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Water and bottom sediments quality of brackish water shrimp farms in Kaliganj Upazila, Satkhira, Bangladesh

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Abstract

Shrimp culture plays a central part in the fisheries sector of Bangladesh that leads to a significant change in the structure and composition of frozen food export sector. An investigation was carried out to determine physiochemical parameters, nutrients content, bacterial contamination and metal content in shrimp "Gher" (Farms) water and sediments. Physicochemical parameters were analyzed in situ by portable meters. Ammonia, phosphate, bacterial counts, and metals contents were analyzed by Nesslerization, colorimetric and standard microbiological methods and Atomic Absorption Spectrophotometery (AAS), respectively. Except Dissolve oxygen and temperature all other physiochemical parameters were unsuitable for shrimp culture. The concentration of ammonia was 0.384 to 1.5 mg L^{-1} and the concentration of phosphate ranged from 0.02 to 0.818 mg L^{-1}. In bacteriological analysis, highest levels of coliform were found in the tested samples and total colifom count reached up to $2.04x10^3$ cfu mL^{-1}. Among the tested metals, Cr was highest in water and sediment samples. Concentration of Cr ranged from 0.150 to 0.807 mg L^{-1} and 1.957 to 3.436 mg kg^{-1} in water and sediment samples, respectively. A significant difference was observed for the concentration of metals in sediment and water samples. The high concentration of nutrients and metals in shrimp "Gher" water and sediment as well as the presence of pathogenic bacteria in the "Gher" and river water indicated unhygienic environment and the sources of contamination of shrimp "Gher".

Key words: *Bacterial contamination, heavy metal, nutrients content, sediment and water*

Introduction

Bangladesh is rich in natural shrimp resources and nearly 60 species of shrimp (saltwater) and prawn (freshwater) occur in Bangladesh and they are contributing in fishing for hundreds of years. In the early seventies, Bangladesh entered the world's export market for shrimp and since then this crustacean has suddenly become a very high-priced commodity. In recent decades, due to an increased international demand, shrimp has become one of the most important export product of Bangladesh. The shrimp sector has undergone dramatic changes in terms of area, production, and marketing (DoF, 2009). Two areas in the south, the Chittagong-Cox's Bazaar belt and Khulna-Satkhira-Bagerhat belt, account for 95% of the total area of shrimp culture in the country. Bangladesh produces 2.5% of the total production of shrimp in the world. Directly and indirectly more than 2 million people are engaged in upstream and downstream activities related to shrimp industry in the country (harvesting, culturing, processing and exporting) (BFFEA, 2009).

Shrimp production and cultivation is very important to have its sustained production with exportable quality. Fish and fisheries products are carefully inspected for any risk of contamination from pathogens, natural toxins, bacterial and other possible contaminants (Boyd *et al.,* 1994). Hazards associated with shrimp culture are main concerns of human health and these are categorized into physical, chemical and biological. Physical hazard is a term referring to the dirt, debris and other undesirable materials that can become mixed with a food such as shrimp. Chemical hazard arises due to the use of wide range of chemicals like fertilizers, lime, disinfectants, antibiotics and heavy metals in many stages of shrimp culture, which usually get into the body of shrimp from ponds water, sediment and surrounding environment. Sediments are important sinks for various pollutants like pesticides and heavy metals (Gawad, 2009). Sediments have been reported to form the major repository of heavy metals in aquatic system while both allochthonous and autochthonous influences could make a concentration of heavy metals in the water high enough to be of ecological significance (Adeniyi and Yusuf, 2007) and

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heavy metal pollution is a great concern to the environment because of its prevalence and non-degradability (Bhattacharya *et al*., 2008; Raza *et al.,* 2013). Heavy metals including both essential and non-essential elements have a particular significance in ecotoxicology, since they are highly persistent and all have the potential to be toxic to living organisms (Storelli *et al*., 2005). The pollution of the aquatic environment with heavy metals has become a worldwide problem during recent years, because they are non-degradable and most of them have toxic effects on living organisms (MacFarlane and Burchett, 2000). Among environmental pollutants, metals are of particular concern, due to their potential toxic effect and ability to bioaccumulate in aquatic ecosystems (Censi *et al*., 2006). Heavy metal concentrations in aquatic ecosystems are usually monitored by measuring their concentrations in water, sediments and biota (Camusso *et al*., 1995), which generally exist in low levels in water and attain considerable concentration in sediments and biota (Namminga and Wilhm, 1976; Ndimele and Jimoh, 2011). The presence of coliform and fecal coliform indicated that other harmful and pathogenic bacteria such as *Salmonella spp.*, *Shigella spp.* and *Vibrio spp.* might be present in the samples (Yousuf *et al.,* 2008).

