Can Tho University Journal of Science
website: sj.ctu.edu.vn

DOI: 10.22144/ctu.jen.2016.107

ASSESSMENT OF WATER QUALITY IN CATFISH (*Pangasianodon hypophthalmus*) PRODUCTION SYSTEMS IN THE MEKONG DELTA

Vu Ngoc Ut[1], Huynh Truong Giang[1], Truong Quoc Phu[1], Jack Morales[2] and Nguyen Thanh Phuong[1]

[1]*College of Aquaculture and Fisheries, Can Tho University, Vietnam*
[2]*Sustainable Fisheries Partnership*

ARTICLE INFO

Received date: 03/08/2015
Accepted date: 08/08/2016

KEYWORDS

Water quality, catfish culture, total nitrogen, total phosphorus

ABSTRACT

Water quality in striped catfish (Pangasianodon hypophthalmus) production systems in the Mekong Delta was investigated to assess the potential impacts of the culture activity on the environment. The study was conducted at three culture systems, so called systems 1, 2 and 3 selected from the catfish culture areas of An Giang, Can Tho and Hau Giang provinces. A total of 21 sites were selected from 10 farms of these three systems for sampling. In system 1, sampling was implemented at inlets, culture ponds and outlets, whereas in system 2 and 3 samples were only obtained from inlets and culture ponds. Sampling was conducted three times throughout the production period including beginning, middle and the end. Main water parameters taken for the assessment consisted of pH, DO, BOD, COD, turbidity, TAN, N-NO_2^-, N-NO_3^-, TSS, TN and TP. The results indicated that most of parameters were still in the acceptable ranges except TN and TP. Dissolved oxygen concentrations were constantly above 5 mg/L. The highest concentration of BOD and COD recorded were 10.7 mg/L and 19.6 mg/L in system 1 and system 3, respectively. Mean concentrations of TSS were relatively low in all systems ranging from 21 to 84 mg/L. However, TN and TP concentrations were considerably high. Concentrations of TN and TP recorded outside the culture ponds were 3 and 10 times higher than the standard levels (3 mg/L and 0.1 mg/L for N and P, respectively). TN concentration varied with the sampling periods but accumulation of TP tended to increase steadily throughout the production period.

Cited as: Ut, V.N., Giang, H.T., Phu, T.Q., Morales, J. and Phuong, N.T., 2016. Assessment of water quality in catfish (*Pangasianodon hypophthalmus*) production systems in the Mekong Delta. Can Tho University Journal of Science. Vol 3: 71-78.

1 INTRODUCTION

Striped catfish (*Pangasianodon hypophthalmus*) farming has been substantially developed in the Mekong Delta in the recent years. The unprecedented development of catfish farming has significantly contributed to the global aquaculture production with over one million tons of fish in 2007. It has subsequently brought in considerable benefit for the farmers as well as export turn-over for the country. Within 10 years starting from 1997 to 2007, the production of catfish increased up to 45 times (from 22,500 MT to more than 1,000,000 MT) while the farming area increased only 6 times (from 6000 ha to 9000 ha) (Dzung, 2008). The current statistical data show that striped catfish culture area has not increased since 2013 (5,668 ha) but decreased in 2014 (5,584) and the production remains at more than 1 million MT (MARD, 2014). These figures indicate that intensification of catfish farming has been a crucial factor resulting in rapidly increased production. In practice, level of intensification in aquaculture is directly proportional to feed input. The more intensification, the more amounts of feeds are invested in the culture systems. The amount of feed used in catfish farming was reported to be substantial, especially home-made feeds or farm-made feed with high food conversion ratio ranging from 2 to 3.5 (Hung and Huy, 2006; Phuong, 2013). This type of feed usually contains low concentration of protein but high concentration of carbohydrate. Consequently, significant nutrient redundancy could result in eutrophication to the environment. Recent reports on nutrient mass balance in striped catfish ponds revealed that the amounts of nitrogen and phosphorus discharged to the environment from the striped catfish ponds were about 46.0 kg/ton fish and 14-18 kg/ton fish, respectively (De Silva *et al*., 2010). A million ton of fish obtained would produce tremendous amount of nitrogen and phosphorus and discharge directly to the environment. With the annual production of striped catfish produced, De Silva *et al*. (2010) calculated the amounts of N and P discharged to the environment in the Mekong Delta were 31,602 tons and 9,893 tons in 2007 and 50,364 tons and 15,766 tons in 2008, respectively. In addition, high concentrations of nitrogen and phosphorus accumulated at the bottom of the ponds, accounting for 50% total nutrient which potentially pollutes the environment when being flushed out (Thich, 2008). A similar result by another study on the impact of striped catfish culture on ambient water quality in the Mekong Delta also revealed that when producing 1 ton of frozen fillet catfish (equal to 2.6 tons fresh fish) an amount of 106 kg N and 27 kg P was discharged into the environment (Anh *et al*., 2010). Although high flow of Mekong River could flush significant amount of nutrient down to the estuaries and to the sea, big concerns on the impacts of intensive striped catfish culture on the environment have been still increased. Investigation on water quality in the culture systems both outside and inside of culture ponds may help determine levels of impacts on the environment. The results may serve as bases for master plan of catfish culture in the Mekong Delta as well as for proposing possible measures to monitor and ascertain the sustainability of the culture industry. In addition, investigation of water quality in the culture systems will also help identify potential impacts of effluents on the water resource.

