Physicochemical properties of sediments and water in shrimp farms of Dacope Upazilla in south-west coastal region of Bangladesh

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ARTICLE INFORMATION	ABSTRACT
	Sediments and water quality parameters are the key determinants for sustainable shrimp farming in Bangladesh. In this context, an investigation was carried out to assess the physicochemical properties of sediments and water in shrimp farming areas of Dacope Upazilla of Bangladesh. The data were collected from 21 shrimp farms located in three villages of Dacope Upazilla of Khulna district and the farms were categorized in three different groups including freshwater shrimp + rice, brackish water shrimp + rice and brackish water shrimp farm. Water samples were analyzed for determining quality parameters such as pH, electrical conductivity (EC) and total dissolved solids (TDS). Chemical analyses of both sediments and water samples were done for P, K, S, Ca and Mg contents while total N determination was performed only for soil samples. The values of pH, EC and TDS of water samples in three different shrimp farms ranged from 6.12 to 8.99, 2.10 to 23.50 dS m^{-1} and 103 to 437 mg L^{-1}, respectively. The contents of P, K, S, Ca and Mg contents in water samples of three different shrimp farms ranged from 1.17 to 4.93 mg L^{-1}, 8.57 to 38.24 mg L^{-1}, 10.65 to 47.48 mg L^{-1}, 65.22 to 273.49 mg L^{-1} and 45.38 to 243.85 mg L^{-1}, respectively. On the other hand, the contents of total N, available P, exchangeable K, available S, Ca and Mg contents in sediment samples of three different shrimp farms ranged from 0.112 to 0.289%, 13.58 to 50.61 µg g^{-1} , o.51 to 2.28 me 100g^{-1}, 111.26 to 150.91µg g^{-1}, 3.46 to 20.64 me 100g^{-1} and 2.20 to 14.58 me 100g^{-1}, respectively. For both sediments and water samples, the highest values of quality parameters and nutrient contents were found in brackish water shrimp farm while the lowest values were recorded in freshwater shrimp + rice farm which might be due to level of salinity, farm practices and season. Hence, the impact of shrimp farming could be minimized by flushing saline water to leach salinity of sediments in time with available supply of freshwater in association with rice cultivation. **Keywords:** Shrimp farming, soil quality, water quality, coastal area

1 Introduction

Shrimp is an important export item for the economy of Bangladesh (FRSS, 2016). It is estimated that there are 200,000 ha of coastal shrimp farms in Bangladesh, producing an average of 75,000 metric tons of shrimp per year and contributing 6% of the country's GDP (Rahman et al., 2013). The coastal region, especially the south-western portion of Bangladesh is the major shrimp cultivation area (Hossain, 1995). Shrimp farming is mostly concentrated in the southwest coastal belts of Bagerhat, Khulna and Satkhira (80% of the area) and the southern coastal belts of Cox's bazar (20% of the area) in Bangladesh (Rahman et al., 2013). Saline water is a prerequisite input for the shrimp farming because of its important role on the phys-

iological functions of culture organisms and salinity variation is considered as determinant factor for shrimp production. In traditional intensive shrimp culture, the deteriorated pond water is frequently exchanged with new external water supply to maintain desirable water quality for shrimp growth (Wahab et al., 2003; Boyd and Green, 2002; Hopkins et al., 1995). In coastal areas of Bangladesh, open shrimp farms increased and expanded substantially far from river or canal which causes poor water exchange capacity, leading to low shrimp productivity and environmental problem.

The nutrient laden effluent discharged from shrimp farms can cause eutrophication of coastal waters and its impact has been a major environmental concern (Phillips et al., 1993; Hopkins et al., 1995). Previous reports on nutrient budget reveal that in such open shrimp culture system as much as 90% of the nitrogen and phosphorous input is in the form of feed, out of which the major portion is lost to the system with only less than one sixth being assimilated in the shrimp biomass (Muthuwan, 1991; Briggs and Fvnge-Smith, 1994). Furthermore, nitrogen waste produced in the system (e.g. ammonia and nitrite) that exceed the assimilating capacity of receiving waters lead to deterioration of water quality ultimately making the environment toxic to shrimp. In addition, the structure and composition of bottom sediment are important criteria to determine the suitability of the site for aquaculture (Boyd and Teichert-Coddington, 1994). Newly constructed ponds may accumulate saltwater for shrimp aquaculture and the salt water slowly alters the chemical properties of the pond water and sediments. This alteration renders the land unsuitable for crop production in the future (Chowdhury, 2007).