The present study was aimed to assess the physiochemical parameters and the nutrients (ammonia and phosphate) content of shrimp "Gher" and their surrounding environment. The pathogenic bacterial contamination of shrimp "Gher" water and their surrounding environment as well as the metal contents of shrimp "Gher" water and bottom sediments were observed.

Materials and Methods

Sampling Site

During rainy season (during 2011) **s**ediment and water samples were collected from six different shrimp "Gher" and adjacent environment of Kaligonj Upazila, Satkhira, Bangladesh to assess physiochemical parameters, nutrient, pathogenic bacterial contamination and metal contents.

Study Area

Kaliganj Upazila is situated on the bank of river Kakshialy in Satkhira district which is the most southwest part of the Bangladesh and near the largest mangrove forest Sundarban. Due to the suitable conditions for shrimp farming, black tiger shrimp (*Penaeus monodon* Fabricius) farming in Bangladesh was initiated in south-west coastal region comprising the districts of Khulna, Bagerhat, and Sathkhira.

Sample Collection and Storage

Bottom sediment and water samples were collected from selected shrimp "Gher" in kaliganj upazila in Satkhira district, along Kakshialy River. Ten to twenty samples were collected from different locations of same shrimp "Gher" and mixed together to represent the particular "Gher". Bottom sediment from each study site was collected into pre-cleaned polythene bag washed with 1M HNO_3 solution and rinsed thoroughly with distilled water. Water samples were collected in 1000 mL plastic bottles and 500 mL amber color glass bottles. All samples were transported to the laboratory as early as possible. Water samples were stored at 4 °C and sediments were preserved at -20 °C before analysis.

Analysis of physico-chemical parameters

The physico-chemical parameters of "Gher" water were measured in *situ*. The hydrogen ion concentration (pH) was measured using pH meter (Jenway pH meter, Model-3305, Germany), dissolved oxygen (DO), water salinity, electrical conductivity (EC) and temperature, total dissolved solid (TDS) and turbidity (Hanna Instruments, Model- H19143, Portugal).

Analysis of nutrients (ammonia and phosphate)

Inorganic ammonia-N was determined using Nesslerization method described in standard methods for the examination of water and wastewater (APHA, 1975) and phosphate was measured using the colorimetric method by UV visible spectrophotometer (Model-1650 PC, SHIMADZU, Japan) at 400 nm according to the standard methods for the water and wastewater examination (APHA, 1975).

Analysis of pathogenic bacterial population

For bacteriology analysis, four different media, Macconkey agar medium (Difco, USA) for total coliform count, mFC agar medium for total faecal coliform count, Thiosulfate citrate bile salts sucrose agar medium (TCBS) for total *Vibrio* count, and S–S agar medium for total *Salmonella-Shigella* count were used. Standard plate count (SPC) method was used for quantification of pathogenic bacteria as described in APHA (1998).

Analysis of metal contents in sediment and water

Metals were analyzed by atomic absorption spectrophotometer. The sediment samples were prepared and extracted according to Hussain and Islam (2010). Fifteen grams of the dried and crushed sediment were taken into 150 ml conical flasks and 15 mL of 1M nitric acid (9 mL of water + 1mL of nitric acid) was added then 30 mL of distilled water was added to the mixture. The mixture was covered and kept for 24 h, and distilled water was added to make its total weight about 150 g. The contents were filtered, centrifuged and finally analyzed by a graphite furnace atomic absorption spectrometer (GSA- EX- 71 Shimadju, Japan).

Water samples were digested with nitric acid for heavy metal determination as described by Baker and Amacher (1982). Two milliliters of concentrated nitric acid was added to 250 mL of water sample and was cooled at room temperature. Fifty milliliters of sample was taken into a beaker, concentrated HNO_3 was added to it for digestion and was heated at 95 ± 5 °C without boiling until dried. After cooling, samples were diluted with distilled water, filtered and volume was made up to 50 mL in volumetric flask. A graphite furnace atomic absorption spectrometer (GSA- EX- 71 Shimadju, Japan) was used to determine the Cu, Fe, Pb, Cr, Cd and Mn concentrations of samples.

