized according to the various design parameters, but the three most important criteria are hydrology (open water-surface flow and subsurface flow), type of macrophytic growth (emergent, submerged, free-floating) and flow path (horizontal and vertical). Different types of constructed wetlands may be combined with each other (i.e., hybrid or combined systems) to utilize the specific advantages of the different systems [8-10].One of the major problems with efficient performance of constructed wetlands is clogging of the filtration substrate. Therefore, it is necessary to select the filtration material carefully, distribute the wastewater evenly across the wetland surface, and also select the optimum hydraulic loading rate. Some studies[111] have demonstrated that constructed wetlands can effectively remove the major pollutants from catfish, shrimp and milkfish effluents, including organic matter ,SS, N, and P. CW is not only easy to operate, but also could be built at a relatively lower cost. The results of constructed wetland depend on its microbial activity, hydraulic retention, time, load temperature, and types of vegetation [12]. However, the disadvantages of wetland cannot be ignored[9], the wetland require more land area than other alternative systems, besides, it is not very stable because it requires an extra start-up time until vegetation is well grown, and seasonal uncertainties could damage the wetland for decrease of sunlight and temperature[13]. Although, all of the mentioned systems are efficient in removing contaminants and pathogens from wastewater, however being possessing an elevated evaporation rate as compared to lagoons and ponds, the potential of reusable water in these systems is very limited. To overcome this concern, a configuration named as “hybrid CWs (combination of vertical and horizontal flow)” could be an appropriate alternate by having minimum water loss [14].and improved effluent quality with less total-N concentrations [15].

The main objective of the work was to investigate treatment efficiencies of aquaculture wastewater using hybrid constructed wetland (combination of vertical and horizontal flow).

2. Materials and methods

2.1. The lab-scale wetland systems

The lab-scale hybrid systems were built on campus (outdoors) at Hainan Tropical Ocean University. The hybrid systems consisted of two treatment stages: a HF wetland (A), followed by a VF wetland (B), as shown in Fig. 1.The available materials, organic sugarcane bagasse (size 3.4-8.5 mm) and sylhet sand (size 300.0-600.0 μm), were used as the main media in the VF and HF wetlands, respectively. The bagasse was a by-product of sugarcane processing, which contained 40% cellulose, 24% hemicellulose, and 25% lignin. The packed porosity of the media was measured as 65% and 30% for sugarcane bagasse and sylhet sand, respectively.

The volume of each VF and HF wetland is 57cm*37cm*30cm. The same type of locally available *mangrove* was planted into the wetlands. Experimental arrangement of hybrid wetland systems is shown in Fig.1.

Fig. 1 Diagram of hybrid wetland systems.

2.2. Wastewater sampling and analysis

The seawater sample were collected from Egret park(Sanya), making the water become eutrophic by adding the certain amount of monopotassium phosphate, ammonia chloride, potassium nitrate, sodium nitrite. Table.1 demonstrates two kinds of eutrophic water with different concentration.

Table.1 Eutrophic body of water of different concentration（mg/mL）

Nutrient Content	Mesotrophy	Eutrophy
Total Nitrogen	0.5	1.0
Total Phosphorus	0.05	0.1

During experimental analyses, wastewater samples were collected on a weekly basis from the inlet and outlet of each wetland reactor. The water quality parameters measured included COD, total nitrogen (TN), nitrate nitrogen (NO_3-N), nitrite nitrogen (NO_2-N), ammonia nitrogen (NH_4-N), total phosphorus (TP), phosphate (PO_4-P), and turbidity. Sample analyses were conducted in accordance with the methods described in ‘Water and Wastewater Monitoring and Analysis Methods’ (State Environmental Protection Administration of the People’s Republic of China, 2002).

3. Results and discussion

Nitrate (NO_3-N) and nitrite (NO_2-N) are the major sources of wastewater contamination and their excessive amount in conjunction with phosphorus can cause eutrophication. In the present work, treatment efficiencies of aquaculture wastewater using hybrid constructed wetland were investigated under the same conditions of mesotrophy and eutrophy.