2 MATERIALS AND METHODS

The study was conducted in three culture systems selected from different areas in the Mekong Delta (Figure 1). The culture systems were categorized based on three main criteria including (i) locality of the farms to main big rivers (water sources), (ii) inlets separated from outlets, and (iii) existing discharged areas in the systems. The first system (system 1) characterized with indirect connection to the big rivers, separate inlets and outlets, and with discharged areas where effluents released through a long canal prior to meeting with big rivers. In this system incoming water was taken to ponds through a big pump. In system 2 inlets and outlets were not separated. Incoming water and effluents were taken from and discharged to the same side indicating that system did not have discharged areas. However, the system was connected directly to big rivers. System 3 was similar to system 2 but located by small rivers.

A total of 9 farms were selected from the above three systems from which 21 sites were included in the sampling schedules. Sampling was implemented at the beginning (when fish were about 10 days after stocking or 15-20 g), the middle (after 2 months with sizes of 300-600 g) and the end (before harvesting) of the production cycle. These were corresponded to sampling period described in the results as first, second and third sampling period, respectively. Average stocking densities in systems 1, 2 and 3 were 50, 42 and 39 ind.m^{-2}, respectively. Fish in most of farms were fed with pellets. Water exchange was significantly increased both exchange frequencies and percentages toward the end of production cycle (for example, only 15-20% once a week at the beginning and increased to 30-50% every day toward the end). Water quality parameters monitored included temperature, pH, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), turbidity, total suspended solids (TSS), total ammonia nitrogen (TAN), nitrate (NO_3^-), nitrite (NO_2^-), phosphate (PO_4^{3-}), total nitrogen (TN) and total phosphorus (TP). Temperature, pH and DO were measured directly at site using the YSI meter. The other parameters were analyzed in the laboratory at Can Tho University as presented in Table 1.

