Islamic Azad University
Mashhad Branch

Shrimp Culture Impact on the Surface and Ground Water of Bangladesh

A. K. M. Munirul Haque[1], M. Sarwar Jahan[2] and Md. Abul Kalam Azad[2*]

1. Local and Revenue Audit Directorate, Audit Complex, Segun Bagicha, Dhaka – 1000, Bangladesh .
2. Institute of Environmental Science, University of Rajshahi , Rajshahi – 6205, Bangladesh .

Received 12 March 2010; accepted 28 July 2010

Abstract

A case study was carried out to see the impacts of shrimp culture on the surface (pond) and ground water (tube-well) quality in three coastal sub-districts of Bagherhat Sadar, Rampal and Morrelganj of Bangladesh. The people of Rampal (100%), Morrelgonj (87.5%) and Bagherhat (75.5%) expressed that salinity of both surface and ground water increased after shrimp culture, and water becomes more turbid, odorous and less tasty compared to pre-shrimp culture scenario. The ground water pH was foo be slightly acidic (6.07– 6.71) but the surface water was mildly alkaline in nature (7.00–7.46). Ground water was more saline (1893–2673ppm) than surface water (513-2253ppm). Potassium level of surface water was very high (97-242ppm) compared to the ground water (11.73-27.37 ppm). This exceeds the WHO Guideline Value (10ppm) and the Bangladesh Standard for Drinking Water (12ppm). The pollution levels of phosphorous and iron were found to be a little higher but other pollutants like nitrate, boron and zinc were found to be very low in surface and ground water in the shrimp culture area of Bangladesh.

Keywords: *shrimp culture, ground water, Bangladesh, Potassium level*

1. Introduction

The interface or transition areas between land and the sea including the large inland lakes are commonly known as coastal areas. Coastal areas are diverse in function and form. They are dynamic in nature and difficult to define by strict spatial boundaries [1] .Coastal districts of Bangladesh have been delineated into three contiguous regions, as south-west constituting Satkhira, Khulna and Bagerhat; south-central comprising Jessore, Patuakhali, Noakhali and Barisal districts, and south-east consisting of Chittagong and Cox's Bazar. As per the recent delineation, the coastal zone of Bangladesh consists of 19 districts comprising 147 sub-districts covering an area of 47,201 km^2 and the Exclusive Economic Zone (EEZ). Considering the exposedness to the coast or the estuary, a total of 48 sub-districts in 12 districts covering 23,935 km^2 are exposed to the sea or lower estuaries (defined as the exposed coast). The remaining 99 sub-districts of the coastal areas comprising 23,266 km^2 are termed as interior coast [2].

The coastal zone of Bangladesh contains several ecosystems that have important conservation values such as the world's largest mangrove ecosystem in the Sundarbans, which was declared as World Heritage Site in 1997.

These ecosystems are rich in biodiversity and provide the ecological base for the fisheries resources in the Bay of Bengal [2]. The zone has various natural resources including marine fisheries and shrimp, forest, salt, minerals and potential onshore and offshore natural gas. The Coastal zone of Bangladesh is prone to several natural disasters such as cyclones, storm surges, tidal floods and soil erosion. In the recent past, the coastal area is also facing some hazards like water logging and increasing trends of water and soil salinity.

The shrimp culture in Bangladesh has a long history. For centuries, the local people used to practice traditional coastal aquaculture locally called 'Bheri-Culture' for shrimp, fish and paddy. They used to trap tidal water within the paddy fields during January/February to June/July for aquaculture followed by T-Aman plantation during monsoon. Such traditional aquaculture didn't require fry harvesting and stocking, chemical treatment and supplementary feeding. It was a sustainable and environment friendly aquaculture practice which rotated with agriculture.

In Bangladesh, shrimps are mainly cultivated in two coastal regions – south-west coastal region comprising the districts of Khulna, Bagerhat, Sathkhira and south-east coastal region which includes Chittagong and Cox's Bazar. It is estimated that 250,000 ha of land have a good potential for coastal aquaculture [3]. In 1983-84, the total shrimp area in Bangladesh was 51,812 ha and it rose to 217,877 ha in 2005-06 indicating a 420.5% increase sharply in last 22 years.

