USING PLANTED CONSTRUCTED WETLANDS TO TREAT WASTEWATERS FROM CIRCULATING AQUACULTURE OF CLARIAS FUSCUS

LIU Wen-Sheng[1], XIAO Jian-Guang[1], LIN Qi-Peng[2], WANG Zhi-San[1], LI Yong[1] and LI Wei-Xia[1]

(1. *Department of Aquaculture, College of Animal Science, South China Agricultural University, Guangzhou* 510642;
2. *Office of Teaching and Research Base, South China Agricultural University, Guangzhou* 510642)

Abstract: The vertical-flow constructed wetland which was in the base of gravel-*Canna indica* was designed and applied to purify wastewaters for reusing in the culture of *Clarias fuscus*. Observations were taken on parameters of water quality during breeding *Clarias fuscus*. The results showed that the planted constructed wetland had considerably effective purification in water body of aquaculture. The average removal rate of BOD_5, COD, and TN of wastewaters during breeding periods was 81.77%, 55.55%, and 65% respectively. After being purified, the water quality partly accorded with the National Standard of Fishery Water Quality, and the culture water could be recycled. However, because there was no treatment in the control pond, BOD_5, COD and TN increased continually. The turbidity degree was obviously higher than that in the experimental pond. Algae bloomed in the control pond. This study demonstrated the advantage for planted constructed wetlands which were simple mechanisms and easily generalized to treatment of wastewaters in circulating aquaculture.

Key words: Constructed wetland; *Clarias fuscus*; *Canna indica*; Water purification; Circulating aquaculture
CLC number: S954, S963 **Document code:** A **Article ID:** 1000-3207(2008)01-0033-05

Constructed wetlands constitute a compound ecosystem that incorporates various trophic levels including microorganism, micro-algae, benthic invertebrates and plants, all for which can exert a synergistic effect of waste removal through physical, chemical and biological processes, achieving effective removal of sewage components[1]. In 1953, it was found firstly that constructed wetlands could remove a mass of organic matter and mineral in Germany[2]. In the 1980's and 1990's, constructed wetlands were widely used in treating domestic sewage from cities[3]. In aquaculture, the growth of aquatic and telluric plants were used for nutrient uptake from farming wastewaters to fulfill the requirements for purification standards which are not only of concern by ecologists but also legal demands in many European countries where fish farms are not allowed to release effluents containing higher concerntrations as permitted by these standards. To achieve low effluent concentrations, the fish-vegetable and fish-alga symbiotic system were widely established and applied in aquaculture. Therefore, recycling aquacultural waters is the sign to distinguish modern aquaculture from traditional aquaculture[4-6]. At present, a modern ecotype and close integrated production system based on the ecological engineering criteria, which allow system stability and self-control are inevitable in a trend of developmental aquaculture-agriculture system in the world[7]. Constructed wetlands provide many benefits, such as high efficiency, low investment, low cost, low energy expenditure and cheap operational costs, and so on[8]. Compared with costly biochemical water purifying methods, such as rotating bio-disc, anaerobic baffled reaction filter (ABRF), and biological reaction basins, constructed wetlands have potential application and broad extension prospect[9]. Wetland plants are better for enhancing nitrification of the system on condi-

Received date: 2006-02-13; **Accepted date:** 2007-01-15
Foundation item: Plan of Science and Technology from Guangdong Province (No. 2004B20301017)
Corresponding author: Liu Wen-Sheng (1965—), born in Chenhai, Guangdong Province; Prof; major in aquaculture and ichthyology. E-mail: wsliu@scau.edu.cn

tions[10]. Lin proposed that planting a wetland with macrophytes with high productivity could be an economic way for removing nitrate from groundwater[11]. Accordingly, in the year 2003 - 2004, researches were conducted to evaluate effectiveness of constructed wetlands for purification and recycling of waters for breeding *Clarias fuscus*, in order to find a new model of aquaculture installations integrating waste treatment with plant production, which will be helpful to environmental protection and water saving aquaculture in the country.