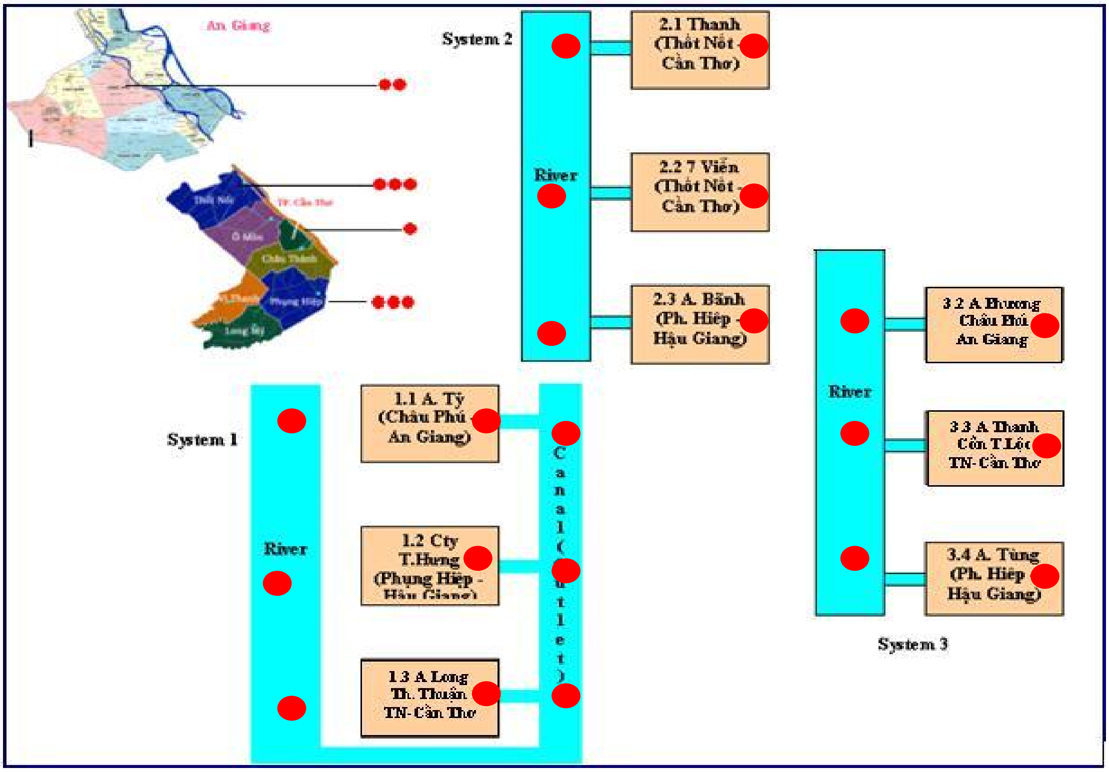

Fig. 1: General layout of study systems with locations and sites selected for sampling at 9 striped catfish farms in Can Tho City (Thot Not), An Giang province (Chau Phu) and Hau Giang province (Phung Hiep). Round spots represent for sampling sites (21 sites). System 1 was not directly connected to the river

Table 1: Sampling and analyzing methods for main water quality parameters

Parameters	Sampling methods	Analytical methods
COD	Water was filled in 125 mL white glass bottle and preserved with 2 mL H_2SO_4	Oxidized with $KMnO_4$ in alkaline medium
BOD	Water was filled in 2 L plastic bottles and kept in cool box at temperature of <4^0C	Respirometric
Turbidity		Nephelometric (NTU)
PO_4^{3-} (Reactive phosphorus)		Ascorbic acid
TAN (Total Ammonia Nitrogen)		Indo-phenol blue
TN (Total Nitrogen)		Kjeldahl and Indo-phenol blue
TP (Total Phosphorus)		Kjeldahl and Acid Ascorbic
TSS (Total Suspended Solids)		Filtering and drying at 103-105^0C

Water samples were taken from the rivers/canals that directly (systems 2 and 3) or indirectly (system 1) connected to the farms, in the culture ponds and discharged areas (system 1) representing for inlets, culture ponds and outlets of the production systems. In system 1, samples were taken at three sites whereas in system 2 and 3, only at the inlets and culture ponds. Samples were regularly collected before discharge or water exchange taken place. Integrated samples (water samples were taken from different places on a sampling site and mixed thoroughly to obtain the integrated samples for analysis) were applied.

Data were treated as mean ± STDEV and analyzed using analysis of variance (ANOVA) to compare mean within and between systems using MANITAB package version 12.

3 RESULTS

3.1 Temperature, pH and turbidity

Temperature was rather stable between sampling periods among the inlets, culture ponds and outlets, though it was fairly low for all three sites in the first sampling period compared to period 2 and 3. Mean temperature recorded in these sites was 29.13 ± 1.02, 29.91 ± 1.07, 29.96 ± 1.00°C, respectively. pH did not fluctuate significantly between sampling period and sites, ranging from 6.75-7.30. However, significantly lower pH was recorded in the culture ponds (6.75 ± 0.06) and outlets (6.79 ± 0.05) at the last sampling in system 1. Mean turbidity increased from the inlets to culture ponds and outlets, ranging from 36.56 ± 25.52, 41.07 ± 24.99, 63.59 ± 36.02, respectively. Highest turbidity was recorded in the outlets at the first sampling period (88.78 ± 89.77 NTU). Turbidities were low in all sites at the second sampling period (7-37 NTU).

3.2 DO, BOD and COD

DO concentrations were high in all sampling sites of system 1. Mean concentrations of DO in this system at the inlets, culture ponds and outlets areas were 8.11 ± 0.13, 6.14 ± 0.88, and 6.48 ± 1.38 mg/L, respectively. Similarly, in system 2, DO concentrations were reasonably high and not significantly different between sites ranging from 6.98 ± 0.62 and 6.50 ± 1.01 mg/L in the inlets and culture ponds, respectively. In system 3, DO concentrations were also high in all sites except in the culture ponds at the first sampling (3.77 ± 1.15 mg/L). In general, DO concentrations were appropriate in the water sources as well as in culture ponds.

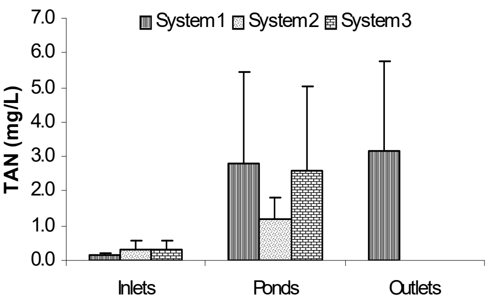

Fig. 2: TAN concentrations between inlets, ponds and outlets in 3 striped catfish production systems

BOD levels were low in most of the sampling sites (<5 mgO_2/L). There only BOD in the culture ponds and outlets of the system 1 at the first sampling period slightly exceeded levels of 5 mg/L (9.07 ± 0.83 and 7.07 ± 3.21 mgO_2/L, respectively). In the second sampling period, BOD was dramatically decreased in all systems (<2 mgO_2/L) and did not increased significantly toward the end of the production cycle. Within the systems, no significant difference was found in BOD concentrations between inlets, ponds and outlets. However, between the systems, only significant difference was found between the culture ponds of system 1 and 2 ($P<0.05$) in the first sampling period. BOD concentrations in culture ponds of system 1, 2 and 3 at the first sampling period were 4.93 ± 3.21, 7.07 ± 1.49, and 4.67 ± 2.89 mgO_2/L, respectively).

