Quality and Characteristics of Effluents from Hybrid Catfish Ponds

Yont Musig[1] and Dusit Aue-umneoy[2]

ABSTRACT

Hybrid catfish pond effluents were found to contain high concentrations of total suspended solids, phosphorus and nitrogen. The effluents contained 568.3-925.5 mg/l total suspended solids, 25.1-61.7 mg/l BOD5, 0.652-6.140 mg/l total phosphorus, 0-0.170 mg/l hydrogen sulfide, 0-1.666 mg/l nitrite nitrogen, 5.654-69.389 mg/l ammonia nitrogen, 0.014-0.292 mg/l nitrate nitrogen and 12.354-114.901 mg/l total kjeldahl nitrogen. Average concentrations of the pollutants in the effluents were 699.2, 43.0, 2.710, 51.293, 31.790, 0.205, 0.148 and 0.033 mg/l for total suspended solids, BOD_5, total phosphorus, total kjeldahl nitrogen, total ammonia nitrogen, nitrite nitrogen, nitrate nitrogen and hydrogen sulfide, respectively. pH of the effluents varied between 6.8-8.2 and dissolved oxygen concentrations varied between 0.3-4.2 mg/l. Most of the suspended solids in the effluents from hybrid catfish ponds were settleable suspended solids with very high settling velocity. Almost half of the total suspended solids settled down within 3 hrs while 74.4-80.9 % settled down within 12-24 hrs. Organic matter and phosphorus in the effluent were mostly in particulate form of settleable suspended solids and were quickly removed from the effluent by sedimentation. Removal rates were 43.5, 46.9, 52.8, 71.1, 78.0, 78.6 and 78.9 % for BOD_5 and 53.8, 55.7, 65.6, 71.3, 73.4, 73.9 and 79.1 % for total phosphorus at 3, 6, 12, 24, 48, 72 and 96 hrs of sedimentation, respectively.

INTRODUCTION

Hybrid catfish (*Clarias macrocephalus* X *Clarias gariepinus*) is one of the major cultured freshwater fish species in Thailand. Annual production in 2006 was 146,482 metric tons (Department of Fisheries, 2008). Most of the catfish farms use trash fish as feed while other farms use pelletized feed or a combination of trash fish and pelletized feed. Production per rai (1,600 m^2) ranged from <500 kg to 10,000 kg (<3125-62500 kg/ha) (Department of Pollution Control, 2008). As an air breather, catfish is very tolerant to low dissolved oxygen (DO) levels and can survive and grow in poor quality water with low oxygen and high concentration of toxic metabolites. Over feeding of trash fish are not uncommon in catfish farms. Water quality management is also poor usually without aeration and with very limited or no water exchange. The deterioration of

[1] Faculty of Fisheries, Kasetsart University, Bangkok 10900, Thailand.
[2] Faculty of Agricultural Technology, King Mongkut's Institute of Technology Lardkrabang, Bangkok10520, Thailand.

water quality and the accumulation of organic wastes and toxic metabolites in hybrid catfish ponds are normally observed. Most of the wastes are released together with pond effluent after fish harvest and have high potential to affect the receiving water body area.

In this study, the quality and characteristics of effluents from hybrid catfish ponds were studied to determine the amount and the nature of the pollutants in the effluent. The results from this study will provide information for the assessment of the degree of environmental impact caused by hybrid catfish pond effluents. Information on the nature of the pollutants will also be useful for the development of an effluent treatment system.