Several research findings identified shrimp as one of the main reasons for increasing sediments salinity in southern Bangladesh (Dutta and Iftekhar, 2004; Fleming, 2004), and prolonged water logging in shrimp ponds elaborates the problem of soil and water salinity (Douglas, 1994; Flaherty et al., 1999). Discharge of highly saline water from shrimp farms into adjacent water reservoirs threatens the surrounding environment (Islam, 1999). Therefore, it is essential to monitor the changes in sediments and water qualities over time due to shrimp farming. Many researchers have been focusing their studies concerning the problem, but limited with special focus on categorized water (fresh or brackish water) with and without rice for shrimp cultivation to determine the effect of salinity on water and sediment nutrients status. Therefore, the present study was conducted to assess the water and sediments quality in the major shrimp farming area of Bangladesh, which could be used as the base line or reference data to monitor the changes in water and sediment qualities over time in the study area.

2 Materials and Methods

The study was carried out at the farmer's shrimp farms of Dacope Upazilla in Khulna district, Bangladesh (Fig. 1). The shrimp farms were categorized into three groups *viz.* freshwater shrimp + rice, brackish water shrimp + rice, and brackish water shrimp. For the convenience of the study, seven shrimp farms were randomly selected from each category (total 21 shrimp farms).

2.1 Water and sediment collection

Water samples were collected from 21 (three from each categories) shrimp culture pond's (Gher) water from different site of the locations using 500 mL bottles marked with code number and sampling date. For the determination of metal ions, water samples were kept in a plastic bottle with 1% HNO_3 and transferred from the field to the laboratory using ice box. Similarly, 21 sediment samples were collected from the bottom sediment of selected shrimp farms (gher) at a depth of 0-15 cm from December to January, 2018. Collected sediment samples were kept in zip lock bags so that they remain in moist condition.

2.2 Analysis of water and sediment

Water pH was determined by glass electrode pH meter as described by Jackson (1958). The EC (dS m^{-1}) of collected water samples was determined electrometrically by a conductivity meter as described by Anderson and Ingram (1994). Measurement of TDS in water samples was done using portable TDS meter (mg L^{-1}) during collection of each water sample from sample sites in the study area. Phosphate of water samples were determined calorimetrically by stannous chloride method as per Chowdhury (2007). Potassium, sulphur, calcium and magnesium content in water samples were determined by following standard methods as described by Golterman (1969), Tandon (1995) and Page (1982), respectively. Available P, exchangeable K and available S content in sediments were determined by following standard methods as described by Olsen et al. (1954), Black (1965) and Page (1982). Calcium and magnesium contents in sediment samples were extracted from the digestion of the sediment samples with $HClO_4$ and HNO_3 mixture (1: 5) and were determined by atomic absorption spectrophotometer in the lab of Department of Soil Science, BAU. Sediments were also analysed for total N content followed by standard method (Khanam et al., 2001).