----

*Corresponding author.
E-mail address (es): akazad_ies@yahoo.com

In 2005-06, south-west region produced 78.9% of the Bangladesh's total shrimp production [4]. Shrimp, the white gold bar of Bangladesh is the second highest foreign exchange earner which accounts for 5.2% of the total export following the ready made garments (RMG) sector. At present Bangladesh is the 8th largest shrimp producer of the world and produces 2.5% of the global shrimp output [4] and [5]. Bagda (*Paeneus monodon*) is cultivated mainly near the coast where water salinity is very high and golda (*Macrobrachium rosenbergi*) is cultivated in the interior areas with low water salinity.

Shrimp culture has flourished in coastal areas due to the abundance of shrimp fry in the Bay of Bengal and creeks and rivers nearby the coast. In most of the ponds bagda shrimps (*Paeneus monodon*) are cultivated in extensive method; very few farms are of improved traditional nature.

The shrimp culture of Bangladesh has both beneficial and detrimental effects. Shrimp culture has caused increasing salinity, destruction of mangrove resources and other vegetation, biodiversity reduction, declining land productivity and reduction of forest area in the south-western coastal region of Bangladesh [6]. Considering these environmental effects, a study on surface and ground water quality was carried out in shrimp cultivation areas under the coastal sub-districts of Bagherhat Sadar, Rampal and Morrelganj of Bangladesh. Therefore, this study was done considering the following objectives:

i) To analyze the water quality of the surface (pond) and groundwater (tube-well) of the shrimp culture area, and
ii) To assess the impact of shrimp culture on the water quality

2. Methodology

2.1 Study Area

The present study was scheduled to be conducted in the Bagerhat district of the south-west coastal region of Bangladesh situated between 21°49' and 22°59' north latitude and between 89°32' and 89°98' east longitude. Three coastal sub-districts (Rampal, Morrelgonj and Bagerhat) where shrimp culture is dominant were selected (Fig. 1). Considering the limitations of time and resources, three unions from each sub-district and two villages from each union were selected following the stratified random sampling technique. Thus a total of 18 villages having shrimp culture practices were finally selected for this study.

The three coastal sub-districts of Rampal, Morrelgonj and Bagerhat were selected as they are well connected with the Bay of Bengal by the rivers of Mongla, Daudkhali, Passur, Panguchi, Katakhali, Baleshwar, Bhola and Dartana .They also have the top ranking with respect to shrimp area coverage.

2.2 Collection of Surface Water

Local people use surface water from the ponds as potable water in the shrimp culture area. Therefore, surface water samples were collected from different ponds located in three coastal sub-districts of Bagherhat Sadar, Rampal and Morrelganj of Bangladesh. Samplings were performed in the month of October (2003 and 2004) for the rainy season and in April (2004 and 2005) for the summer season.

Each time a total of 18 samples from the ponds were collected from 18 villages of the three coastal sub-districts of Bagherhat Sadar, Rampal and Morrelganj. Surface water from the ponds was collected from 30 cm below the water surface in a clean and well-dried 500 ml plastic bottle with airtight screw cork. Before collection of water the bottles were rinsed with pond water from the specific sources. Immediately after sampling the water was transferred to laboratory for chemical analysis.

2.3 Collection of Ground Water

For assessment of ground water quality of shrimp culture areas of Bangladesh, two tube-wells were randomly selected from each village of the study area under the three coastal sub-districts of Bagherhat Sadar, Rampal and Morrelganj. A total of 33 tube-well water samples (instead of 36) were collected from 18 villages because 3 tube-wells in two villages were inactive. To observe the seasonal variation, ground water sampling was done both in the summer (April 2004 and 2005) and in the rainy season (October 2003 and 2004).

During ground water sample collection, the tube-well was first pumped for 30 minutes to pump out the stagnant water present in the pipes. Next, fresh ground water was collected in a 500 ml clean plastic bottle with airtight screw cork from each of the selected tube-wells. Before collection of water the bottle was rinsed with tube-well water several times. The collected samples were preserved in a cool place in the lab before analysis.

