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Water quality parameters of coastal shrimp farms from southwest and southeast regions of Bangladesh

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Abstract
The impacts of shrimp farming on water quality and effluent loading of shrimp farms in southwest (Khulna) and southeast (Cox's Bazar) regions of Bangladesh was investigated during March-August and August-October season, respectively. Water salinity fluctuated from 3.0 to 15.0 ppt in the southwest, whereas it was between 2.5 to 20.0 ppt. in southeast region. Total ammonia nitrogen as recorded in most farms of Cox's Bazar region was higher (0. 1160.438 mg/L) than the recommended level of shrimp farming. Mean values of total ammonia nitrogen and total nitrogen at the outlet of shrimp farms were higher than those of inlet in both regions. Mean values of phosphate phosphorus and total phosphorus at outlet were lower than inlet except in harvest time of *Penaeus monodon*. Total suspended solids were deposited on the bottom of shrimp farms in both regions, which resulted in higher concentration in inlets than outlets in both regions.

Key words : *Penaeus monodon,* Shrimp farm, TSS, Total nitrogen, Total phosphorus

Introduction

Shrimp farming in Bangladesh has rapidly developed due to an increase in demand of cultured marine shrimp in the international markets. Shrimp alone earned about US$350 million foreign exchange from its export of more than 29,713 mt processed products in 2001 and ranked second export item contributing 5.77% to the total export earning (DoF 2002).

Despite the apparent economic success of shrimp farming, the question of sustainability has a great issue in recent years. Shrimp farming does not only generate significant benefits, but also contributes to degradation of coastal environment and may threaten sustainability of shrimp production. Water quality problems resulting from high stocking, increased feeding rates and intake of polluted water are increasingly common in shrimp farming. Good water quality directly influences shrimp growth, survival and overall production. Poor water quality causes disease, mortality, slow growth and low production of shrimp. The discharge of pond water effluent is another activity associated with environmental degradation in the receiving waters.

Effluent from shrimp pond is a source of nutrient enrichment and eutrophication of natural water bodies and its impacts on coastal environment has caused greater concern (Phillips *et al.* 1993). An increasing eutrophication in natural water can lead to ecologically undesirable consequence. The water quality issues of the aquaculture systems as well as environmental impacts associated with shrimp farms have to be carefully evaluated in this country for future policy formulation. Very little works have so far been done on environmental variables of shrimp farms in Bangladesh. There is no detailed study on the water quality parameters and extent of effluent loading from shrimp farms in the environment. In view of the above, the present study has been undertaken to determine the water quality variables of some shrimp ponds and quantify the effluent discharge from the shrimp ponds in both Southeast and Southwest regions to understand the nature of changes take place in water quality over time and the quantity of effluent discharge especially total N, total P and TSS into the environment.

Materials and methods

Study area

Five shrimp farms such as Saral, Alamdanga, Roadanga, Charmulai and Soladana in Southwest Khulna and farm nos. 1, 2, 3, 4 and Beximco in Southeast Cox's Bazar areas were selected for this study. All shrimp farms in Khulna area are fed by the Shibsa river and in Cox's Bazar areas by the Bakkhali river. The farms were all different in areas and most of these have only one channel for both intake and drainage.

Water quality parameters analysis

Water samples were collected monthly from 4 selected *ghers* (impoundment) of each region to estimate the water quality parameters. Four *ghers* were used to conduct routine sampling. The routine sampling involved collection of water samples from three spots inside each farm along with those taken from inlet. The water quality parameters recorded and methods used for this study are shown in the following Table.

Parameters	Methods used
Temperature (^{0}C)	Graduated Celsius thermometer
Salinity (ppt)	Refractometer, mod. 4200/REV A/05-95
pH	pH meter, Hach EC 10 portable pH meter,
Dissolved oxygen (mg/L)	DO meter- YSI mod. 58
Alkalinity (mg/L)	Titrimetric
TSS (mg/L)	Standard procedure and method
NO_2-N (mg/L)	Diazotization method
NO_3-N (mg/L)	Cadmium reduction
TAN (mg/L)	Nessler
PO_4-P (mg/L)	PhosVer 3 (Ascorbic acid)
Total-N (mg/L)	Persulfate digestion
Total-P (mg/L)	PhosVer 3 with acid persulfate digestion