Results and Discussion

Physico-chemical parameters of Shrimp "Gher" water

The results of physiochemical parameters of different shrimp "Gher" water samples are presented in Table 1. The physiochemical parameters of shrimp "Gher" water such as, pH, temperature, DO, values were found suitable for shrimp culture but TDS and turbidity values were very high. On the other hand, salinity levels were suitable for shrimp cultivation. The recorded temperature ranged around the optimum level (32°C) as per recommendations for *P. monodon* culture (Chiu *et al.,* 1988). The optimum range of pH 6.8 to 8.7 is maintained for maximum growth and production (Ramanathan *et al.,* 2005). The pH values of all shrimp "Gher" water recorded were slightly deviating from the optimum range (7.5-8.5) recommended for ideal shrimp culture (Chiu *et al.,* 1988). Dissolved oxygen plays an important role on growth and production through its direct effect on feed consumption and maturation. Low level of oxygen tension hampers metabolic performances in shrimp and can reduce growth and molting and cause mortality. The balance between the autotrophic and heterotrophic productions in brackish water shrimp culture ponds determines the oxygen dynamics (Chiu *et al.,* 1988).

The salinity measured of all the shrimp "Gher" water ranged from 8.78 to 10.48 ppt, although the optimum salinity for shrimp culture is about 15-25 ppt (Boyd, 1995) which is vital for pond dynamics conditions. Turbidity is important in aquatic system since it may interfere with light penetration thereby potentially affecting photosynthetic reaction and organism distribution within the water body. Lowered level of photosynthesis will lead to decrease in dissolved oxygen in the water body. The turbidity of the six mixed shrimp "Gher" water samples was measured and the values ranged from 7.76 to 80 NTU which was deviated from optimal value (7 to 30) recommended by Lin *et al.* (1993).

Dissolved solids could directly influence water conductivity, the higher the dissolved solids the higher the conductivity. In the present study, total dissolved solids of "Gher" water was measured from 622 to 714 mg L^{-1} which was a deviation from EPA Secondary Regulations advise which is 500 mg L^{-1}, a maximum contamination level (MCL) of TDS. High level of TDS value could be due to the presence of organic sources such as leaves, silt, plankton sewage, and other sources including leachate of fertilizers and pesticides used in surrounding farms, inorganic materials such as rocks and air that may contain calcium bicarbonate, nitrogen, iron, phosphorous, sulfur and other minerals.

Nutrients (ammonia and phosphate) contents in Shrimp "Gher" water

Nitrogen and phosphorus are the two most important nutrients in ponds, because they should be in adequate concentration to provide optimum phytoplankton growth. The nutrient (ammonia and phosphate) contents in different shrimp "Gher" water samples are presented in Table 2. The ammonia concentrations ranged from 0.344 mg L^{-1} to 1.50 mg mL^{-1}. The concentrations of phosphate observed in different shrimp "Gher" are presented in Table 2, which

Table 1: Physico-chemical parameters of water samples collected from different shrimp "Gher"

Sample ID	Parameter						
	pH	DO (mg L^{-1})	Salinity (ppt)	EC (µs m^{-1})	TDS (mg L^{-1})	Turbidity (NTU)	Temperatures (°C)
Gh-1	7.9	5.82	9.25	1286	644	13.31	32
Gh-2	8.8	6.51	9.20	1340	669	7.76	31
Gh-3	8.1	4.92	8.78	1245	622	35.67	32
Gh-4	8.2	7.78	9.93	1244	622	45.13	32
Gh-5	8.5	7.05	10.48	1328	663	51	32
Gh-20	8.2	6.97	9.89	1430	714	80	32

ranged from 0.073 mg L^{-1} to 0.81 mg L^{-1}. The concentration of ammonia of shrimp "Gher" water was higher than the optimum value 0.1 mg L^{-1} recommended by Chien (1992). The highest value was recorded as 1.5 mg L^{-1} at twenty year old "Gher". The concentration of nitrogen which includes ammonia, nitrite and nitrate is usually affected by many factors that include water temperature and pH, in addition to surface runoff from the surrounding catchment area, streams, discharge of effluent from wastewater treatment plants, agricultural fertilizers and industrial wastes which are considered major sources of inorganic nitrogen entering aquatic systems (Anon, 1997). Phosphorus is another nutrient, which is necessary for plant and animal growth. Phosphates stimulate the growth of plankton and water plants that provide food for fish. This may increase the fish population and improve the waterways life quality. The recorded phosphorus (phosphate) concentration of shrimp "Gher" water ranged between 0.073 to 0.818 mg L^{-1}, which is greater than optimum value (0.005 to 0.2 mg L^{-1}). Since natural concentrations of phosphorus usually are low, so the high concentration of phosphorus was due to the presence of feed and phosphorus containing fertilizer in high amounts.