2.4 Preparation of Water Samples

The collected water samples were first filtered through a Whatman No.1 filter paper for phosphorous, sulfur, boron, iron and zinc. The filtrate was collected in a clean well dried plastic bottle with airtight screw cap. In the case of non-clear filtrate, filtration was repeated on the same filter paper. The clean filtered water was used for necessary chemical analysis.

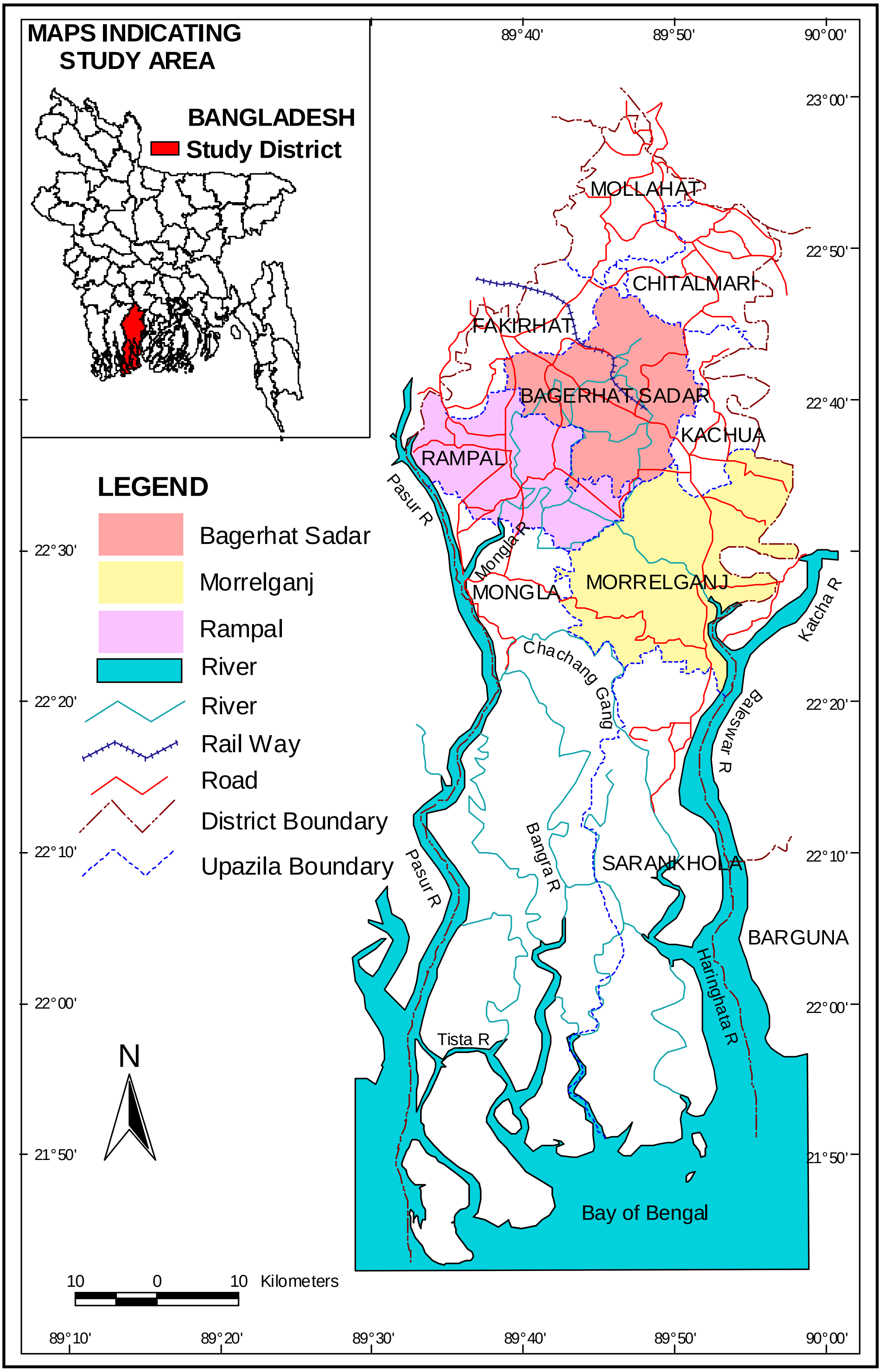

Fig. 1. Location of Study Area in Bangladesh Map

2.5 Water Analysis

Water pH was measured directly in sampled water immediately after sampling in the field using the HACH pH meter. Electrical conductivity was measured directly in water by the Metrohm EC Meter at 25 °C.