Results

Water quality parameters of shrimp farms

Southwest region

The results of water quality parameters of the shrimp farms are shown in Table 1. Mean values of water temperature at inlet and within farms varied from 31.5-33.33 and 32.5-33.5^{0}C, respectively. Salinity ranged from 9.83-10.83 and 9.83-10.67 ppt, and pH varied from 7.3-7.4 and 7.4-7.5, respectively. Dissolved oxygen contents were found to vary from 4.50-5.3 and 4.46-5.42 mg/L, respectively. Total alkalinity values at inlet and within were between 120.67-132.33 and 127.5-131.33 mg/L, respectively.

Table 1. Mean values of water quality parameters of shrimp farms in Paikgacha

Parameters	Sampling spot	Name of ghers			
		Saral	Alamdanga	Roadanga	Charmuli
Temperature (°C)	Inlet	33.33±3.33	32.67±4.13	31.5±2.25	32.33±3.72
	Within	33.0±4.05	33.5±3.39	32.5±3.02	32.5±3.08
	Inlet	10.5±4.59	10.67±3.56	9.83±2.86	10.0±2.53
Salinity (ppt)	Within	10.33±4.63	10.83±3.76	9.83±3.06	10.67±3.26
	Inlet	7.32	7.3	7.4	7.3
pH	Within	7.5	7.4	7.4	7.5
Dissolved oxygen	Inlet	4.60±0.52	4.50±0.30	5.30±0.12	4.98±0.12
(mg/L)	Within	5.42±0.31	4.46±0.20	5.11±0.08	5.21±0.10
	Inlet	120.67±10.61	127.83±14.13	132.33±13.4	128.33±19.38
Alkalinity (mg/L)	Within	129.0±10.58	128.83±6.31	127.5±11.5	131.33±11.09
	Inlet	213.17±73.84	205.17±75.16	147.5±59.48	157.67±84.57
TSS (mg/L)	Within	128.17±60.04	148.5±43.7	149.83±76.97	138.33±59.3
	Inlet	0.004±0.002	0.003±0.002	0.003±0.001	0.003±0.001
NO_2-N (mg/L)	Within	0.004±0.004	0.004±0.004	0.002±0.001	0.005±0.008
	Inlet	0.10±0.04	0.08±0.02	0.08±0.02	0.07±0.02
NO_3-N (mg/L)	Within	0.08±0.01	0.09±0.03	0.06±0.02	0.08±0.02
	Inlet	0.04±0.02	0.03±0.01	0.04±0.01	0.05±0.02
TAN(mg/L)	Within	0.05±0.02	0.06±0.02	0.03±0.01	0.05±0.03
	Inlet	1.85±0.59	1.53±0.61	1.2±0.45	1.23±0.29
Total N (mg/L)	Within	1.33±0.54	1.52±0.84	1.02±0.45	1.3±0.22
	Inlet	0.049±0.02	0.058±0.02	0.035±0.01	0.053±0.02
PO_4-P (mg/L)	Within	0.041±0.02	0.057±0.01	0.039±0.01	0.048±0.02
	Inlet	0.81±0.52	0.68±0.09	0.44±0.08	0.56±o.14
Total-P (mg/L)	Within	0.77±0.48	0.58±0.06	0.39±0.08	0.52±0.12

Mean values of TSS at inlet and within farms varied between 147.5-213.17 and 128.17-149.83 mg/L, respectively. Nitrite nitrogen concentrations varied from 0.003-0.004 and 0.002-0.005 mg/L, respectively, and nitrate nitrogen (NO_3-N) was found to range between 0.07-0.10 and 0.06-0.09 mg/L, respectively. Significant variations in

nitrate nitrogen were not found at inlet and within the different *ghers.* TAN was found to range from 0.03-0.05 and 0.03-0.06 mg/L, respectively.

Mean values of total nitrogen (TN) at inlet and within varied between 1.2-1.85 and 1.02-1.33 mg/L, respectively, and phosphate-phosphorus (P04-P) concentrations ranged between 0.035-0.058 and 0.039-0.057 mg/L, respectively. The range of total phosphorus (TP) as recorded was 0.44-0.81 and 0.39-0.77 mg/L, respectively. Comparatively high concentration of total phosphorus was recorded at inlet than those of inside the *ghers.* Variations in total phosphorus between inlet and inside the *ghers* as well as monthly variations did not follow any definite pattern.