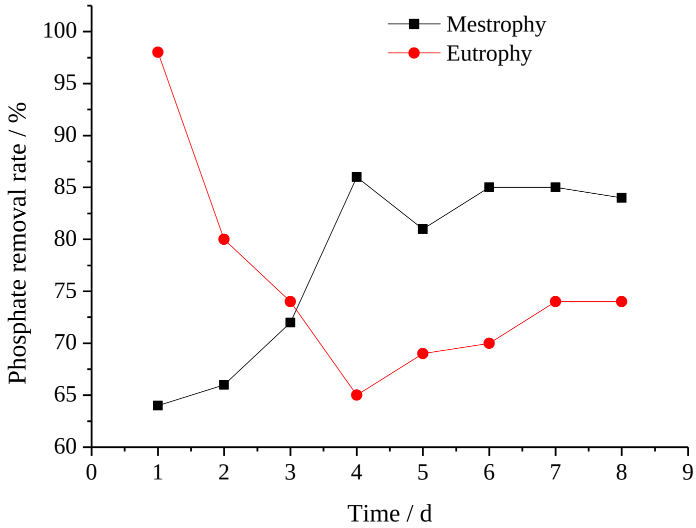

Fig.2 The removal rate of phosphate

It is obvious that the phosphate removal efficiency has decreased dramatically at first, and then it went up slowly from 5th day. By contrast, the removal rate in mesotrophy jumped from 64% to 87%. As shown in Fig.2, it can be found that the phosphate removal efficiency in the condition of mesotrophication is relatively better than that in eutropication.

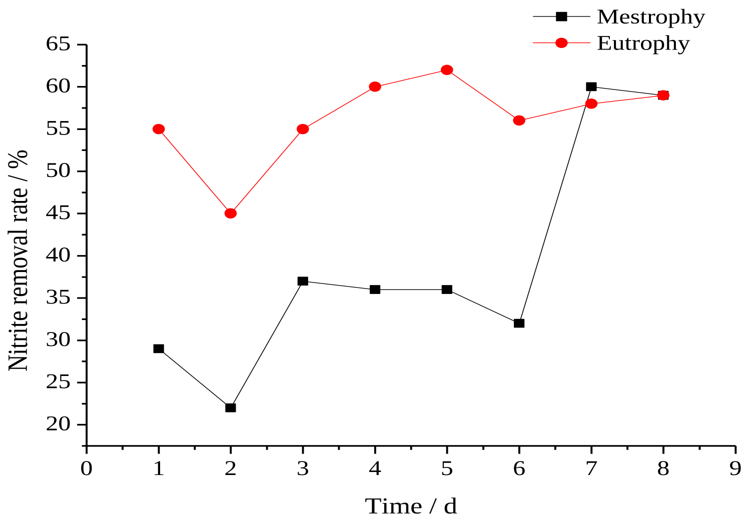

Fig.3 The removal rate of nitrite

During the process of removing nitrite, the removal rate in eutrophication started with 55%, and then it fluctuated from 2nd day to 7th day and finally reached 57%, Compared with mesotophication, the removal rate jumped from 33% to 57%. Fig.3 indicated that the nitrite removal rates both in mesotrophication and in eutropication gained good results.

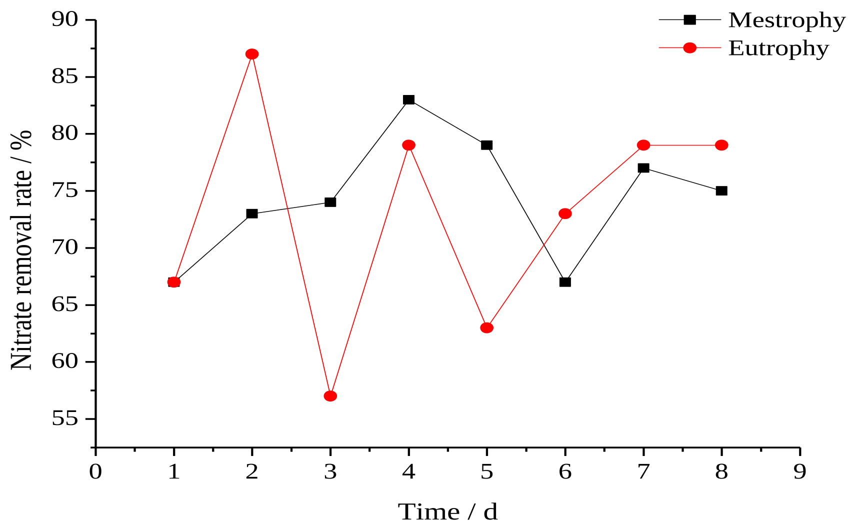

Fig.4 The removal rate of nitrate

As shown in Fig.4, the removal rates of two kinds of aquaculture wastewater have experienced a fluctuating period from day 1 to day 7 and finally reached the same level of around 77%. It can found that the removal rate of eutrophy is slightly higher than that of mesotrophy.

4. Conclusions

Among current wastewater treatment technologies, the constructed wetland technology is considered as an eco-friendly, low cost technology with some distinct advantages such as：low operation and maintenance cost, as well as provide aesthetic value, generate usable plant biomass, and help support wildlife habitat. In the present work, a hybrid wetland system was built to treat two different concentrations of aquaculture wastewater.The experimental results showed that the removal efficiencies of eutrophy aquaculture wastewater achieved 56%, 71%, 73% for nitrite, phosphate and nitrate, respectively. At the same conditions, it can be found that the removal efficiencies of mesotrophy aquaculture wastewater achieved 39%, 74%, 73% for nitrite, phosphate and nitrate, respectively.

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