Potassium (K^+), calcium (Ca^{2+}), iron (Fe^{3+}) and zinc (Zn^{2+}) contents of water were separately measured by Atomic Absorption Spectrophotometer (AAS). Phosphorous (PO_4^{3-}) content of water was determined colorimetrically by measuring the absorbance on a spectrophotometer at 890 nm using molybdate blue-ascorbic acid solution. Sulfur (SO_4^{2-}) content of water was determined turbidimetrically using $BaCl_2$ and polyvinylpyrrolidone by measuring the absorbance at 535 nm on spectrophotometer.

Boron (B) content of water was determined by mixing acetate buffer solution and Azomethine-H reagent with the water and the absorbance was measured at 420 nm on a spectrophotometer. Nitrate content (NO_3^-) of the water was determined by using brucin reagent and conc. H_2SO_4 acid and the absorbance was measured at 410 nm on a spectrophotometer [7].

2.6 People's Perception Study on Water Quality

The scarcity of good quality water is a common phenomenon in the shrimp culture area of Bangladesh. Chemical analysis of surface and ground water is not enough to describe the impact of shrimp culture on the drinking water sources in the study area. Therefore, people's perception of the impact of shrimp culture on the surface and ground water quality was assessed through household questionnaire survey.

Categories of respondents were selected from the adjoining villages surrounding the shrimp culture areas. To get the clear and correct answer, older people over 40 years of age with different professions have been selected as respondents. This helped in getting information from various walks of life with diversified views, which increased the reliability of information and decreased the chance of data missing and error. Considering the available logistic support, resource constraints and time, a total of 325 diversified respondents were selected from the study area (shrimp pond owners – 36, household farmers – 72, shrimp culture labor – 36, professional fishermen – 90, teacher/imam/NGO professionals – 72 and government officials – 21)

3. Results and Discussions

3.1 Analytical Results of Surface and Ground Water

The water quality data of surface (pond) and ground water (tube-well) of the shrimp culture areas of three sub-districts (Rampal, Morrelgonj and Bagherhat) of Bangladesh is presented season wise in Tables 1 and 2, respectively. The pH of surface water varies from 7.29-7.46 in summer season (Table 1), which is higher than the ground water pH (6.46-6.71). However, pH of both surface and ground water was found to slightly lower during the rainy season (Table 2). Seasonal variation of the pH values of surface water did not show great differences. The observed values were within the range to permit all the natural processes of aquatic life [8]. Surface water pH in the summer and rainy seasons and the ground water pH in the summer season were found within the WHO Guideline (6.5-8.5) and Bangladesh Standard for Drinking Water Quality (6.5–8.5). The low pH (6.07) in the ground water of Morrelgonj and Bagerhat areas during the rainy season may be due to the higher organic matter content of underground soils.

The salinity of the ground water was higher than the surface water both in the summer and in the rainy seasons (Tables 1 and 2). The salinity of the ground water was higher in summer (2053–2673ppm) than rainy season (1893–2573ppm). Similarly, the salinity of surface water was higher in summer (1286 –2253 ppm) than rainy season (513–993ppm). During the rainy season, rain water diluted the salt and therefore, a low salinity was observed in that period [9].

The nitrate content of surface water in the summer season varies from 0.43–0.61 ppm, which is higher than the value for the rainy season (0.15–0.19 ppm). However, the nitrate content of groundwater in the summer and rainy seasons was higher than the rainy season value of surface water (Tables 1 & 2). The nitrate level of surface and ground water did not exceed the Bangladesh Standard for Drinking Water, 10 ppm [10].