Southeast region

The results of water quality parameters of the shrimp ponds are presented in Table 2. In Cox's Bazar region, mean values of water temperature at inlet and within shrimp ponds varied from 29.17-30.83 and 29.67-30.67^{0}C, and salinity ranged from 1.83-10.50 and 2.0-10.30 ppt, respectively among the shrimp ponds. pH values were alkaline and almost similar in both inlet (7.3-8.0) and within (7.5-7.8). Dissolved oxygen concentration varied from 4.85-5.10 and 4.74-5.22 mg/L, respectively. Alkalinity at inlet and inside the farms varied from 62.33-122.0 and 60.5-127.7 mg/L, respectively.

Table 2. Mean values) of water quality parameters of Gher 2, 3, 4 and Beximco ponds, Cox's Bazar

Parameters	Sampling spot	Name of *ghers*			
		Gher 2	Gher 3	Gher 4	Beximco
Temperature (°C)	Inlet	29.33±0.76	29.17±0.76	29.17±1.04	30.83±1.04
	Within	30.0±1.0	30.0±1.0	29.67±0.58	30.67±1.15
	Inlet	9.83±7.78	10.5±8.85	8.0±5.27	1.83±0.28
Salinity (ppt)	Within	10.0±7.54	10.3±8.74	10.3±8.74	2.0±0.5
	Inlet	7.46	7.58	7.3	8.0
pH	Within	7.64	7.61	7.5	7.8
Dissolved oxygen	Inlet	4.85±0.47	5.10±0.20	4.55±0.09	4.48±0.13
(mg/L)	Within	5.00±0.33	4.74±0.13	5.22±0.18	5.21±0.20
	Inlet	64.23±10.84	65.0±14.0	62.33±22.85	122.0±50.40
Alkalinity (mg/L)	Within	69.33±9.71	71.5±9.5	60.5±22.15	127.7±51.02
	Inlet	75.0±25.0	88.33±34.03	66.67±28.87	83.33±28.87
TSS (mg/L)	Within	86.67±32.15	83.33±28.87	83.33±57.74	116.67±76.38
	Inlet	0.002±0.00	0.004±0.001	0.003±0.001	0.003±0.001
NO_2-N (mg/L)	Within	0.003±0.00	0.004±0.0001	0.003±0.000	0.003±0.001
	Inlet	0.05±0.03	0.07±0.04	0.06±0.05	0.12±0.17
NO_3-N (mg/L)	Within	0.3±0.40	0.05±0.04	0.05±0.04	0.14±0.20
	Inlet	0.08±0.02	0.11±0.05	0.08±0.02	0.05±0.04
TAN(mg/L)	Within	0.09±0.04	0.08±0.02	0.09±0.01	0.18±0.22
	Inlet	1.27±0.47	1.13±0.35	1.53±0.25	2.43±0.68
Total N (mg/L)	Within	1.77±0.65	1.37±0.47	1.73±0.45	2.73±0.86
	Inlet	0.122±0.110	0.071±0.008	0.102±0.094	0.520±0.150
PO_4-P (mg/L)	Within	0.168±0.212	0.065±0.015	0.086±0.051	0.598±0.335
	Inlet	0.70±0.13	0.91±0.44	0.50±0.16	1.62±0.44
Total-P (mg/L)	Within	0.56±0.17	0.58±0.05	0.45±0.16	1.61±0.74

Mean values of TSS ranged from 66.67-88.33 and 83.33-116.67 mg/L, respectively. Nitrite nitrogen ranged from 0.002-0.004 and 0.003-0.004 mg/L among the farms, and nitrate nitrogen varied from 0.05-0.12 and 0.05-0.30 mg/L, respectively. The range of TAN recorded was 0.05-0.11 and 0.08-0.18 mg/L at inlet and inside different shrimp ponds.