Mean COD concentrations in system 1 were low ranging from 9.02 ± 5.56, 8.61 ± 2.94, and 9.37 ± 4.20 mgO_2/L for the inlets, culture ponds and outlets, respectively. Among the sampling periods of this system, COD levels recorded in period 3 were increasingly higher than those in other periods (e.g. 15.07 mgO_2/L compared to 7.87 and 4.13 mgO_2/L for period 1 and 2 at the inlets, respectively). There was no significant difference in COD concentrations between the outlets and inlets of system 1 at all sampling periods ($P>0.05$).

Only two highest concentrations of COD were recorded in the culture ponds at the second and third sampling periods in system 3 (20.40 and 28.8 mgO_2/L, respectively). Generally, COD levels were still in the suitable range complied with the national standards.

3.3 Total ammonia nitrogen (TAN), Nitrite (NO_2^-) and nitrate (NO_3^-)

Total ammonia nitrogen (TAN) concentrations varied considerably between sampling periods in system 1. Highest concentrations were found at the third sampling period but the lowest concentrations were recorded at the second instead of the first one in all inlets, culture ponds and outlets (Table 1). However, between sampling sites, TAN concentrations increased from inlets to ponds and outlets. Highest TAN concentrations were recorded in culture ponds and outlets at the third sampling period (5.49 and 5.10 mg/L, respectively) and significantly higher than those in inlets ($P<0.001$). In system 2, TAN concentrations were much lower (the highest was 1.75 mg/L in the culture pond of the second period) and also increased from inlets to culture ponds. TAN in system 3 had also similar trend but highest concentration was much higher than those of system 2, up to 5.12 mg/L in culture ponds at the end of production cycle. Trend of increase in TAN concentrations between inlets, ponds and outlets in three systems were illustrated in Figure 2.

Nitrite concentrations recorded in culture ponds, inlets and outlets of system 1 were low varying within the acceptable ranges from 0.04 ± 0.02, 0.23 ± 0.14, 0.23 ± 0.18 mg/L, respectively. At the inlets nitrite concentrations were relatively low, not exceeding 0.1 mg/L in all three sampling periods. Similarly, in system 2 and 3 nitrite concentrations at the inlets and culture ponds were also suitably low.

Nitrate concentrations were steadily increasing from the inlets to culture ponds and the outlets of the system 1, starting from 1.08 ± 0.66 to 2.91 ± 2.08 and 4.97 ± 4.51 mg/L, respectively. In this system, at one of the discharged areas the nitrate concentration was dramatically increasing up to 25.64 mg/L at the first sampling period making overall mean concentration of nitrate in the outlets of this system high (9.56 ± 13.93 mg/L). Within the outlets, the concentrations of this parameter were also variable, high at the first sampling period (9.56 ± 13.93 mg/L) but very low in the third one (0.55 ± 0.35 mg/L). This means that the concentrations of nitrate were fluctuating depending on farm to farm practices. Similarly, nitrate concentrations in system 2 were also decreasing from the beginning to the end of the culture duration in both inlets and culture ponds but the concentrations were lower than those in system 1. It had similar trend in system 3, decreasing toward the end of production cycle.

Table 1: Concentrations of TAN (mg/L) recorded during three sampling periods in all three systems

	Systems	Period 1	Period 2	Period 3
Inlets	I	0.18 ± 0.13	0.07 ± 0.05	0.18 ± 0.03
	II	0.29 ± 0.36	0.10 ± 0.06	0.59 ± 0.34
	III	0.11 ± 0.29	0.19 ± 1.27	0.62 ± 0.50
Culture ponds	I	2.67 ± 1.24	0.19 ± 0.34	5.49 ± 0.31
	II	0.51 ± 0.81	1.75 ± 2.09	1.26 ± 0.98
	III	0.18 ± 0.31	2.41 ± 1.38	5.12 ± 1.04
Outlets	I	4.15 ± 3.37	0.23 ± 0.15	5.10 ± 0.70