1 Materials and methods

1.1 Culture ponds and constructed wetlands The volume of each culture pond was about 41m^3 (length : width : height = 15.7m : 2.9m : 0.9m). They were disinfected before stocking. An accompanying constructed wetland was designed in vertical-flow, and composed of five step-by-step purifying ponds, each of which was 6.6m^3 in volume (length : width : height = 4m : 2.2m : 0.75m). Integrated wetland features included *Canna indicas* planted into the gravel of 30 - 50mm in diameter and covered by gravel supporting media with 40cm height. The young macrophyte was seeded at a density of 4 rows and 8 stands. The experimental pond was connected to the wetland while the control pond was not connected. Waters pumped from the experimental pond flowed into the constructed wetlands by way of conduit. After step by step purification, they flowed back to the original pond, and the water body of experimental pond was recycled. By contrary, waters of the control pond were pumped from one end and flowed into the other end of the pond without passing through constructed wetlands. This system operated for one week initial period of wetland stabilization before stocking.

1.2 Fry of *Clarias fuscus* **and parameters of water quality** All fry of *Clarias fuscus* with seven-centimeter approximately in total length chose to breed were strong, no disease and unhurt. Following a dip in 3 % salt solution for five minutes, 730 fry in total number were put in the experimental pond and the control pond separately. The culture density was 16 fry/m^2. Daily, water pumps each with the power of 350 watt were operated for purification and circulating twice, separately in the morning and afternoon three hours at a time, except for rainy days. After that aqueous samples began to be taken for examination and test.

The water sampling places included farming ponds and the outlet of constructed wetlands. Aqueous samples from four corners of farming ponds were combined appropriately. Water temperature, pH, DO and turbidity were checked and measured every two days. BOD_5, COD and TN were tested every five days. The water sampling lasted for one month. BOD_5, COD and TN were measured according to "dilution and seeding method", "potassium dichromate method", "$K_2S_2O_3$ oxidation ultraviolet-spectrophotometry" respectively. Except for BOD_5, all aqueous samples being acidulated by sulfuric acid in advance were determined in the laboratory within 24 hours when the pH was less than two. A water analyzer with functions made in HANNA Instruments Srl was used in this experiment.

2 Results and analysis

2.1 BOD_5 and COD removal Overall BOD_5 trended to rise both in the control pond and in the experimental pond during the culture period (Tab. 1). The highest concentration on an average of the control pond was 55.5mg/L measured in the 27th day. At that time, the values were much lower in the experimental pond, when the highest mean value measured was 35mg/L on day 23rd, indicating that both pond systems performed differently. Relatively, the BOD_5 concentration was obviously lower in the experimental pond than it was in the control pond. Aqueous samples of wetland outflows were collected determination of BOD_5 which was degressive by the time. Among them, the highest value was only 8.75mg/L in the 13th day, and the lowest value was 1.95mg/L, which was tested at the last time. In this evaluation of constructed wetlands, average BOD_5 removal was 81.77 %, while the highest value was 92.11 %. Effective removal of BOD_5 in this particular wetland design for fishery water was observed, and the capability of purification was positive correlation with the degree of sewerage.

Tab. 1 The change of BOD_5 of water body in one month (mg/L)

Time (d)	2	7	13	18	23	27
Control	23.35 ±0.74	38.70 ±0.48^c	47.30 ±0.61^c	43.10 ±0.72^b	46.00 ±0.84^b	55.50 ±0.91^c
Experimental	19.20 ±0.56	21.95 ±0.61^b	24.70 ±0.39^b	33.10 ±0.83^b	35.00 ±0.73^b	24.70 ±0.67^b
Wetland outflet		5.40 ±0.22^a	8.75 ±0.47^a	4.10 ±0.55^a	3.80 ±0.36^a	1.95 ±0.41^a

Notes: values within a column with the same superscript letter are not significant difference among groups ($p > 0.05$)

COD also constantly rose both in the control pond and in the experimental pond with time (Tab. 2). In the 23rd day, COD of ponds reached the highest point, which was 330.4mg/L and 211.5mg/L, respectively. Thereafter, concentrations descended in the 27th day because some waters were appended. COD concentrations in the experimental pond were obviously lower than those in the control poad. The maximum discrepancy was 167.1mg/L and the minimal one was 83.5mg/L. The variation of COD in wetland outflows was likely the same as that of BOD_5. It was 91.29mg/L in the 13th day. And it descended to 30.48mg/L in the 27th day. The average COD removal of constructed wetlands was 55.55 %. Obviously, the worse quality of fishery waters was, the higher efficiency of removal was.