Mean values of total nitrogen were found to range from 1.13-2.43 and 1.37-2.73 mg/L, respectively. Phosphate-phosphorus concentrations varied from 0.071-0.520 and 0.056-0.598 mg/L, respectively at inlet and inside different *ghers.* Total phosphorus varied between 0.50-1.62 and 0.45-1.61 mg/L, respectively.

Discussion

Discernible variation in water temperature among the *ghers* within the region was not observed. Stress inducing temperature levels up to 33.0-39.0^{0}C during the study period was found in all 5 shrimp farms in Khulna region, which might be due to lower water depth. But this alarming level was not found in Cox's Bazar region. Inlet water temperature was lower than that of within the farms might be due to evaporation of water from the shallow farms. The optimal level of water temperature for *P. monodon* culture is 25-30^{0}C as suggested by Boyd and Fast (1992).

Tiger shrimp can tolerate freshwater for about one month (Chakraborti *et al.* 1986). Predalumpaburt and Chaiyakam (1994) reported that the salinity should be in the range of 5-32 ppt for shrimp production. Salinity dropped to 3-9 ppt after June in Khulna region and it was 2.5-9 ppt before October in Cox's Bazar area, exceptional salinity range of 1.5-2.5 ppt over the study period was recorded in Beximco farm. Higher salinity was found in Cox's Bazar compared to Khulna region. In this regard, the salinity of farms was found unfavourable for shrimp culture, which might have resulted in poor production. The pH values did not show any definite monthly variations among the farms in both regions. Boyd and Fast (1992) and Chanratchakool *et al.* (1995) reported that the optimum pH range for *P. monodon* is 8.0-8.5 and 7.5-8.5, respectively. The obtained pH values 7.3-7.5 in Khulna and 7.3-8.0 in Cox's Bazar were, therefore in optimum level for shrimp growth.

Dissolved oxygen content did not follow any definite pattern during the study period. Chin and Ong (1994) pointed out a DO concentration of 3.8 to >5.0 mg/L is generally found favourable for shrimp culture, which supports the present findings (4.5- and 4.46-5.42 mg/L in Khulna and 4.48-5.10 and 4.74-5.22 mg/L in Cox's Bazar). Islam *et al.* (1998) reported the ranges of DO in Mongla and Paikgacha area of Bagerhat and Khulna districts were 5.1-8.7 and 5.7-8.1 mg/L, respectively. Dissolved oxygen content as recorded from the investigated farms is therefore suitable for shrimp culture.

Natural fertility of pond water increases with increase in total alkalinity up to at least 150 mg/L (Boyd 1998). Ahmed *et al.* (1997) found the range of alkalinity in semiintensive farms of Cox's Bazar district was 44.0-195 mg/L, and Islam *et al.* (1998) also found 130.0-217.5 and 118.0-187.5 mg/L total alkalinity in Mongla and Paikgacha area of Bagerhat and Khulna district, respectively. These are more or less similar with the present findings (120.67-132.33 and 127.5-131.33 mg/L in Khulna and 62.33-122.0

and 60.5-127.7 mg/L in Cox's Bazar region). Noticeable variations in alkalinity were not found in either region. The lower values of total alkalinity might be due to rainfall and cloudy weather. Larkins (1995) suggested that the alkalinity range from 60-140 mg/L is suitable for shrimp culture.

The higher values of TSS were found in Khulna farms compared to Cox's Bazar farms. No definite pattern of TSS concentrations between inlet and inside the *ghers* and within the months was observed. Lin *et al.* (1991) stated that 30-190 mg/L TSS was found in intensive shrimp ponds, and Deb (1998) reported 119.0-225.0 mg/L TSS in effluent water of semi-intensive shrimp farm in Cox's Bazar area. The findings reported by Deb (1998) are more or less similar with the findings from Khulna (147-213 and 128.17-149.83 mg/L) and higher than those of findings of Cox's Bazar (66.67-88.33 and 83.33-116.67 mg/L).

Remarkable variations in NO_2-N were not found in any *gher* in any region. The ranges of nitrite nitrogen concentration 0.004-0.01 and 0.002-0.01 mg/L recorded by Warisara (2000) in two shrimp ponds in Thailand, respectively are quite similar to the present findings (0.003-0.004 and 0.002-0.005 mg/L in Khulna and 0.002-0.004 and 0.003-0.004 mg/L in Cox's Bazar). According to Chien (1992), the favourable level of nitrite concentration for penaeid shrimp is 1.3 mg/L, 0.25 mg/L and 1.0 mg/L, respectively.