3.4 TSS, TN and TP

In system 1, TSS concentrations at the inlets and ponds were gradually increasing from the first sampling period to the end except the outlets where TSS was highest at the beginning (73.41 mg/L) then decreased dramatically (35.65 mg/L) and increased again before harvest (62.71 mg/L). Mean TSS concentrations increased from inlets to ponds and outlets ranging from 40.90 ± 17.05, 43.26 ± 12.24 and 57.26 ± 19.46 mg/L, respectively. In system 2, at the inlets, TSS concentrations fluctuated during 3 sampling periods. Highest concentration was recorded at the second period (84.06 mg/L) but decreased (42.21 mg/L) at the third period. However, the mean concentrations were 56.04 mg/L and 53.07 mg/L for inlets and ponds, respectively, lying in the acceptable range (less than 100 mg/L). Similar fluctuation was found in system 3 for both inlets and culture ponds. The mean concentrations ranged from 38.35 mg/L to 63.89 mg/L from inlets to ponds, respectively. There was no significant difference in TSS concentrations between sampling sites and systems.

TN concentrations in system 1 were substantially high with mean values of 5.14 ± 3.20, 14.59 ± 5.17 and 10.25 ± 7.14 mg/L for inlets, ponds and outlets, respectively. TN concentrations in culture ponds were significantly higher in the inlets ($P<0.05$). In system 2, highest TN concentrations recorded at the inlets and ponds in the first sampling period were 8.69 mg/L and 13.65 mg/L, respectively. In system 3, substantial TN concentrations were also measured in the first sampling period and significantly higher than those found in the second and third periods. In the inlets TN was as high as 36.33 mg/L whereas it was up to 48.42 mg/L in the ponds that resulted in very high mean TN in the system. Mean TN concentrations in all 3 systems were presented in Figure 3. Between the systems, TN concentrations at the inlets of system 3 were significantly higher than those of system 1 and 2 ($P<0.05$). However, in the culture ponds, TN concentrations of system 1 were significantly higher than those of system 2.

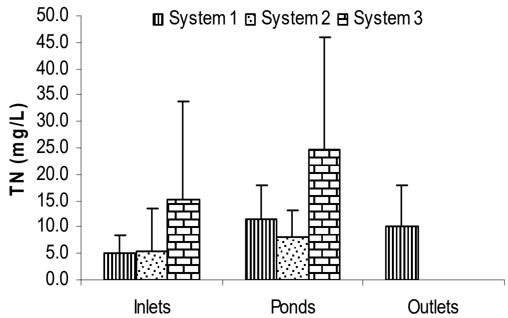

Fig. 3: TN concentrations (mg/L) in the inlets, culture ponds and outlets of three study systems

TP concentrations were also high in all systems. In system 1, highest TP concentration recorded in culture ponds of the third sampling period was 2.49 mg/L. Mean TP concentrations in inlets, ponds and outlets were 1.05 ± 0.75 mg/L, 1.99 ± 0.88 mg/L and 1.55 ± 0.51 mg/L, respectively. In system 2, at the third sampling period, TP concentration was recorded as highest with 4.32 ± 3.99 mg/L. In average TP concentrations in the inlets and culture ponds of this system were 1.43 ± 0.88 mg/L and 2.81 ± 2.06 mg/L, respectively. Mean TP concentrations in system 3 were very high in both inlets and culture ponds ranging from 2.11 ± 1.31 mg/L to 4.78 ± 1.24 mg/L, respectively. Mean concentrations of TP in three systems were presented in Figure 4.

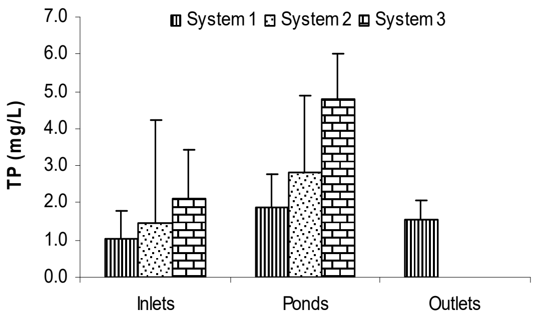

Fig. 4: TP concentrations (mg/L) in the inlets, culture ponds and outlets of three study systems

4 DISCUSSIONS

4.1 Temperature and pH

Temperature was in suitable ranges (27-31°C) although slightly variable among sampling sites due to different sampling time and locations. Too high temperature (>34°C) may increase effects of NH_3 on fish and aquatic animals. However, temperature recorded in this study at all sampling sites did not reach this threshold. According to Boyd (1998), the most suitable temperature for tropical fish is from 28°C to 32°C. Similarly, pH was also in the preferable range (6.5-7.5). Similar to temperature, too high pH (>8.5) will increase toxicity of ammonia (Durborow *et al*., 1997). However, in normal catfish intensive ponds, pH is usually relatively low, ranging from 7-8, except in ponds with high densities of algae, pH may rise up to 9 (Ut *et al*., 2007; Giang *et al*., 2008). A study by Nguyen *et al*. (2014a) revealed that pH in the intensive striped catfish decreased toward to the end of the culture period and ranged from 6.05 to 7.78 which are suitable for striped catfish and would not increase toxicity of NH_3. In a study on water quality in channel catfish (*Italurus punctatus*) ponds, Ghate *et al*. (1993) reported that pH of 7-8.4 was the desirable range for this catfish production.