Tab. 2 The change of COD of water body in one month (mg/L)

Time (d)	2	7	13	18	23	27
Control	183.5 ±4.94^b	198.3 ±5.12^b	216.2 ±7.78^b	250.4 ±6.43^c	330.4 ±6.99^c	289.0 ±6.04^c
Experimental	98.2 ±3.86^a	98.25 ±4.03^a	115.3 ±4.59^a	139.1 ±5.02^b	211.5 ±5.67^b	121.9 ±4.76^b
Wetland outflet		67.88 ±3.20^a	91.29 ±4.21^a	46.38 ±3.28^a	33.04 ±3.45^a	30.48 ±3.33^a

Notes: values within a column with the same superscript letter are not significant difference among groups ($p > 0.05$)

Constructed wetlands have strong capability of removing BOD_5 and COD from the industrial wastewater, the effluent of animal farms and the domestic sewage. Average BOD_5 removal was 80 %, while NH_3-N decreased by an average of 95 % through using constructed wetlands to treat ammonia associated with a refinery effluent[12]. The removal rate of COD was reported more than 60 %[13]. Especially, the removal effect of the subsurface constructed wetland is more than 75 %[14]. The best removal efficiency of BOD_5 and COD was more than 85 %[15]. Nevertheless, investigations about the effectiveness of constructed wetlands for treatment of wastewaters in aquaculture were seldom reported. This experiment demonstrated the potential for subsurface constructed wetlands to decrease BOD_5 and COD of waters for being recycled and breeding *Clarias fuscus*. The effective removal of BOD_5 by the constructed wetland was quite obvious in the breeding period. The water quality of the constructed wetland outflow came to the standard of fishery waters. However, BOD_5 of the control pond ascended continually in a month because waters of the pond were not purified. COD removal rates by constructed wetlands ranged from 30.01 % to 75 %. After being purified, the water of the experimental pond was obviously improved and became more steady, and there were not large numbers of algae appearing during the period of culture. However, algae bloom appeared several times in the control pond.

2.2 The removal efficiency of total nitrogen Tab. 3 indicates an upward trend in TN concentrations in both fish ponds reaching the highest mean value in the control pond which was significantly greater than that in the experimental pond which reached a mean value at the end of the test period of less than 1/3 of the control pond. During purification period, there was no significant difference among TN concentrations which increased small in the experimental pond. The concentration of TN descended after the water flew through the constructed wetland. And the higher TN concentrations of inflows were, the more obviously that of outflows descended. The variation of TN concentrations in outflows was between 1.91mg/L and 2.18mg/L. This showed that the constructed wetland had much strong removal effect on TN in farming water body, and the average removal rate reached to 65 %. In experimental period, the concentration of TN in the control pond was very high, and this is the reason for appearing algae bloom several times. Besides, the increasing of TN concentrations resulted in the acidification of water quality[16]. Generally, it is easy to deteriorate when the pond is stagnant, in which waters have not been renewed for long time, moreover, it accepts much more nitrogen during the fishery term.

Tab. 3 The change of TN of water body in one month (mg/L)

Time (d)	2	7	13	18	23	27
Control	7.49 ±0.52	11.61 ±0.94[b]	12.54 ±0.67[c]	12.57 ±0.95[c]	18.42 ±0.86[c]	16.25 ±0.88[c]
Experimental	4.34 ±0.26	4.78 ±0.85[a]	5.90 ±0.88[b]	5.90 ±0.84[b]	5.85 ±0.59[a]	6.98 ±0.97[b]
Wetland outlet		2.05 ±0.21[a]	1.91 ±0.12[a]	2.16 ±0.35[a]	2.18 ±0.41[a]	2.18 ±0.44[a]

Notes: values within a column with the same superscript letter are not significant difference among groups ($p > 0.05$)

2.3 The change of pH, DO and turbidity Values of pH were not quite different between the control pond and the experimental pond in the breeding term. The changes ranged from 7.03 to 8.36, which were in the extension of pH values for the aquaculture water quality. The pH value changed irregularly and it was closely linked with the weather. Sometimes, there was one level changed existing from morning to evening a day. As an important index of the water quality in fishponds, pH directly affected on chemical and biologic functions in the water body as well as growth of the fish. But in this test, pH was not out of the range of the normal need for growth of *Clarias fuscus*.