Potassium content of surface water was found to be very high compared to the ground water. The potassium content of surface water was 140.7–242.4 ppm in summer and 97.7 ppm–125ppm in rainy season. The potassium content of ground water ranges from 11.7 to 27.3 ppm in rainy season and 11.7–23.3ppm in summer season. Both surface water and ground water potassium content exceeded the WHO Guideline Value (10.0 ppm) and Bangladesh Standard for Drinking Water, 12.0 ppm [10].

Calcium content in surface and ground water is nearly the same during summer season (Tables 1 & 2). In that season, the calcium content of the surface and ground water ranges from 82– 118ppm and 46to 122 ppm, respectively. The main source of calcium is the result of weathering [11]. The high concentration of calcium in the studied area is mainly responsible for the hardness of water.

Phosphorous content in ground water was found to be higher than the surface water both in summer and rainy seasons. It is because of the weathering of the phosphate rocks and decomposition of organic substances in the soil [12]. The ground water phosphorous level is nearly the same in the two seasons and varies from 0.13 to 1.70 ppm. However, the phosphorous content of surface water in the summer season ranges from 0.26 to 0.35 ppm and in the rainy season it varies from 0.17 to 0.42 ppm (Table 1). In the study area, phosphorous content of surface and ground water exceeded the Bangladesh Standard for Drinking Water (0 ppm). The high levels of phosphorous in the surface water could possibly result from the agricultural fertilizer runoff reaching the ponds by rain drainage [13].

Sulphur content in the surface water is much higher than the ground water. The sulphur level in the surface water in summer season lies between 10.19 to 22.98 ppm, which is higher than the rainy season (10.57–13.78 ppm). However, the sulphur level in ground water is 2.2 –5.7 ppm in the summer season and 0.76-5.8 ppm in the rainy season.

The ground water of the study area contained a higher level of boron than the surface water and it varies from 0.35 to 0.55 ppm in the summer and 0.31 to 0.49 ppm in the rainy seasons (Table 2). The boron content in the surface water is nearly the same for both the summer (0.15-0.20 ppm) and the rainy (0.18-0.21 ppm) seasons. Boron level in surface and ground water is found within the range of WHO guideline values (0.5 ppm) and Bangladesh Standard for Drinking Water, 1 ppm [10].

Iron content in the ground water varies from 2.07 to 2.36 ppm (Table 2). The sediment of Bangladesh is rich in iron and therefore, a high level of iron was found in ground water [14]. Iron level in surface water ranges from 1.51 to1.61 ppm in the summer and 1.21 to 1.42 ppm in the rainy seasons (Table 1). Both surface and ground water iron level exceeded the WHO guideline value (0.3 ppm) and Bangladesh Standard for Drinking Water (0.3-1.0 ppm). Zinc content in surface and ground water is very low and it varies from 0.02 to 0.04 ppm.

Based on the analyzed water quality parameters of surface water, it can be inferred that the surface water of the study area fails to fulfill the water quality standards set by WHO and Bangladesh. Long distance of the study locations from the university, high work volume and resource constraints have led to limit the analyzable parameters. But these factors didn't act as a barrier to draw a conclusion on the surface water quality of the study area. Intake of surface water degraded due to shrimp culture caused the coastal people to suffer from various waterborne diseases. The findings of this study have congruence with SRDI [15] and Saha [16]. SRDI analyzed the surface water of Morrelgonj, Mollahat and Fakirhat sub-districs of Bagerhat district and observed results similar to this study. Saha [16] analyzed water from 18 ponds of Bagerhat town and found similar analytical results for the respective parameters of the present study.

Furthermore, the average ground water quality of the study area is not good. The situation is better in Rampal sub-district due to the installation of a considerable number of deep tube-wells in the recent past. But in Morrelgonj and Bagerhat, as far as the study area is concerned, there is no deep tube-well. Instead, there are shallow tube-wells (50-75 ft depth) which produce ground water from shallow aquifer contaminated with saline water. The findings of this study are similar to those of SRDI [15] and Das [17]. SRDI [15] analyzed some ground water samples from shrimp culture areas of Paikgacha and Batiaghata sub-districts of Khulna district, and Satkhira and Tala sub-districts of Satkhira district and observed more or less similar analytical results to the present study. Das [17] analyzed water quality parameters of 26 tube-wells of Bagerhat municipality and these results have congruence with the analytical findings of the present research work.