Table 2: Ammonia and phosphate contents of water of different shrimp "Gher"

Sample ID	Nutrient concentrations (mg L^{-1})	
	Ammonia-N	Phosphate
Gh-1	0.384	0.073
Gh-2	0.399	0.106
Gh-3	0.560	0.168
Gh-4	0.666	0.818
Gh-5	0.910	0.334
Gh-20	1.50	0.359

Bacterial Content of Shrimp "Gher" water

Pathogenic bacteria were found in most of the tested samples. The results of bacteriological analysis of "Gher" water and its adjacent river are represented in Table 3. Total coliform in the "Gher" water samples ranged was up to 2.04 × 10^3 cfu mL^{-1}. The highest coliform and faecal count was observed in the river water. The faecal coliform count was up to 4.40 × 10^2 cfu mL^{-1}. The Salmonella- Shigella count reached up to 9.70 × 10^2 cfu mL^{-1}. However, vibrio count was up to 8.85 × 10^2 cfu mL^{-1}.

The bacterial count of "Gher" water reflected that the quality of shrimp "Gher" water are influenced by river water because river carried domestic and industrial waste that contaminated shrimp "Gher" water via surface runoff especially during rainy season. According to International Commission on the Microbiological Specification of Foods (1982), acceptable limit of total coliform and faecal coliform for shrimp 10^2 and 10 cfu g^{-1}, respectively and *E. coli* should not be present. Bhaskar *et al.* (1995) reported that the major source of coliform in the pond appears to be the sediment for which manure and feed are the contributing factors. Large quantities of coliform bacteria in water and shrimp are not pathogenic to human, but may indicate a higher risk of pathogen presence (Doyle and Ericson, 2006).

The United States Food and Drug Administration showed that the prevalence of *Salmonella* in imported and domestic seafood were 7.2% and 1.3%, respectively, from 1990 to 1998, with raw seafood showing the highest contamination rates: 10% import and 2.8% domestic (Heinitz *et al*., 2000). However, there are reports of the absence of *Salmonella* from all samples of water, sediment, shrimps and chicken manure collected from the cultured shrimp producing areas of southern Thailand (Dalsgaard *et al.,* 1995). Other investigators also reported that Salmonella was a part of the natural flora of the shrimp culture environment (Iyer and Varma, 1990; Reilly and Twiddy, 1992; Bhaskar *et al.,* 1995, 1998; Norhana *et al.,* 2001. However, Dalsgaard *et al.* (1995) strongly maintained that Salmonella did not appear to constitute a normal part of the microflora in tropical brackish-water environment, a point of view supported by the low occurrence of Salmonella in some studies (Leangphibul *et al*., 1986; Putro *et al.,* 1990). In the present study, the vibrio was detected in water samples at a relatively low level as compared to other organisms. This organism has been found to be autochthonous to marine (Mathew *et al.*, 1988) and brackish water systems (Blake *et al.,* 1980). *Vibrio spp.* was found to be associated with pond mud, water and shrimp samples analysed in Thailand (Leangphibul *et al.,* 1986), and in India (Bhaskar and Setty, 1994).

Metal content in shrimp "Gher" water and sediment

There was significant difference recorded in concentration between sediment and water. The concentration of the metals in sediments and "Gher" water are presented in Tables 4 and 5, respectively. In the study area, copper (Cu) levels ranged from 0.624-1.176 mg kg^{-1} in sediment sample but in water sample ranged from 0.107 to 0.136 mg L^{-1}. Iron was only detected in sediment sample with the range between 17.499 to 19.228 mg kg^{-1}. In the study area, Pb levels ranged from 0.619-1.113 mg kg^{-1} in sediment sample but in water samples it ranged from 0.235 to 0.345 mg L^{-1}. In the study area, chromium (Cr) levels varied from 1.957 to 3.436 mg kg^{-1} in sediment samples and between 0.150 to 0.807 mg L^{-1} in water samples. Cadmium (Cd) level was varying from 0.116 - 0.160 mg kg^{-1} in sediment samples and ranged between 0.106 to 0.115 mg L^{-1}

in water samples. In the study area, Mn levels ranged from 13.608 to 24.044 mg kg^{-1} in sediment sample but in water sample varied slightly from 0.129 to 0.195 mg L^{-1}.

pH in shrimp “Gher” water. At higher pH, lead hydroxide and carbonate species tend to dominate (Zweig, *et. al*., 1999).

