CONSTRUCTED WETLANDS AS BIOFILTERS IN CLOSED RECIRCULATING TANK CULTURE SYSTEMS OF ASIAN TIGER SHRIMP (PENAEUS MONODON)

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Received: 1 April 2016; Accepted for publication: 15 June 2016

ABSTRACT

The study was conducted to monitor the real-time status of toxic compounds to P. monodon in intensive recirculating aquaculture system integrated constructed wetlands (CWs) designed with surface flow (SF), vertical subsurface flow (VF) and horizontal subsurface flow (HF), and to examine removal efficiency of contaminants in different CWs. Plants used in the system were cattail (Typha sp.), elephant grass (Pennisetum purpureum) and unplanted systems used as referenced samples. Recirculating rate per day was 50% of total water volume in tanks. Water from culture tanks was purified by passing through SF, VF and HF then return to original tanks without water exchange in entire study period. After 72 days, concentration of NO2-N, NH4-N and NO3-N was building up over study period and was not significantly different among treatment systems (except the concentration of NO3-N). At the end of study period, NH3 concentration was below the toxic threshold for P. monodon in accordance to Circular No. 45/2010/TT-BNNPTNT. P. monodon grew slowly and the survival rate was as low at 30%, 43% and 60.5% in the HF, SF and VF systems, respectively. The average water volume added in each tank in entire study period was 393 ± 1.7 L. Despite of low survival and growth rates, the integration of CWs in intensively recirculating shrimp systems helps to improve water quality in accordance to Circular No. 45/2010, to diminish pollutant discharging and to maximize efficiency of water use which minimizes environmental pollution.

Keywords: cattail, constructed wetlands, biofilter, elephant grass, Penaeus monodon, recirculating aquaculture system, water quality

1. INTRODUCTION

The aquaculture farms of Asian tiger shrimp (Penaeus monodon) in the Mekong Delta (MD), Vietnam are increasing in term of area and density [1]. However, shrimp farming is encountering many difficulties and challenges due to the substantial diminishing in water quality
of cultivation areas and thus is leading a major loss [2]. The process of intensive culture raises accumulation of pollutants like NH$_4$-$N$, NO$_3$-$N$, NO$_2$-$N$, NH$_3$ and H$_2$S; therefore, monitoring of water quality in earthen ponds plays a vital role in the growth and development of *P. monodon*. Practically, farmers prefer using biological products for water treatment instead of exchange water. This method helps to secure pond water quality but it is costly and declines economic efficiency for farmers. Finding an effective method in terms of economy and environmental protection is strongly needed for Vietnamese brackish aquaculture industry. Using constructed wetlands (CWs) for purification of recirculated aquaculture water has been proven as potential approach which provided significant water savings and nutrient recycling as compared with traditional fish ponds [3, 4]. *Pennisetum purpureum* and *Typha* sp. were recognized as good quality forages for ruminants [5]. AL-Shoaibi [6] reported that *P. purpureum* could attain high rates of photosynthesis at NaCl concentrations of 100 and 200 mM. In addition, *Typha* sp. is cultivated in the MD for human food and also provides marketable values for the farmers. Lin et al. [7] confirmed that CWs helped to improve water quality in recirculating aquaculture (RAS) of whiteleg shrimp culture system. To our knowledge, application of *P. purpureum* and *Typha* spp. planted in CWs to purify wastewater from RAS of *P. monodon* has not studied yet in Vietnam. For this reason, this research was carried out to evaluate performance of CWs designed with surface flow (SF), vertical subsurface flow (VF) and horizontal subsurface flow (HF).

### 2. MATERIALS AND METHODS

#### 2.1. Experimental setup

Six composite tanks (volume of 1 m$^3$) were used as culture tank of *P. monodon*. There were three CWs types of surface flow (SF), vertical subsurface flow (VF) and horizontal subsurface flow (HF) planted with *P. purpureum* and *Typha* spp. at a density of 15 plants/m$^2$ and the unplanted one was considered as control treatment. They were arranged in completely randomized design in duplication (Fig. 1). The SF wetlands was rectangular blue plastic tank (94 × 84 × 43 cm; length x width x height), the VF wetlands was cylindrical blue plastic tank (49 × 49 cm), and the HF wetlands was rectangular blue plastic tank (60 × 40 × 30 cm). The VF systems were set up with a system of perforated Ø 21 mm pipes that was installed to facilitate distribution of the influent equally over the surface of the VF. Water level was controlled below the HF systems’ media at 5 cm while water level was higher than media surface at 20 cm in the SF systems. Each of CWs was filled with a 60 L of mixed recycling pottery and honey-comb coal at a ratio of 1:2 (2.0 < d ≤ 5.0 mm).

#### 2.2. System operation and monitoring

The entire systems were operated at an recirculation rate of 3.3 L/min (equivalent to 50 % volume shrimp tank per day). This flow rate (3.3 L/min) was controlled by a timer which was set at every 26 minutes pumping for 3 minutes. Water from the shrimp tanks was distributed to the CWs and their outlets were collected at the sumps before pumped back to the shrimp tanks (Fig. 1). Postlarvae (PL) of *P. monodon* was reared at a stocking density of 100 PL/m$^3$. The shrimps were fed 4 times/day with commercial floating pellets containing 45 % crude protein. The feeding rate was based on 8 % of body weight and adjusted according to the intake rate of the shrimp. The study was monitored for 72 days.
2.3. Water sampling and analysis

Water in the shrimp tanks was not exchanged during the experiment, but tap water was added twice a week to replace water lost by evapotranspiration. Water sampling was carried out every two weeks at 07:00 - 08:00 A.M. to analyze water quality of the shrimp tanks. Water temperature, dissolved oxygen (DO), pH and electric conductivity (EC) were measured at the experimental site using portable meters. Ammonium nitrogen (NH$_4$-N), nitrite nitrogen (NO$_2$-N) and nitrate nitrogen (NO$_3$-N) and H$_2$S concentration in water samples were determined according to the Standard methods [8]. Ammonia nitrogen (NH$_3$-N) concentration was calculated regarding to Albert [9].