3.2 Correlation Analysis among the Water Quality Parameters of Surface Water

Pearson correlation matrix (2-tailed) was done to see the correlation among the different water quality parameters of surface water in the shrimp culture area. This correlation analysis reveals that significant negative correlation exists between Fe and Zn ($p<0.01$) in the summer season (Table 3.1). However, in the rainy season, a positive correlation between B and Zn ($p<0.01$) is found (Table 3.2).

3.3 Correlation Analysis among the Water Quality Parameters of Ground Water

Correlation analysis among the ground water quality parameters reveals there are negative correlations between pH and K ($p<0.05$) and positive correlations between Fe and NO_3 ($p<0.05$) in the summer season (Table 4.1). However, in the rainy season, only positive correlation between Fe and Ca ($p<0.05$) is noticed (Table 4.2).

3.4 People's Perception on Surface and Ground Water Quality

The scarcity of good quality water is a common phenomenon in the study area. The people's perception on the shrimp culture impact on the surface and ground water quality was assessed through household questionnaire survey. This opinion survey data is presented in Table 3. From the people's perception study, it is found that the water quality of both surface and ground water was degraded due to shrimp culture. The local people thought that underground water aquifers become saline by longtime holding of saline water in shrimp fields.

In addition to the groundwater, the surface water of the study area becomes more saline. All the people of Rampal (100%), and most of the people of Morrelgonj (87.5%) and Bagerhat (75.5%) sub-districts opined that water salinity increased due to shrimp culture (Table 5). People of the study area also thought that water becomes more turbid, odorous and less tasty for shrimp cultivation. High levels of turbidity over long periods can greatly diminish the health and productivity of the pond water ecosystem in the coastal area [18].

4. Conclusions

People of the shrimp culture area opined that the water salinity and turbidity were increased and water taste was deteriorated by shrimp culture in three coastal sub-districts of Rampal, Morrelgonj and Bagerhat of Bangladesh. From physical analysis, pH was found within the limit of drinking water but salinity level is very high. From chemical analysis of water, nitrate, boron and zinc levels were found within the limits of Bangladesh Standard for Drinking Water and WHO guideline value. However, the level of potassium, phosphorous and iron in surface and ground water exceeded the limit of drinking water quality.

Table 1. Surface (ponds) Water Quality of Shrimp Culture Area of Bangladesh in Summer and Rainy Seasons

Parameters	Surface Water Quality in three Sub-districts					
	Rampal		Morrelgonj		Bagerhat	
	Summer	Rainy	Summer	Rainy	Summer	Rainy
pH	7.46	7.00	7.35	7.04	7.29	7.03
Salinity (ppm)	2253.33	993.30	1466.70	686.61	1286.66	513.31
NO_3 (ppm)	0.44	0.15	0.61	0.16	0.43	0.19
K (ppm)	222.87	113.39	140.76	97.75	242.42	125.12
Ca (ppm)	118.20	50.06	82.10	28.03	90.11	22.03
P (ppm)	0.31	0.17	0.26	0.21	0.35	0.42
S (ppm)	22.47	13.73	22.98	10.57	10.19	13.78
B (ppm)	0.20	0.18	0.15	0.21	0.17	0.20
Fe (ppm)	1.51	1.21	1.61	1.42	1.61	1.30
Zn (ppm)	0.04	0.02	0.03	0.03	0.03	0.03

Table 2. Ground Water (Tube-wells) Quality of Shrimp Culture Area of Bangladesh in Summer and Rainy Seasons

Parameters	Ground Water Quality in three Sub-districts					
	Rampal		Morrelgonj		Bagerhat	
	Summer	Rainy	Summer	Rainy	Summer	Rainy
pH	6.71	6.56	6.47	6.07	6.62	6.08
Salinity (ppm)	2053.20	1893.12	2673.33	2573.29	2380.00	2266.51
NO_3, (ppm)	0.53	0.06	1.34	0.34	1.09	0.24
K (ppm)	11.73	11.73	23.37	27.37	15.51	15.64
Ca (ppm)	46.05	16.02	100.13	62.08	122.15	50.06
P (ppm)	0.13	0.16	1.70	1.66	0.35	0.70
S (ppm)	2.22	0.76	4.81	5.78	5.71	5.19
B (ppm)	0.46	0.48	0.55	0.49	0.35	0.31
Fe (ppm)	2.09	2.07	2.36	2.26	2.26	2.22
Zn (ppm)	0.03	0.03	0.04	0.02	0.02	0.03