Table 3: Quantitative analysis of pathogenic bacterial population in shrimp “Gher” water

Sample ID	Total coliform count	Total faecel coliform count	Total Salmonella-Shigella count	Total vibrio count
	cfu g^{-1}			
Gh-1	9×10^1	7.0×10^1	7.0×10^1	3.0×10^1
Gh-2	0.0	0.0	0.0	0.0
Gh-3	5.10×10^2	3.70×10^2	9.5×10^1	0.0
Gh-4	0.0	0.0	0.0	3.5×10^1
Gh-5	2.0×10^1	0.0	2.0×10^1	0.0
Gh-20	1.20×10^2	3.0×10^1	6.5×10^1	6.0×10^1
River	2.04×10^3	4.40×10^2	9.70×10^2	8.85×10^2

Table 4: Content of metals found in sediments of different shrimp Gher

Sample ID	Metal concentration (mg kg^{-1}) dry weight					
	Cu	Fe	Pb	Cd	Cr	Mn
Gh-1	1.038	19.228	0.921	0.160	1.957	13.608
Gh-2	1.054	19.176	1.113	0.141	2.368	14.356
Gh-3	0.905	18.328	1.031	0.151	2.614	24.044
Gh-4	0.923	18.284	1.004	0.130	3.436	18.356
Gh-5	0.801	18.494	0.976	0.122	3.271	20.866
Gh-20	1.176	18.527	1.058	0.127	3.436	14.784
River	0.624	17.499	0.619	0.116	2.943	22.025

Table 5: The content of metal concentration of water from different shrimp Gher

Sample ID	Metal concentration (mg L^{-1})					
	Cu	Fe	Pb	Cd	Cr	Mn
Gh-1	0.137	0.0	0.235	0.108	0.314	0.195
Gh-2	0.128	0.0	0.262	0.106	0.150	0.164
Gh-3	0.119	0.0	0.262	0.106	0.561	0.164
Gh-4	0.118	0.0	0.290	0.106	0.807	0.129
Gh-5	0.107	0.0	0.345	0.115	0.807	0.171

The concentration of Cu in shrimp “Gher” water was almost similar to the optimum 0.1mg L^{-1} for black tiger prawn recommended by Chien (1992). The maximum admissible copper concentration in water was in the range of 0.001 to 0.01 mg L^{-1} depending on the species of fish and physico-chemical state of the water (Svobodová and Vykusová, 1993). Copper (Cu) is used in antifouling paints, applied to boats and submerged structures. In addition, copper is used as fungicides and algaecides. These uses, as well as copper mining activities are the major source of copper contamination in the aquatic environment (Zweig, *et al*., 1999). The concentration of lead in water is higher than optimum value < 0.02 mg L^{-1} [recommended by Meade (1989)]. There was significant difference observed between sediment and water sample which would be due to the high

According to Svobodová and Vykusová (1993), the dissolved forms of cadmium that may be toxic to fish include the free ion and various inorganic and organic complex ions. Cadmium is of particular concern to aquaculture as it bioaccumulates (DWAF, 1996). Chromium is of concern for aquaculture due to its ability to bioaccumulate in sediment. The concentration of Cr in water sample was higher than the critical value (0.03 mg L^{-1}) for brackish water (Meade, 1989). The concentration of iron was recorded in sediment ranging from17.499 to 19.277 g kg^{-1} but in water samples iron was not detected, where detection limit was 0.0001 mg L^{-1}. This could be the reason that ferrous ion ($Fe^{2+)}$ converts into insoluble ferric ion (Fe^{3+}) that complex in the sediment with the presence of oxygen since shrimp “Gher” water average dissolved concentration was 7 mg L^{-1}. Manganese is an essential micronutrient for aquatic organism but is neurotoxic in excessive amounts. In the present study, the concentration of manganese in sediment ranged from 13.60 to 24.04 mg kg^{-1} and the concentration in water ranged from 0.129 to 0.195 mg L^{-1}. DWAF (1996) notes that manganese concentrations in the mg L^{-1} range can be found in anaerobic bottom water bodies where manganese has been mobilized from the sediments.

Conclusion

Except DO and temperature other physicochemical parameters of shrimp “Gher” water were not suitable for shrimp cultivation and the nutrient (ammonia and phosphate) concentrations were higher than the optimum limit. “Gher” water samples were contaminated with pathogenic bacteria, like coliform, faecal coliform, Salmonella-Shigella and Vibrio etc. “Gher” water was less contaminated compared to the river water due to the presence of domestic and industrial pollutants. Sediments act as a sink for metals because concentration of metal in sediment was much higher than the concentration in water.

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