4.2 Dissolved oxygen, BOD and COD

Although fish were cultured with very high densities, dissolved oxygen concentrations were relatively high (above 4- 5 mg/L). High water exchange rate (20-70% daily) applied by the farms would be a way to generate and maintain high oxygen levels. In addition, oxygen seems not a critical factor in striped catfish ponds as the fish can tolerate as low as 2 mg/L oxygen without any effects (Yen, 2003). High oxygen concentrations in the rivers or canals indicated that organic contents in the environment were low (Kazanci and Girgin, 1998). This was proved by low BOD and COD contents recorded during the sampling periods. BOD and COD are parameters displaying the levels of pollution of a water body. Based on their concentrations pollution can be assessed (Boyd, 2002). According to Cat *et al*. (2006) a water source containing a BOD concentration of greater than 5 mgO_2/L is considered polluted. Trinh (1997) reported that some of rivers and canals in Long An, Can Tho in the Mekong Delta were polluted as BOD concentrations measured in these areas were higher than 10 mgO_2/L. However, Boyd (1998) suggested that acceptable BOD concentration in an aquaculture pond can be up to 10 mgO_2/L. He further stated that the effluents from a shrimp pond can be accepted with BOD concentrations of below 30 mgO_2/L (Boyd, 2003). BOD concentrations recorded in all catfish production systems in this study are therefore in the acceptable ranges. COD concentrations were reasonably low (<35 mgO_2/L). According to the surface water quality standard (QCVN 08:2008/BTNMT) a water body with 35 mgO_2/L is considered organically polluted. As the result, water quality in the studied catfish production systems is adequate with low organic contents.

4.3 Total ammonia nitrogen, nitrite and nitrate

Total ammonia nitrogen (TAN) concentrations that affect aquatic organisms (e.g. fish) depend on pH and temperature which give rise to dominance of NH_3 or NH_4^+. Increased temperature and pH will increase toxicity of NH_3. Concentrations of NH_3 can be calculated based on TAN levels in relation with given temperature and pH (Robinette, 1983). The effect of pH on toxicity of NH_3 has been confirmed by a study conducted by Nguyen *et al*. (2014) on the striped catfish that toxicity of NH_3 increases when pH increases. Highest toxic NH_3 concentration calculated from the highest recorded TAN in the outlets of system 3 was 0.5 mg/L. According to the Circular of Vietnamese Government (MOFI, 2006) on limits of pollutants accepted in freshwater areas, NH_3 concentration should not exceed 1.0 mg/L. In another regulation (QCVN 08:2008/BTNMT), quality of water used for aquatic life should contain a concentration of NH_3 less than 0.5 mg/L. TAN concentrations measured in the study catfish production systems are therefore still in acceptable ranges. Nitrite is a toxic nitrogen product and readily oxidized into nitrate. At high concentration, nitrite will severely affect the respiration of fish as it reduces hemoglobin, increases methemoglobin and increase oxygen threshold

(Huong *et al*., 2011). These authors studied on the effects of nitrite on striped catfish fingerlings of 15–20 g/fish in the laboratory and found that LC50-96 hours of nitrite on the striped catfish fingerlings was 75.6 mg/L. At this concentration, fish died due to increased oxygen demand and as oxygen transportation is blocked by the increased formation of methemoglobin. In the normal aquaculture conditions, nitrite concentrations are usually very low (<0.1 mg/L) unless organic pollution is high (Wetzel, 2001). Boyd *et al*. (2000) and Timmons *et al*. (2002) suggested that nitrite concentrations in aquaculture ponds should be less than 1.0 mg/L. However, according to the national regulations on limits of pollutants in aquaculture areas nitrite concentrations must be less than 0.01 mg/L (MOFI, 2006) or 0.04 mg/L (QCVN 08:2008/BTNMT). Nitrite concentrations recorded in the study areas were much higher than this limit, especially in the culture ponds although fish did not show any sign of effects. The concentrations in the inlets of all three systems although were higher than the regulated limit but could be reasonably accepted (<0.05 mg/L). Nitrate is normally non-toxic to aquatic organisms and not stipulated by any regulation. However, if nitrate is in excessive concentration it will cause eutrophication and reduce water quality. Excess in nitrates can cause low levels of dissolved oxygen and can become toxic to warm-blooded animals at higher concentrations (10 mg/L) or higher under certain conditions (EPA, 1997). However, Carmargo *et al*. (2005) after reviewing published scientific literature on the impacts of nitrates to freshwater animals concluded that nitrate levels in freshwater should not exceed 2 mg/L. Nitrate concentrations recorded in three systems of this study were relatively low and appropriate.