The ranges of nitrate concentration obtained in the present study were more or less similar to the ranges 0.00-0.30 and 0.00-0.21 mg/L with mean value 0.03 mg/L reported by Warisara (2000) in Thailand. The ranges of nitrate 0.010-0.040 and 0.010-0.020 mg/L reported by Islam *et al.* (1998) were also more or similar to the findings of present study (0.07-0. 10 and 0.06-0.09 mg/L in Khulna and 0.05-0.12 and 0.05-0.3 mg/L in Cox's Bazar). Boyd (1998) stated that the acceptable concentration of nitrate nitrogen in pond waters is 0.2-10.0 mg/L.

TAN concentration at inlet and inside the *ghers* did not show any significant difference in both regions. Higher concentration of TAN was found in Cox's Bazar area compared to Khulna area. Concentrations of unionized ammonia above I mg/L are potentially lethal, concentrations greater than 0.1 mg/L may adversely affect the growth of marine shrimp (Boyd and Fast 1992). The optimal level of ammonia for *P. monodon* culture is <0.1 mg/L (Chien 1992, Boyd 1998). According to them the ranges of ammonia nitrogen (0.03-0.05 and 0.03-0.06 mg/L in Khulna and 0.05-0.11 and 0.08-0.18 mg/L in Cox's Bazar) obtained in the present study were within acceptable range.

Total nitrogen (TN) content between inlet and inside the *ghers* did not show any significant difference in both regions. Lin *et al.* (1991) reported the range of TN in shrimp ponds in Thailand was 0.5-5.0 mg/L, which is more or less similar with the present findings (1.2-1.85 and 1.02-1.52 mg/L in Khulna and 1.13-2.43 and 1.37-2.73 mg/L in Cox's Bazar). According to Boyd and Green (2002) the TN concentrations of 0. 1 to 0.75 mg/L in coastal waters can cause plankton blooms and they suggested that the level of TN should exceed 10 mg/L in effluents of shrimp farms.

Variations in the phosphate content between inlet and inside the *ghers* as well as monthly variations did not follow any well-defined pattern in both regions. The ranges

of phosphate for lower and higher stocking densities reported by NACA (1995) were 0.0- and 0.0-0. 18 mg/L, respectively, and Islam *et al.* (1998) found 0.04-0.12 and 0.030- 12 mg/L phosphate-phosphorus, respectively, which support the present findings from Khulna region (0.035-0.058 and 0.039-0.057 mg/L), but higher than the findings from Cox's Bazar (0.071-0.520 and 0.056-0.598 mg/L). According to Boyd (1998) the suitable range of phosphate phosphorus in pond waters is 0.005-0.2 mg/L.

Total phosphorus in discharged water of intensively managed shrimp ponds with stocking density of 30 PL/m2 and 60 PL/m2 was 0. 18 mg/L and 0.49 mg/L, respectively (Tunvilai *et al.* 1993a), and Lin *et al.* (1991) found 0.05-0.40 mg/L TP in intensive shrimp ponds. These are comparatively lower than the present findings (0.44-0.81 and 0.39-0.77 mg/L in Khulna, and 0.50-1.62 and 0.45-1.61 mg/L in Cox's Bazar), which might be attributed to the agricultural farm runoff, as source of phosphorus. A high concentration was observed in the last harvest time when sludge and sediments were released into the outlet for catching the last shrimp by draining the *ghers.* The higher values of TSS were found in Khulna farms compared to Cox's Bazar farms. No definite pattern of TSS concentrations between inlet and inside the *ghers* and among the months was observed. TN content between inlet and inside the *ghers* did not show any significant difference in both regions. Comparatively high concentration of total phosphorus was recorded at inlet than that of inside the *ghers.* Variations in total phosphorus between inlet and inside the *ghers* as well as monthly variations did not follow any definite pattern in both regions. The effluent loading is strongly affected by the water exchange rate throughout the growth cycle. Low or no water exchange rate from stocking to harvest reduces the potential for environmental impacts (Hopkins *et al.* 1993).

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