MATERIALS AND METHODS

The study on the quality of the effluents from hybrid catfish ponds was done by taking effluent samples from 14 fish ponds in 14 hybrid catfish farms in Pathumthani and Suphanburi provinces. Eight catfish farms are located in Suphanburi and the other six are in Pathumthani. Water samples were collected immediately after seining the fish for harvesting and prior to draining the pond water into the effluent canal. Water samples were taken at the depths of 30, 60, 90 cm and at pond bottom (120 cm) and were analyzed for pH, dissolved oxygen (DO) total suspended solids (TSS) Biological Oxygen Demands (BOD_5) total ammonia nitrogen, nitrite, nitrate, total kjeldahl nitrogen, total phosphorus and hydrogen sulfide. Data from each depth were averaged for each parameter. Effluent characteristics were further studied in the laboratory using an effluent samples from a hybrid catfish pond in Pathumthani province. The effluent sample was taken after harvesting the hybrid catfish, then the sample was transported to the laboratory in plastic containers. The effluent samples were poured into three 40 L- aquaria at 30 L /aquarium, and then let to stand without any disturbancefor 96 hrs. After which water samples were taken from the aquaria and analyzed for pH, DO, TSS, BOD_5, total ammonia nitrogen, nitrite, nitrate, total phosphorus and hydrogen sulfide at 0, 1, 3, 6, 12, 24, 48, 72 and 96 hrs. Details of analytical methods used listed in Table 1 (APHA *et al*., 1992).

Table 1. Analytical methods used for analysing hybrid catfish pond effluents

Parameter	Analytical method
pH	pH meter YSI Model 63
Dissolved oxygen (DO)	Dissolved oxygen meter YSI Model 95
Total kjeldahl nitrogen	Kjeldahl method (APHA *et al*., 1992)
Ammonia	Phenate method (APHA *et al*., 1992)
Nitrite	Colorimetric method (APHA *et al*., 1992)
Nitrate	Cadmium reduction method (APHA *et al*., 1992)
BOD_5	Modified dilution methods (APHA *et al*., 1992)
Total suspended solids (TSS)	Filter through grass-fiber filter and dry at 103-105 ^{o}C (APHA *et al*., 1992)
Hydrogen sulfide	Methylene blue method (APHA *et al*., 1992)

RESULTS AND DISCUSSION

Quality of the effluents from hybrid catfish ponds

Effluents from hybrid catfish ponds contained 331.7-925.5 mg/l total suspended solids, 25.1-61.7 mg/l BOD_5, 0.652-6.140 mg/l total phosphorus, 0-0.170 mg/l hydrogen sulfide, 0-1.666 mg/l nitrite nitrogen, 5.654-69.389 mg/l ammonia nitrogen, 0.014-0.292 mg/l nitrate nitrogen and 12.354-114.901 mg/l total kjeldahl nitrogen. pH of the effluents varied between 6.8-8.2 (average pH 7.3) while dissolved oxygen concentrations varied between 0.3 -4.2 mg/l. (average DO 1.8 mg/l). Average concentrations of the pollutants in the effluents were 699.2, 43.0, 2.710, 51.293, 31.790, 0.205, 0.148 and 0.033 mg/l for total suspended solids, BOD_5, total phosphorus, total kjeldahl nitrogen, total ammonia nitrogen, nitrite nitrogen, nitrate nitrogen and hydrogen sulfide, respectively (Table 2).

Table 2. Quality of the effluents from hybrid catfish ponds

Farm	pH	DO	TAN	NO_2^--N	NO_3^--N	TKN	TP	H_2S	BOD_5	TSS
						mg/l				
1	7.3	0.8	49.475	0.000	0.014	79.623	4.083	0.077	48.4	721.8
2	7.1	0.3	42.269	0.000	0.016	66.130	3.140	0.033	34.2	639.5
3	7.2	2.9	7.110	0.077	0.398	23.260	1.318	0.000	25.1	925.5
4	7.1	2.3	5.654	0.032	0.427	29.021	0.652	0.000	30.1	755.7
5	7.4	0.3	69.389	0.000	0.018	114.901	6.140	0.170	57.7	675.9
6	7.1	0.5	54.956	0.021	0.063	81.463	1.889	0.061	54.5	787.1
7	6.8	0.6	30.094	0.021	0.035	51.489	4.266	0.039	50.7	726.8
8	7.2	1.7	25.582	0.216	0.166	39.316	3.491	0.020	38.4	675.0
9	7.5	0.4	34.270	0.016	0.033	55.238	3.204	0.026	40.7	737.7
10	7.3	2.1	21.302	0.135	0.240	35.364	3.070	0.019	35.7	652.9
11	7.2	2.5	39.849	0.003	0.041	-	1.435	0.001	32.2	331.7
12	8.4	4.2	40.138	0.668	0.292	56.594	2.151	0.022	61.7	826.7
13	6.7	3.9	9.581	1.666	0.284	12.354	1.504	0.001	41.5	765.0
14	8.2	3.1	15.399	0.018	0.055	22.055	1.605	0.002	52.0	568.3
Average	7.3	1.8	31.790	0.205	0.148	51.293	2.710	0.033	43.0	699.2
Range	6.8	0.3	5.654	0	0.014	12.354	0.652	0	25.1	568.3
	-8.2	-4.2	-69.389	-1.666	-0.292	-114.901	-6.140	-0.170	-61.7	-925.5