4.4 Total nitrogen (TN) and total phosphorus (TP)

TN and total TP concentrations recorded were very high in all systems, both in culture ponds and water sources. Nitrogen and phosphorus are key elements for algae growth and play important roles in aquaculture ponds. However, excess amounts of these will lead to eutrophication and reduce water quality (Boyd and Clay 1998; Hein, 2002). TN and TP concentrations in water should not be greater than 3 mg/L and 0.1 mg/L, respectively to prevent eutrophication and pollution (Boyd, 2002). The author also recommended that TP levels of 0.001-0.1 mg/L could cause algae blooming. In this study, TN and TP concentrations were much higher than the recommended levels indicating potential eutrophication in the environment where effluents were discharged. In addition, with high fish stocking densities, pond water effluent could become a significant source of water pollution discharged to rivers because of increased levels of nitrogen, phosphorus, and organic material resulting from high feed input (Boyd, 1982). However, as the catchment- basin of the lower Mekong river is large with substantial annual flowing volume (54 billion m^3) (The World Bank, 2002; Frappart *et al*., 2006) together with strong effects of diurnal tidal regimes, the effluents may have been transported to downstream toward the estuaries. As the result prominent and direct impacts of eutrophication may have not been realized in the surrounding production areas (indicated by low densities of algae reported by Oanh *et al*., 2008). However, in system 3 where water flow was low as it was located far from big rivers, nutrients tended to accumulate. This might be the reason why TN levels in system 3 were much higher than those in system 1 and 2. Previous results on nutrient mass balance study in striped catfish ponds revealed that when producing one kg of fish, amounts of nitrogen and phosphorus discharged to the environment were 23.5-25.2 g and 8.6-12.6 g, respectively (Ngoc, 2004; Phu and Thich, 2008). Serious eutrophication and pollution would be inevitable if culture areas and production of striped catfish are continuously expanded and increased without any control or measures of waste treatments.

5 CONCLUSIONS

Organic matters were found to be low in the study areas of striped catfish production systems displayed by low BOD and COD contents. However, the areas have been subjected to potential problem of eutrophication as considerable nitrogen and phosphorus concentrations were recorded both in culture ponds and water sources. In order to help sustain the culture industry, planning and monitoring should be seriously taken into consideration. Reliable and viable treatment methodologies (e.g. chemical, biological or microbiological approaches) should be therefore investigated and developed.

ACKOWLEDGEMENT

This study was financially supported by the Sustainable Fisheries Partnership, USA.

REFERENCES

Anh, P.T., Kroeze, C., Bush, S.R., Mol, A.P., 2010. Water pollution by Pangasius production in the Mekong Delta, Vietnam: causes and options for control. Aquaculture Research. 42(1): 108-128.

Boyd, C.D., 1982. Managing water quality in channel catfish ponds. J. Soil and Water Conservation. 37 (4): 207-9.

Boyd, C.E., 1998. Water quality for pond Aquaculture. Department of Fisheries and Allied Aquacultures. Auburn University. Alabama 36849 USA.

Boyd, C.E., Clay, J.W., 1998. Shrimp aquaculture and the environment. Scientific and Ame. 7: 58–65.

Camargo, J.A., Alonso, A., Salamanca, A., 2005. Nitrate toxicity to aquatic animals: a review with new data for freshwater invertebrates. Chemosphere. 58(9): 1255-1267.

Cat, L.V., Nhung, D.T.H., Cat, N.N., 2006. Water for aquaculture-Quality and measures for improving quality. Science and technology Publisher. (In Vietnamese).

De Silva, S.S., Ingram, B.A., Nguyen, P.T., Bui, T.M., Gooley, G.J., Turchini, G.M., 2010. Estimation of nitrogen and phosphorus in effluent from the striped catfish farming sector in the Mekong Delta, Vietnam. Ambio. 39(7): 504-514.

Durborow, R.M., Crosby, D.M., Brunson, M.W., 1997. Ammonia in fish ponds. SRAC publication No.463.

Dzung, N.H., 2008. Vietnam Pangasius and world market. Handbook and Abstracts, Catfish Symposium: Catfish Aquaculture In Asia: Present Status And Challenges For Sustainable Development, 4-7 Dec. 2008, Cantho University, Vietnam.

Environmental Protection Agency, 1997. Volunteer Stream Monitoring: A Methods Manual.

Frappart, F. Do Minh, K., L'Hermitte, J., Cazenave, A., Ramillien, G., Le Toan, T., Mognard-Campbell, N., 2006. Water volume change in the lower Mekong from satellite altimetry and imagery data. Geophysical Journal International. 167(2): 570-584.