Table 3.1. Pearson Correlation Matrix for Surface Water in Summer Season (2-Tailed)

	pH	Salinity	NO_3	K	Ca	P	S	B	Fe	Zn
pH	1.000									
Salinity	0.984	1.000								
NO_3,	-.118	-.294	1.000							
K	-.014	.165	-.991	1.000						
Ca	0.843	.925	-.635	.527	1.000					
P	-.287	-.112	-.917	.962	.274	1.000				
S	.747	.617	.571	-.675	.272	-.851	1.000			
B	.722	.834	-.773	.682	.981	.455	.080	1.000		
Fe	-.938	-.985	.457	-.335	-.977	-.064	-.469	-.918	1.000	
Zn	.938	.985	-.457	.335	.977	.064	.469	.918	-1.000*	1.000

Table 3.2. Pearson Correlation Matrix for Surface Water in Rainy Season (2-Tailed)

	pH	Salinity	NO_3	K	Ca	P	S	B	Fe	Zn
pH	1.00									
Salinity	-.821	1.000								
NO_3,	.500	-.905	1.000							
K	-.240	-.357	.721	1.000						
Ca	-.866	.997	-.866	-.277	1.000					
P	.417	-.861	.996	.782	-.816	1.000				
S	-.682	.142	.293	.874	.224	.381	1.000			
B	.971	-.934	.693	.000	-.961	.623	-.486	1.000		
Fe	.953	-.609	.213	-.524	-.673	.122	-.872	.852	1.000	
Zn	.971	-.934	.693	.000	-.961	.623	-.486	1.000**	.852	1.000

Table 4.1. Pearson Correlation Matrix for Ground Water in Summer Season (2-Tailed)

	pH	Salinity	NO_3	K	Ca	P	S	B	Fe	Zn
pH	1.000									
Salinity	-.982	1.000								
NO_3,	-.930	.983	1.000							
K	-1.000*	.976	.918	1.000						
Ca	-.566	.713	.830	.541	1.000					
P	-.973	.911	.819	.979	.360	1.000				
S	-.594	.736	.849	.570	.999	.392	1.000			
B	-.586	.421	.246	.610	-.336	.758	-.304	1.000		
Fe	-.953	.993	.998*	.943	.790	.856	.810	.312	1.000	
Zn	.775	-.881	-.954	-.756	-.960	-.608	-.969	.058	-.931	1.000

Table 4.2. Pearson Correlation Matrix for Ground Water in Rainy Season (2-Tailed)

	pH	Salinity	NO_3	K	Ca	P	S	B	Fe	Zn
pH	1.000									
Salinity	-.901	1.000								
NO_3,	-.942	.994	1.000							
K	-.706	.944	.903	1.000						
Ca	-.972	.977	.994	.852	1.000					
P	-.786	.977	.948	.993	.909	1.000				
S	-.997	.934	.967	.762	.988	.835	1.000			
B	.441	-.007	-.114	.324	-.218	.208	-.365	1.000		
Fe	-.983	.965	.987	.823	.999*	.886	.995	-.270	1.000	
Zn	1.000*	.893	-.936	-.693	-.968	-.775	-.995	.457	-.980	1.000

Table 5. Peoples perception on Pond and Ground Water (Tube-well) in Shrimp Culture Area of Bangladesh

Parameter	People's Perception (%) on Water in three Sub-districts					
	Rampal		Morrelgonj		Bagerhat	
	Pond	Ground Water	Pond	Ground Water	Pond	Ground Water
Increased salinity	100.0	100.0	87.5	87.5	75.0	75.0
Increased turbidity	66.7	33.4	83.3	20.8	54.2	58.3
Odor	75.0	4.2	54.2	0.0	62.5	4.2
Loss of water taste	95.8	100.0	91.7	100.0	83.3	20.8

References

[1] FAO, 1998, Integrated Coastal Area Management and Agriculture, Forestry and Fisheries, FAO Guidelines, Rome, p. 2.