Remark: DO=Dissolved oxygen; TAN=Total ammonia nitrogen; TKN=Total kjeldahl nitrogen; TP=Total phosphorus; TSS=Total suspended solids

Effluents from hybrid catfish ponds contained much higher concentrations of total suspended solids, total ammonia nitrogen andtotal phosphorus when compared to effluents from intensive shrimp ponds. The concentration of nitrite nitrogen in hybrid catfish pond effluent was also higher than that found in intensive shrimp pond effluents. Musig *et al* (1995) reported an average concentration of 132.6 mg/l total suspended solids, 0.334 mg/l total ammonia nitrogen, 0.240 mg/l total phosphorus and 38.2 mg/l BOD_5 in intensive shrimp pond effluents. The Department of Pollution Control (2002) also reported concentrations of 25.0-736.0 mg/l total suspended solids, 3.0-37-0 mg/l BOD_5, 0.035-0.554 mg/l total phosphorus, 0-0.190 mg/l hydrogen sulfide, 0.001-2.308

mg/l nitrite nitrogen, 0.024-4.281 mg/l ammonia nitrogen, 0-0.260 mg/l nitrate nitrogen and 2.571-11.832 mg/l total nitrogen in intensive shrimp pond effluents.

High concentrations of pollutants in hybrid catfish pond effluents are mainly the result of feeding and pond management regimes. In hybrid catfish culture, the ponds are not aerated and most of the farms use the closed culture system without water exchange. Trash fish is used as feed in most of the farms and over feeding is normally observed (Department of Pollution Control, 2008). These practices cause a high rate of accumulation and decomposition of organic matter resulting in low DO levels and high nutrient content of the effluents. Up to 78.6 % of the hybrid catfish pond effluents have DO levels of less than 3 mg/l, 50 % of the effluents have DO levels of less than 2 mg/l while 42.8 % of the effluents have DO levels of less than 1 mg/l. Hydrogen sulfide was detected in 85.7 % of the effluents at concentrations between 0.01-0.170 mg/l.

Decomposition of uneaten trash fish could be the major cause of high levels of ammonia and total kjeldahl nitrogen in effluents. Among 14 effluent samples, only one effluent had total kjeldahl nitrogen content of 12.354 mg/l while the rest contained between 22.055 and 114.901 mg/l. The highest ammonia nitrogen content of the effluents was 69.389 mg/l. Among the effluent samples, 71.4 % of them had ammonia nitrogen content above 21 mg/l while 57.1 % had ammonia nitrogen content above 30 mg/l.

The absence of nitrite in three effluent samples with DO levels between 0.3 and 0.8 mg/l indicated that nitrification of ammonia in these sediments was prohibited because of low oxygen levels. Nitrification is prohibited at oxygen levels below 2 mg/l (Lawson, 1995). High concentration of nitrite (0.668 and 1.666) were detected in effluents with DO levels of 4.2 and 3.9 mg/l, respectively.