2.3 Statistical analysis

A one-way ANOVA was also conducted to identify significant difference among the treatments by STAR
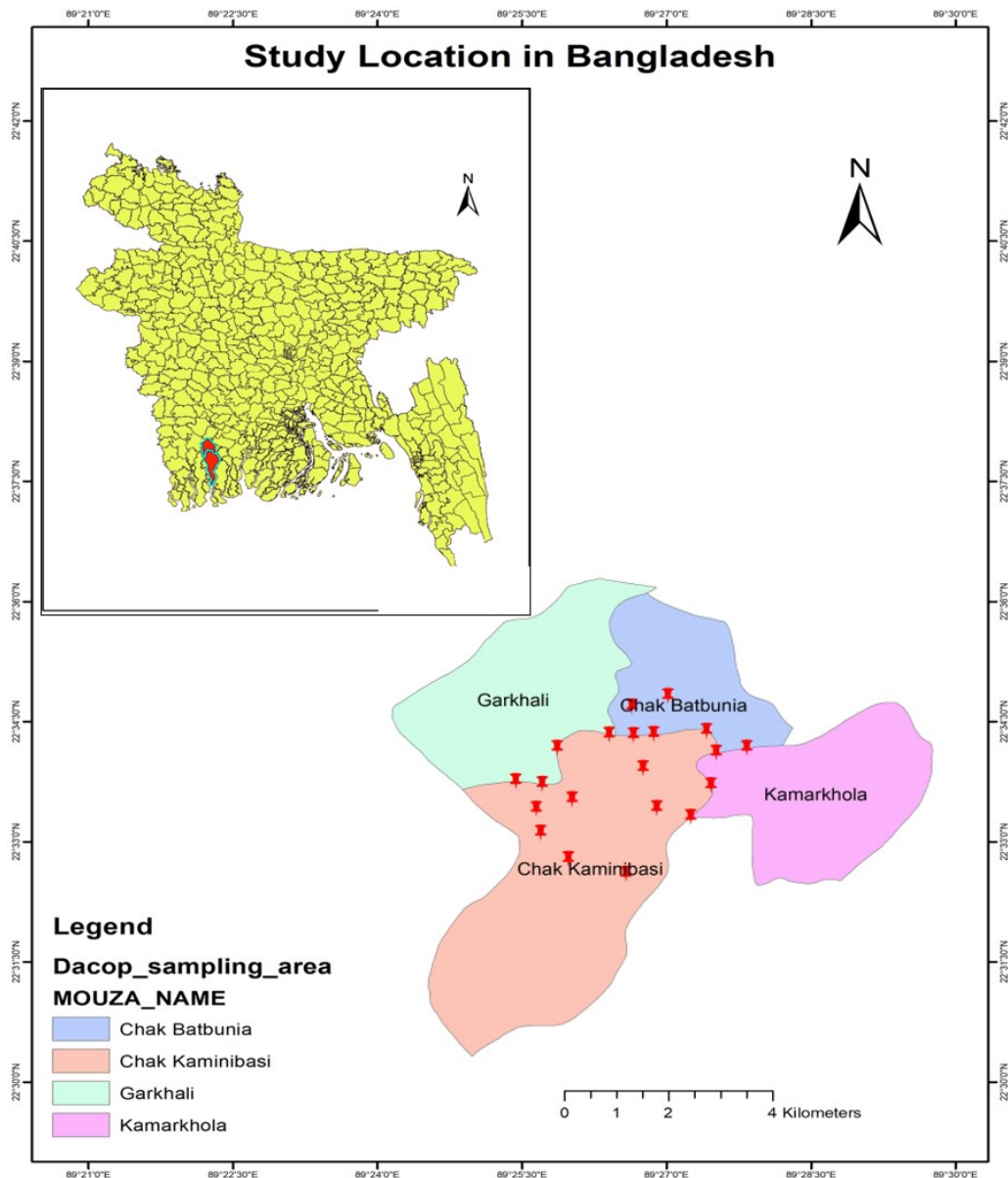
Figure 1. Study location with the sampling sites

statistical software, version 2.0.1 2014 (Biometrics and Breeding Informatics, PBGB Division, International Rice Research Institute, Los Banos, Philippines) (Gulles et al., 2014).

3 Results

Sediment samples exhibited significant difference in term of their ionic composition. Ionic composition of the sediment samples are presented in Table 1. All the parameters such as total N, P, K, S, Ca and Mg content were significantly higher in brackish water shrimp farming practice compared to freshwater and brackish water shrimp farming with rice. Ionic composition was significantly the lowest in freshwater shrimp with rice farming. Thus, the sediment qual-

ities may be ranked in the order of brackish water shrimp > brackish water shrimp + rice > fresh water shrimp + rice.

Water pH was significantly higher in brackish water shrimp farming compared to fresh water and brackish water shrimp with rice farming. Electrical conductivity (dS m^{-1}) and TDS (mg L^{-1}) were significantly higher in brackish water shrimp farming compared to freshwater shrimp farming and brackish water shrimp with rice farming. Ionic composition in water samples were also significantly higher in brackish water shrimp farming practice compared to others, except phosphate P content in water samples. Thus, the water qualities may also be ranked in the order of brackish water shrimp > brackish water shrimp + rice > fresh water shrimp + rice. Water pH, EC, TDS and ionic compositions are presented in Table 2.

Table 1. Sediments quality in different categories of shrimp farms under Dacope Upazilla of Bangladesh

Sediment characteristics	FW shrimp + Rice	BW shrimp + Rice	BW shrimp
Total N (%)	0.12 c	0.17 b	0.25 a
Available P (μg/g)	19.2 c	30 b	43.1 a
Exchangeable K (me/100 g)	0.72 c	1.41 b	1.98 a
Available S (μg/g)	119.86 c	142.21 b	285.66 a
Ca (me/100g)	4.16 c	11.11 b	17.95 a
Mg (me/100g)	2.91 c	6.93 b	13.10 a

FW = Fresh water, BW = Brackish water; Values presented here are the average of 7 different shrimp farms from each categories. Values are means of 7 replicates and significant at 5% level of probability. Means with the same letter in a row are not significantly different.