[2] Islam, Md. R., 2004, Where the Land Meets the Sea: A Profile of Coastal Zone of Bangladesh, the University Press Ltd., Dhaka, p.4-5.

[3] Ahmed, A.T.A., 1995, Impact of Shrimp Culture on the Coastal Environment of Bangladesh, Proceedings of CAEM'95: *Workshop on Coastal Aquaculture and Environment Management*, Chittagong Institute of Marine Science, University of Chittagong, and UNESCO, p.77.

[4] DoF, 2006, Shrimp Sub-sector Strategy, Department of Fisheries, Ministry of Fisheries and Livestock, Government of the People's Republic of Bangladesh, p.1-13.

[5] BCAS, 2001, The Cost and Benefit of Bagda Shrimp Farming in Bangladesh: An Economic, Financial and Livelihood Assessment, Prepared as part of the Fourth Fisheries Project, August, 2001 by Bangladesh Centre for Advanced Studies (BCAS), Dhaka, p.143.

[6] Alauddin, M., and Hamid, M.A., 1998, Shrimp Culture in Bangladesh with Emphasis on Social and Economic Aspects, Queensland: Department of Economics, University of Queensland, Australia 4072, p.53-62.

[7] Trivedy, R.K., and Goel, P.K., 1986, Chemical and Biological Methods for Water Pollution Studies, Environmental Publications, Karad, India, p.50-75.

[8] Bellos, D. and Sawidis, T., 2005, Chemical Pollution Monitoring of the River Pinios (Thessalia-Greece), Journal of Environmental Management, v. 76, p.282-292.

[9] Sundaramanickam, A., Sivakumar, T., Kumaran, R., Ammaiappan, V. and Velappan, R., 2008, A Comparative Study of Physico-Chemical Investigations along Parangipettai and Cuddalore Coast, Journal of Environmental Science and Technology, v. 1 (1), p.1-10.

[10] ECR, 1997, Environment Conservation Rules, Bangladesh Gazette, Ministry of Environment and Forest, Government of the People's Republic of Bangladesh, p.3125-3127.

[11] Hossain, S., Alam, D. and Anam, K., 1991, Chemical Characters of Ground Water Samples Collected from some Deep and Hand Tube-wells in and around Dhaka City: Bangladesh Journal of Scientific Research, v. 9 (2), p.171-176.

[12] Arms, K., 1989, Environmental Science, Saunders College Publishing, Philadelphia, USA, p.111-112.

[13] Karakoc, G., Erkoc, F.U. and Hikmet, K., 2003, Water Quality and Impacts of Pollution Sources for Eymir and Mogan Lakes (Turkey), Environment International, v. 29, p.21-27.

[14] Khanam, J. A., Azad, M. A. K, Zaman, M.S. and Mottaleb, M.A,. 2000, Analysis of Ground Water Samples of Gadagari Region in Western part of Bangladesh: Journal of Rajshahi University Studies, part-B, v. 28, p.17-25.

[15] SRDI, 2003, Soil Salinity in Bangladesh 2000, Dhaka: Soil Resource Development Institute, Ministry of Agriculture, Government of the Peoples Republic of Bangladesh, p.1-114.

[16] Saha, C., 2006. Chemical Characterization of Dry Season Surface Water from Bagerhat Municipality, Graduation Thesis (un-published), Environmental Science Discipline, Khulna University, Khulna, Bangladesh, p.33-34.

[17] Das, R., 2006, Nature of Dissolve Solute Load in the Water from Aquifer of Bagerhat Municipality, Graduation Thesis (un-published), Environmental Science Discipline, Khulna University, Khulna, Bangladesh, p. 41-43.

[18] Elmanama, A.A., Afifi, S. and Bahr, S., 2006, Seasonal and Spatial Variation in the Monitoring Parameters of Gaza Beach during 2002-2003, Environmental Research, v. 101, p.25-33.