Effluent characteristics

After the effluent from a hybrid catfish pond was put into aquaria and let stand for 96 hrs, changes in effluent quality were been observed. Total suspended solids in the effluent decreased from 331.7 mg/l to 85.0 mg/l within 12 hrs and further decreased to 63.3, 37.5, 30.8 and 28.7 mg/l within 24, 48, 72 and 96 hrs, respectively. BOD_5 decreased from 32.2 mg/l to 15.2 mg/l within 12 hrs and further decreased to 9.3, 7.1, 6.9 and 6.8 mg/l within 24, 48, 72 and 96 hrs, respectively. Total phosphorus decreased from 1.435 mg/l to 0.494 mg/l within 12 hrs and decreased to 0.412, 0.382, 0.375 and 0.300 mg/l within 24, 48, 72 and 96 hrs, respectively. Total ammonia nitrogen also decreased from 39.849 mg/l to 39.297 mg/l within 12 hrs and decreased to 38.672, 35.257, 34.611 and 33.424 mg/l within 24, 48, 72 and 96 hrs, respectively. Nitrate nitrogen increased from the initial concentration of 0.041 mg/l to 0.045 mg/l within 3 hrs, decreased to 0.018 mg/l at 72 hrs then increased again to 0.020 mg/l at 96 hrs. Nitrite nitrogen increase steadily throughout the experimental period from an initial concentration of 0.003 mg/l to 0.006 mg/l within 12 hrs and further increased to 0.007, 0.008, 0.010 and 0.032 mg/l within24, 48, 72 and 96 hrs, rspectively. pH of the effluent also increased from 7.2 to 7.5 at 12 hrs and then to 8.2 at 96 hrs. Dissolved oxygen decreased from 2.5 mg/l to 2.0 mg/l at 3 hrs

and then fluctuated between 2.1-2.3 mg/l. Hydrogen sulfide was disappeared within 3 hrs (Table 3).

Table 3. Changes in effluent quality within 96 hours

hours	DO	pH	BOD_5	TAN	NO_2^--N	NO_3^--N	H_2S	TP	TSS
	mg/l		mg/l	mgN/l	mgN/l	mgN/l	mgS/l	mgP/l	mg/l
0	2.5	7.2	32.2	39.849	0.003	0.041	0.001	1.435	331.7
3	2.0	7.2	18.2	39.774	0.005	0.045	0.000	0.663	176.7
6	2.3	7.3	17.1	39.521	0.006	0.042	0.000	0.635	140.8
12	2.1	7.5	15.2	39.297	0.006	0.031	0.000	0.494	85.0
24	2.2	7.5	9.3	38.627	0.007	0.021	0.000	0.412	63.3
48	2.3	8.0	7.1	35.257	0.008	0.020	0.000	0.382	37.5
72	2.3	8.0	6.9	34.611	0.010	0.018	0.000	0.375	30.8
96	2.2	8.2	6.8	33.424	0.032	0.020	0.000	0.300	28.7

Most of the suspended solids in the effluents were settleable suspended solids with high settling velocity. Almost half of the total suspended solids settled down within 3 hrs, while 74.4-80.9 % settled down within 12-24 hrs. Sedimentation rates of suspended solids were 46.7, 57.6, 74.4, 80.9, 90.7 and 91.3 % at 3, 6, 12, 24, 48, 72 and 96 hrs, respectively (Table 4).

Table 4. Rate of reduction of pollutants in hybrid catfish farm effluents left for settling for a period of time

hours	BOD_5	TAN	NO_2^--N	NO_3^--N	H_2S	TP	TSS
			%				
3	43.5	0.2	-66.7	-9.8	100	53.8	46.7
6	46.9	0.8	-100.0	-2.4	-	55.7	57.6
12	52.8	1.3	-100.0	24.4	-	65.6	74.4
24	71.1	3.1	-133.3	48.8	-	71.3	80.9
48	78.0	11.5	-166.7	51.2	-	73.4	88.7
72	79.6	13.1	-233.3	56.1	-	73.9	90.7
96	78.9	16.1	-966.7	51.2	-	79.1	91.3