2.3. Statistical analysis

Data were tested for normal distribution and variance homogeneity (Levene’s test) and logarithmically transformed if necessary. Differences in water quality were identified by two-way ANOVA (3 wetland types and 5 sampling times) using Type III sum of squares. Tukey Honestly Significant Differences (HSD) was used to compare significant differences between treatments at the 5% probability level. The software Statgraphics Centurion XV (StatPoint, Inc., USA) was used for all statistical analyses.

3. RESULTS AND DISCUSSION

3.1. Dissolved oxygen, pH, temperature and H$_2$S values in the shrimp tanks
Dissolved oxygen (DO, mg/L), pH, temperature (°C) and H₂S (mg/L) values in the shrimp tanks over 5 sampling times were presented in Figure 2. Dissolved oxygen concentrations reduced over time in all systems and slightly increased at the last sampling (p < 0.05; Fig. 2A). This might be due to accumulation of feces and excess food in the zero-discharged aquaculture system [10]. However, the wetlands types did not influence DO concentration which should be hypothetical higher in the VF system [11]. The average DO concentration in all systems was in the optimum level for *P. monodon* growth [12].

During the experiment, the pH in the shrimp tanks maintained in the range of 5.4 - 7.5 (Fig. 2B) and was slightly lower than the optimum level for *P. monodon* growth [12]. To ensure condition for shrimp molting water pH should be in the range of 7.5 - 8.5 [13]; therefore, water pH should be improved by adding lime in this system. Water temperature was in the range of 27.4 – 28.7 °C and fluctuated among sampling times and wetlands types (p < 0.05; Fig. 2C). The variation of temperature over time might be affected by weather condition during a 72-day experiential period and it was in the optimum level for *P. monodon* growth [12].

Flow direction of water in the three wetlands types resulted in accumulation of organic matter and/or death algae biomass in the substrates which contributed to a lower concentration of H₂S in the VF system compared to the SF and HF systems (p < 0.05; Fig. 2D). H₂S concentration was in the range of 0.5 - 1.3 that was higher than the optimum level for *P. monodon* growth [12]. Kungvankij and Chua [14] reported that at level of 0.1 – 0.2 mg/L in the water, *P. monodon* appeared to loss their equilibrium and die instantly at a concentration of 4 mg/L.
3.2. Nitrogen concentrations in the shrimp tanks

Ammonium (NH$_4$-N), ammonia (NH$_3$-N), nitrite (NO$_2$-N) and nitrate (NO$_3$-N) nitrogen concentrations in the shrimp tanks were shown in Figure 3. There was an accumulation of all nitrogenous forms in all systems and was reduced at the last sampling (Fig. 3). It indicated that constructed wetlands (i.e. biofilters) started their function due to stable microorganism’s development. Lin et al. [10] reported that the wetlands system showed process stabilities for nitrogen removal in the subsurface flow wetlands after 1 month and in the free water surface after 2 to 3 months of operation. That contributed to a significant lower than the threshold level of NH$_3$-N for *P. monodon* growth [12] (Fig. 3B). Therefore, toxicity of NH$_3$-N in this system was not a concern issue. In contrast, average concentration of NO$_2$-N in all systems (Fig. 3C) was slightly higher than the permitted limit for *P. monodon* growth [12] (NO$_2$-N < 0.35 mg/L). That might be the reason causing a slow growth and low survival rate of *P. monodon* (30 %, 43 % and 60.5 % in the HF, SF and VF systems, respectively). The NO$_3$-N concentration is not harmful for shrimp growth, however, higher accumulation of NO$_3$-N might be toxic to shrimp [15]. In this study, NO$_3$-N concentration likely accumulated overtime (p < 0.001; Fig. 3D) but it was still lower than 10 mg/L, level affects shrimp growth [16].

During study period water in the shrimp tanks did not renew but tap water and brine water (105 ‰) was added to replace water loss by evapotranspiration and sampling. For respective SF,
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HF and SF system volume of tap water and brine water were 442.5 and 62 L; 495 and 96.5 L; 242.5 and 92.5 L to ensure salinity level in the culture tanks at 15 – 18 ‰. According to Luc Minh Diep [17] to produce 1kg of whiteleg shrimp 20 m³ water was needed. That indicated integration of CWs in closed-recirculating shrimp tank culture enhanced water use efficiency and reduced wastewater discharge into the environment.

4. CONCLUSIONS

The study was conducted for 72 days without water exchange. However, with the present of the CWs helped to maintain good water quality in the optimum and permitted levels for requirements on shrimp rearing water quality (according to Circular No. 45/2010/TT-BNNPTNT). In addition, zero-discharge character which more critical in the context of climate change is the most important of this system.

Acknowledgement. This work was financially supported by the project grant A/5038-1 (No. EUSWE00112MTNC) from the International Foundation for Science (IFS, Sweden). The authors thank to the Department of Environmental Sciences for providing laboratories which enable us to complete our study.

REFERENCE

1. Directorate of Fisheries - Preliminary conference of brackish water shrimp farming in the first half of 2014 and planed for the latter half of 2014, 2014.