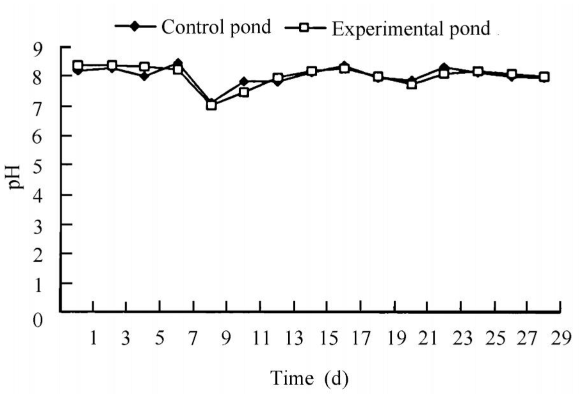

Fig. 1 The change of pH in water body

As a whole, the value of dissolved oxygen (DO) in the water of fishponds changed a little. Seen from the mensuration, the value in the experimental pond was higher than that in the control pond. It showed that the amount of DO was heightened after the water was purified by constructed wetlands. The survival and growth of the fish mainly depends on DO values which must be more than 3mg/L at any time during 24 hours according to the standard of fishery water quality. Certainly, because the suprabranchial organ assists its breath, *Clarias fuscus* has a strong ability to endure low oxygen, and can grow normally even when the DO of waters is below 0.8mg/L.

The turbidity was decided by the number of the plankton and tiny particles in the water, which was the important basis to evaluate the purification efficiency of water treatment system and state of the water treatment technique. The turbidity in the control pond was much higher than that in the experimental pond in this experiment. Waters of the control pond appeared in black-green colour and there were algae blooms several times late in the culture term. The extent of pollution was pricked up because of the eutrophication arose from more and more organic matter. This condition was disadvantageous to *Clarias fuscus*.

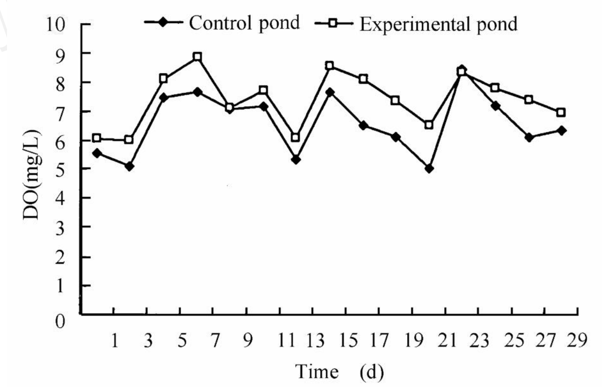

Fig. 2 The change of DO in water body

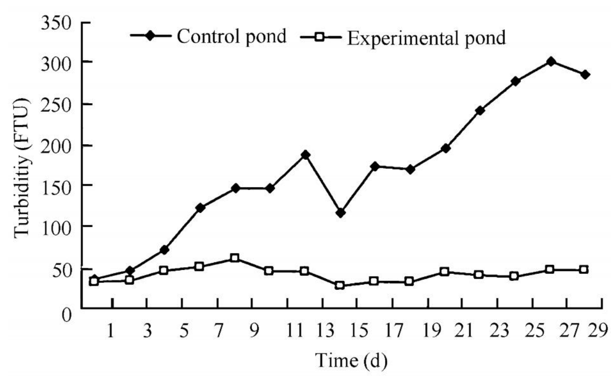

Fig. 3 The change of turbidity in water body in FTU units

3 Conclusions

In this study, the constructed wetland in the base of gravel-*Canna indica* was used as the companion system of culture ponds for breeding *Clarias fuscus*. It was demonstrated that the vertical-flow constracted wetland had a good removal efficiency to organic matter, suspension, and plankton. The results showed that *Canna indica* which had the characteristics of rapid growth, much biomass, strong stooling ,and fast regeneration and so on could effectively improve the culture water quality and cultural environment. After circulating purification by constructed wetlands, the removal rate of BOD_5, COD and TN was 81.77 %, 55.55 % and 65 % respectively, and the turbidity degree descended obviously, the dissolved oxygen increased on the contrary. Especially, the outflow of wetlands measured up to the standard of water quality for aquaculture. For the first time the constructed wetland was used internally to receive farm effluents of *Clarias fuscus* and assisted probably to solve problems, such as the eutrophication of waters in aquaculture, the pollution to environment outside water. Then the overall objective would be realized that healthy aquaculture without environmental pollution is established to help for protection and restoration of natural environment. This aqucultural model of circulating purification with characteristics and advantages making it easy to be applied generally in China is facility and effective as well as.