BOD_5 and total phosphorus contents of the effluents decreased at almost the same rate as that of total suspended solids sedimentation. Removal rates of BOD_5 and total phosphorus were significantly correlated ($P<0.01$) to the removal rate of total suspended solids with coefficient of determination (r^2) values of 0.9562 and 0.9639, respectively (Table 5). Organic matter and phosphorus in the effluent were mostly in particulate form of settleable suspended solids and were also removed from the effluent by sedimentation. Removal rates were 43.5, 46.9, 52.8, 71.1, 78.0, 78.6 and 78.9 % for BOD_5 and 53.8, 55.7, 65.6, 71.3, 73.4, 73.9 and 79.1 % for total phosphorus at 3, 6, 12, 24, 48, 72 and 96 hrs of sedimentation, respectively.

Table 5. Relationship between reduction rates of total suspended solids and other pollutants.

Y	**X = % reduction of total suspended solids%**		
	Regression equation	**r**	**r^2**
% reduction of total phosphorus	Y = 5.3762 + 0.8256X	0.9779**	0.9562
% reduction BOD_5	Y = 0.2598 + 0.8347X	0.9818**	0.9639
% reduction of ammonia	Y = -2.0907 + 0.0845X	0.6218	0.3866

** = 1% level of significant

Very small amount of ammonia were nitrified to nitrite and nitrate during the 96 hrs sedimentation period. At 96 hrs, nitrite nitrogen in the effluent increased from an initial level of 0.003 mg/l to 0.032 mg/l while ammonia content of the effluent was still as high as 33.424 mg/l. The decreasing trend of nitrate concentration in the effluent during sedimentation period indicated that some of the nitrate were denitrified by denitrifying bacteria in certain anaerobic areas.

CONCLUSION

Results from this study indicated that effluents from hybrid catfish ponds contained high concentration of pollutant especially total suspended solids, total ammonia nitrogen, total kjeldahl nitrogen, and total phosphorus. Most of the effluents had low dissolved oxygen (less than 3 mg/l) and 42.8% of the effluents had dissolved oxygen of less than 1 mg/l. BOD_5 values of the effluents were also high (25.1-61.7 mg/l). Without an effective treatment system, hybrid catfish pond effluents may certainly create serious environmental problems for receiving water bodies. However, most of the suspended solids in the effluent were settleable suspended solids, with as much as 80.9 % settling down within 24 hrs. Most phosphorus and organic matter in the effluents were also in particulate form of settleable suspended solids which could be removed during sedimentation. Up to 71.1 % of BOD_5 and 71.3 % of total phosphorus were removed from the effluents during 24 hrs sedimentation. According to this finding, sedimentation ponds can be used effectively to remove total suspended solids, BOD_5 and total phosphorus from hybrid catfish pond effluents. Further study is needed to develop an effective treatment method for the removal of nitrogen which are present in very high concentrations in the effluents.

LITERATURE CITED

APHA, AWWA and WPCF. 1992. Standard Method for the Examination of Water and Wastewater. 18thed. APHA, Washington D.C. 1931 p.

Department of Fisheries. 2008. Fisheries Statistics of Thailand 2006. Department of Fisheries, Ministry of Agriculture and Cooperatives. 91 p.

Department of Pollution Control. 2002. The Development of effluent treatment system for coastal aquaculture and the control of pond effluents: Project Report. Department of Pollution Control, Ministry of Natural Resources and Environment.

Department of Pollution Control. 2008. Report on the Evaluation of Freshwater aquaculture status in Bangpakong River basin. Department of Pollution Control, Ministry of Natural Resources and Environment.

Lawson, T.B. 1995. Fundamental of Aquaculture Engineering. Chapman & Hall, Ney York. 355 p.

Musig, Y., W. Ruttanagosrigit and S. Sumpawapol. 1995. Effluents from intensive culture ponds of tiger prawn (*Penaeus monodon* Fabricius). Kasetsart University Fisheries Research Bulletin No. 21 pp. 17-24.