Ghate, S.R., Burtle, G.J., Smith, C.M., 1993. Water Quality in Catfish Ponds Subjected to High Stocking Density Selective Harvesting Production Practice. Aquacultural Engineering. 12: 169-181.

Giang, H.T., Ut, V.N., Phuong, N.T., 2008. Study on fluctuation of water quality in catfish (Pangasius hypophthalmus) in An Giang. Science Journal of Can Tho University Vol. 1, ISSN 1859-2333. In Vietnamese.

Hein, L., 2002. Toward improved environmental and social management of Indian shrimp farming. Environment Management. 29: 349–359.

Hung, L.T., Huy, H.P.V., 2006. Status of feed use in Tra and Basa catfish culture in the Mekong Delta. Science Journal of Can Tho University, pp. 144-151 (In Vietnamese).

Huong, D.T.T., Quyen, M.D., Lefevre, S., Wang, T., Bayley, M., 2011. Effect of nitrite on some physiological parameters of striped catfish (Pangasianodon hypophthalmus) fingerlings. Can Tho University. Proceeding of Aquaculture Conference the fourth: 166-177. (In Vietnamese).

Kazanci, N., Girgin, S., 1998. Distribution of Oligochaeta species as bioindicators of organic pollution in Ankara Stream and their use in biomonitoring. Tr. J. of Zoology. 22: 83-87.

MOFI, 2006. Circular number 02/2006/TT-BTS dated March 20, 2006 on "Accepted levels of pollutants in freshwater aquaculture areas".

Nguyen, P.Q., Y, L.H., Cong, N.V., Phu, T.Q., 2014a. Fluctuation of some water parameters in striped catfish (Pangasianodon hypophthalmus) intensive culture ponds. Science Journal of Can Tho University, Part A: Natural Science, Technology and Environment, 34:128-136. (In Vietnamese).

Nguyen, P.Q., Y, L.H., Phu, T.Q., Cong, N.V., 2014b. Effects of pH on toxicity of TAN to the striped catfish (Pangasianodon hypophthalmus) fingerlings. Science Journal of Can Tho University, Part B: Agriculture, Aquaculture and Biotechnology: 30: 64-71. (in Vietnamese).

Nguyen, T.P., 2013. On-farm feed management practices for striped catfish (Pangasianodon hypophthalmus) in Mekong River Delta, Viet Nam. In M.R. Hasan and M.B. New, eds. On-farm feeding and feed management in aquaculture. FAO Fisheries and Aquaculture Technical Paper No. 583. Rome, FAO. pp. 241–267.

Oanh, D.T.H., Loc, N.H., Ut, V.N., 2008. Phytoplankton community in striped catfish (Pangasianodon hypophthalmus) production systems in the Mekong Delta. Handbook and Abstracts, Catfish Symposium: Catfish Aquaculture In Asia: Present Status And Challenges For Sustainable Development, 4-7 Dec. 2008, Can Tho University, Vietnam. (In Vietnamese)

Phu, T.Q., Thich, C.V., 2008. Nutrient mass balance in striped catfish (Pangasianodon hypophthalmus) ponds. Handbook and Abstracts, Catfish Symposium: Catfish Aquaculture In Asia: Present Status And Challenges For Sustainable Development, 4-7 Dec. 2008, Can Tho University, Vietnam. (In Vietnamese)

QCVN 08:2008/BTNMT. National technical regulation on surface water quality.

Robinette, J.R., 1983. Ammonia, nitrite, and nitrate. In Water Quality in Channel Catfish Ponds. Southern Cooperative Series Bulletin 290, Mississippi Agricultural and Forestry Experiment Station, Mississippi State University, Mississippi State, MS, 28-34.

The World Bank, 2002. Vietnam Environment Monitor.

Thich, C.V., 2008. Fluctuation of water quality and nutrient mass balance in intensive striped catfish ponds in Omon, Can Tho City. MSc. Thesis, Can Tho University, 74 pp. (In Vietnamese)

Timmons, M.B., James, M.E., Fred, W.W., Steven, T.S., Brian, J.V., 2002. Recirculating Aquaculture Systems (2nd Edition). NRAC Publication No. 01 – 002.

Trinh, L., 1997. Water environment control and monitoring. Science and Technology Publisher, 231p (in Vietnamese).

Wetzel, R.G., 2001. Limnology: Lake and River Ecosystems. Academic Press. 1066 p.

Yen, D.T., 2003. Investigation of some characteristics on traits, morphology, growth and physiology of Basa catfish (P. bocourti), and Tra catfish (P. hypophthalmus) and their hybrids. MSc thesis, Can Tho University. (In Vietnamese).