Table 2. Water quality in different categories of shrimp farms under Dacope Upazilla of Bangladesh

Sediment characteristics	FW shrimp + Rice	BW shrimp + Rice	BW shrimp
Water pH	6.55 c	7.18 b	8.78 a
Water EC (dS/m)	2.79 c	8.89 b	16.68 a
TDS (mg/L)	116.43 c	174.71 b	331.71 a
Phosphate P (mg/L)	1.71 c	2.98 b	4.11 a
Exchangeable K (mg/L)	11.73 c	24.92 b	35.16 a
Ca (mg/L)	71.91 c	193.37 b	262.05 a
Mg (me/100g)	55.81 c	105.99 b	225.72 a

FW = Fresh water, BW = Brackish water; Values presented here are the average of 7 different shrimp farms from each categories. Values are means of 7 replicates and significant at 5% level of probability. Means with the same letter in a row are not significantly different.

Table 3. Pearson's rank correlation coefficients (r) between water pH and other water and sediment qualities

Correlation	Quality parameters							
	Total N	EC	TDS	P	K	S	Ca	Mg
Water pH *vs.* Water qulaity	–	0.85	0.84	0.81	0.9	0.74	0.87	0.87
Water pH *vs.* Sediment quality	0.88	–	–	0.81	0.87	0.87	0.9	0.88

Significant (5% level of probability) correlations are presented in this table.

Water pH exhibited significant correlation with other water quality parameters and ionic composition. Correlation coefficient showed pair-wise association between water pH with EC, TDS and ionic composition in water samples (Table 3). All water parameters and ionic contents in the sediments were positively correlated with water pH and the correlation was very strong (r>0.8) except sulphate S content (r = 0.74) in water samples. Among the water qualities, the strongest positive correlation (r = 0.90) with water pH was found for exchangeable K content. And, Ca content in sediments showed the strongest positive correlation (r = 0.90) with water pH.

4 Discussion

Shrimp farming is likely to accelerate the leaching of base minerals and increases salinity and acidity of sediments. According to the reports of FAO (1981), NACA (1994) and DoF (2009) the optimum range of water pH for shrimp and prawn was 7 to 8.5. Results from this study suggests that monoculture shrimp farming (brackish water shrimp farming) exceeds the optimum level of water pH. The results are also in agreement with Islam et al. (2004) who also obtained similar results in sediments of shrimp gher located at the south-western coast of Bangladesh. Water pH and TDS level was around 6 and 3-times higher compared to fresh water shrimp farming with rice, respectively. It is also evident from this study that continuous shrimp farming with brackish water caused a drastic increase in salinity and accumulation of solids in brackish water, which is strongly correlated with water pH (Table 3). Based on the present study, continuous shrimp farming contributes to increase nutrients (N, P, K, S, Ca and Mg) concentration in water and sediments. It is already established

that the drastic increase in nutrient content in water and sediments of continuous shrimp farms (brackish water shrimp farming) contributes to decrease in shrimp growth, reproduction, development and production as well as create water quality deterioration. Whereas, co-culture (Freshwater shrimp + rice farm) maintained optimum condition for aquatic environment of shrimp farms. This obviously due to unbalanced use of chemicals (as feed or medicines) and contributes to decrease in shrimp farming and crop production at later stages. Therefore, rice shrimp co-culture might be contributing positively in increasing shrimp production as well as in maintaining optimum water and sediments qualities.

It is evident from this study that continuous shrimp farming in brackish water leads to gradual build-up of sediments salinity, toxicity of heavy metals that may render a sediment unfit for crop production in the long run. We can predict that continuous monoculture shrimp farming may increase disease infestation of prawns leading to the fall of shrimp production. Thus, maintenance of optimum level of water and sediments quality parameters in the co-culture shrimp farms is crucial for maintaining water and sediment qualities of shrimp farms.

5   Conclusions

The results suggests that nutrients status both in water and sediments were very high in brackish water shrimp farming while the lowest values were recorded in freshwater shrimp farming with rice. We may conclude that continuous shrimp farming in brackish water (monoculture) increased the level of pH and salinity of the stagnant water and enhanced accumulation of excess nutrient elements that may be a threat for sustainable shrimp production and safety of environment. Among three types of shrimp farming, the sediments and water quality parameters were optimum in co-culture shrimp farming i.e. freshwater shrimp farming with rice. Therefore, co-culture shrimp farming may contribute to maintain optimum sediments and water qualities in Bangladesh.

Acknowledgments

Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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