References :

[1] Li G, Wu Z B, Hou Y S. Perspective of bio-eco remediation technology for ammonia removal from intensive aquaculture waters [J]. *Journal of Dalian Fisheries University*, 2004, **19** (4): 281-286 (In Chinese)

[2] House C H. Combining constructed wetlands and soil filter for reclamation and reuse of water [J]. *Ecol. Eng*, 1999, **12**: 27-38

[3] Ji G D, Sun T H, Li S. Constructed wetland and its application for industrial wastewater treatment [J]. *Chinese Journal of Applied Ecology*, 2002, **13** (2): 224-228 (In Chinese)

[4] Pan J M, Shao Z P, Miao X W. Optim ization of fish to grass ratio in a recirculating fish-grass system [J]. *Acta Ecologica Sinca*, 2004, **24** (2): 389-393 (In Chinese)

[5] Chen M, Liu Z Z, Bian Z L. Wastewater purifying technology of intensive aquiculture greenhouse: A case study on an automatically controlled ecological greenhouse [J]. *Transactions of the CASE*, 2002, **18** (6): 95-97 (In Chinese)

[6] Tan H X, Liu Y H, Zhu X B. The producing effect and technological design for integrated system of closed circulating aquaculture and plant hydroponics [J]. *Journal of Fisheries of China*, 2004, **28** (6): 687-694 (In Chinese)

[7] Amelia K, Kivaisi. The potential for constructed wetlands for wastewater treatment and reuse in developing countries: a review [J]. *Ecological Engineering*, 2000, **16**: 545-560

[8] Yu S P, Wang H X, Wan Z J. Treatment technology of wastewater using constructed wetland and its present status and future prospects in China [J]. *Progress in Geology*, 2004, **13** (1): 20-29 (In Chinese)

[9] Xie K J, Miao, X W, Cui S R. Studies on purifying efficiency of wastewater in culture of soft-shell turtle by neans of herbage [J]. *Fishery Modernization*, 2004, **2**: 4-7 (In Chinese)

[10] Wu Z B, Cheng S P, He F. Design and purification performance of vertical flowconstructed Wetland [J]. *Chin. J. Appl. Ecol*, 2002, **13** (6): 715-718 (In Chinese)

[11] Lin Y F, Jing S R, Wang T W, *et al*. Effects of macrophytes and external carbon soures on nitrate removal from groundwater in constructed wetlands [J]. *Enviromental Pollution*, 2002, **119**: 413-420 (In Chinese)

[12] Huddleston G M, Gillespie W B, Rodgers J H. Using constructed wetlands to treat biochemical oxygen demand and ammonia associated with a refinery effluent [J]. *Ecotoxicology and Environmental Safety*, 2000, **45**: 188-193

[13] Li C L. Discuss of improving equality of aquatic products [J]. *Aquatic Science*, 2000, **19** (3): 44-45 (In Chinese)

[14] Wu Z B, Ren M X, Fu G P. The influence of hydraulic characteristics on wastewater purifying efficiency in vertical flow constructed wetlands [J]. *Environmental Science*, 2001, **22** (5): 45-49 (In Chinese)

[15] Wang Q A, Ren Y, Qian J. Study on purifying polluted surface water in constructed wetland pond-bed system [J]. *Si-Chuan Environment*, 2000, **19** (1): 9-15 (In Chinese)

[16] Yue C L, Chang J, Ge Y. Studies on circulating purification of low strength fishery wastewater with compound vertical-flow constructed wetland [J]. *Bulletin of Science and Technology*, 2004, **20** (1): 15-17 (In Chinese)

人工湿地对胡子鲇养殖水体循环净化的研究

刘文生[1] 肖建光[1] 林齐鹏[2] 汪植三[1] 李 勇[1] 李伟霞[1]

(1. 华南农业大学动物科学学院,广州 510642;2. 华南农业大学教学科研基地管理处,广州 510642)

摘要:以大型观光植物美人蕉—砾石为基础的垂直流人工湿地对胡子鲇养殖水体进行净化处理和回流使用,在胡子鲇养殖中测定了水体主要水质指标的变化,表明人工湿地对养殖水体净化效果显著,养殖期间 BOD_5、COD、TN 的平均去除率分别为 81.77 %、55.55 %和 65 %,净化后水质部分符合渔业用水标准,可以循环利用。对照池水体由于 BOD_5、COD、TN 得不到去除而持续增加,混浊度显著高于实验池,并出现水华。这种水体循环养殖模式具结构简单和易推广等优点。

关键词:人工湿地;胡子鲇;美人蕉;水质净化;水体循环养殖