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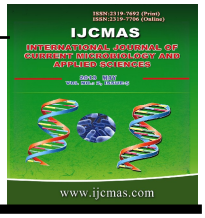

Original Research Article

Seasonal Variations of Physicochemical Parameters of Water in the Pungli River, Tangail, Bangladesh

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Keywords
Pungli River; Water quality; Physico-chemical parameters; Nutrients.

A B S T R A C T

The study was conducted to investigate the water quality of Pungli River in the Tangail region and its temporal change over post-monsoon (October to January), pre-monsoon (February to May) and monsoon (June to September) seasons due to change the physico-chemical parameters during the period from October 2011 to September 2012. The river originated from the Jamuna River which flowing through the Kalihati, Sadar and Bashail upazila of Tangail district and finally fall into the Bangshi River at Bashail upazila. Now a day over exploitation of fisheries resources, river bank erosion and human activities hampered its aquatic environment. For existence and conservation of aquatic resources, it is essential to investigate water quality and surrounding environment of the river. Water samples were collected from five different sampling sites in the river. The results of the study showed that the concentrations of electric conductivity (EC), dissolved oxygen (DO), biochemical oxygen demand (BOD), hardness, sodium (Na), potassium (K) and copper (Cu) were within the standard limit measured by DoE as well as suitable for aquatic lives. The pH was less than the standard i.e. slightly acidic, transparency was incalculable and total dissolved solid (TDS) was increased in both post and pre-monsoon seasons. The content of total nitrogen (N), phosphorus (P) and cadmium (Cd) exceeded the permissible limit in all seasons. The excessive abundance of total nitrogen and phosphorus made the river prone to eutrophication. The comparative study showed that most of the water quality parameters of the Pungli River were suitable for aquaculture of aquatic organisms as well as fishes.

Introduction

The environment, economic growth and development of Bangladesh are all highly influenced by water - its regional and seasonal availability, and the quality of

surface and groundwater. Spatial and seasonal availability of surface and groundwater is highly responsible to the monsoon climate and physiography of the country. In terms of quality, the surface water of the country is unprotected from untreated industrial effluents and municipal wastewater, runoff pollution from chemical fertilizers and pesticides, and oil spillage in the coastal area from the operation of sea and river ports (UNEP, 2001). Surface water monitoring is essential for aquatic resources management and flood forecasting (Haque, 2008).

Bangladesh has extensive water bodies that have a high potential for fisheries production (Mustafa and Brooks, 2009). The productivity depends on physico-chemical characteristics of the water body (Ehiagbonare and Ogunrinde, 2010). The population of natural fish species has declined considerably due to increased fishing pressure and various anthropogenic activities leading to siltation, aquatic pollution and loss of natural habitat for spawning and growth (Akhteruzzaman *et al*., 1998; Hussain and Mazid, 2001). These factors not only destroyed the breeding grounds but also caused havoc to the availability of brood fish including fry and fingerlings (Hussain and Mazid, 2001). As a result, recently the fish is considered as one of the most endangered species in Bangladesh (IUCN, 1998).

Water quality assessments are technical reviews of physical/ chemical data and information to determine the quality of water resources to make decisions on whether a water body is supporting or not supporting its designated uses such as aquatic life support, fishing and drinking water (Rahman *et al.*, 2005).
The quality of aquatic environment generally depends on four kinds of factors, such as physical, chemical, biological and meteorological factors (Stanitski *et al*., 2003). Water quality is controlled and determined by the combinations of all kinds of factors in various ways and intensities (Rahman, 1992). The water quality of a water body largely depends on the interactions of various physico-chemical factors (Momtaz *et al*., 2010). The Pungli River is a silt carrying, flooding and eroding river of Bangladesh (Haque, 2008). Water of the river is mainly used in agricultural purposes and plays a vital role in the economy of the Tangail region of Bangladesh. It supports the habitat for aquatic organisms as well as fisheries and other aquatic vegetations in the bank of the river. The investigation demonstrated the present condition of water quality of Pungli River and its effect on fisheries. The study was carried out with the following objectives: (i) to monitor seasonal variations of physico-chemical parameters in the Pungli river water, (ii) to assess the water quality parameters for aquatic organisms in the Pungli river, and (iii) to compare the water quality parameters with DoE standard for fisheries.

Materials and Methods

Study area

The study was conducted for a period of one year from October 2011 to September 2012 at the Pungli River in Tangail district. It originated from the Jamuna River which flowing through the Kalihati, Tangail sadar and Bashail upazila and meet Bangshi River at Bashail. The total length of the river is 62 km and wide 110 m with an average depth 10 m in rainy season. This is the major source of freshwater comes in towards the north of

Dhaka Metropolitan City. The Pungli is silt carrying, flooding, and eroding river. The total length of the river from Jamuna Bridge to Kaliakoir is about 65 km (Haque, 2008).

Sample collection

The water samples were collected from 5 sampling sites of the river as well as S1 (Elenga), S2 (Pungli bridge), S3 (Suruj), S4 (Nodkhola) and S5 (Bilpara bazar) during post-monsoon (Oct. 2011 to Jan. 2012), pre-monsoon (Feb. to May 2012) and monsoon (Jun. to Sep. 2012) seasons, respectively (Fig.1). It was mentioned that each sampling sites were divided into three sampling points. To analyze the water quality, a 1000 ml of water was collected by plastic bottles with double stoppers from each sampling points. Samples were collected monthly between 9:30-11:30 am from the surface of the river. Before sampling, the bottles were cleaned and washed with detergent solution and treated with 5% HNO_3 over night. The bottles were finally rinsed with deionized water and dried. After sampling, the bottles were screwed carefully and marked with the respective identification number.

Sample analysis

The water quality parameters such as temperature and pH were determined by the Thermometer and digital pH meter (Model: pH Scan WP 1, 2, Malaysia), respectively. Buffer solution containing pH 7.0 was used to calibrate the digital pH meter. Transparency was determined by Secchi Disc method. Electric conductivity (EC) and total dissolved solids (TDS) were determined by digital EC and TDS meter (Model: HM digital, Germany), respectively. Dissolve oxygen (DO) was determined by digital DO meter (Model: D.46974, Taiwan) where sodium thiosulphate (0.025N) was used as a reagent. Alkalinity was measured by titration method with 0.1N HCl after addition 2-3 drops of methyl-orange indicator. The EDTA method was used to determine the hardness of water where Eriochrome Black T was used as indicator and titration with EDTA solution. The biochemical oxygen demand (BOD) was measured by two steps where initial BOD (BOD_1) was measured immediately after collection and after 5 days BOD (BOD_5) was measured by incubation in the dark condition at 20^0C for 5 days. Then the total BOD (BOD_1 - BOD_5) was measured according to Trivedy and Goel (1984), and Huq and Alam (2005). Total Nitrogen (N), Phosphorus (P) and Sulfur (S) were measured according to Semimicro-Kjeldahl method (a wet oxidation process), Olsen method/ Sodium bicarbonate method and Calcium chloride extraction method, respectively followed by Sattar and Rahman (1987). The Sodium (Na) and Potassium (K) concentration were measured according to Ammonium acetate extraction method. Heavy metals such as Cadmium (Cd) and Copper (Cu) were measured by Atomic Absorption Spectrophotometer (Model: UNICAM 969-SOLAR, England). Before analysis, the water samples were preserved immediately with 0.1N HCl. After collecting, all samples were filtered with Whatman No. 1 filter paper to remove unwanted solid and suspended material before Cadmium and Copper analysis.

Statistical analysis

The collected data were analyzed by using the software MS Excel, where the mean and standard deviation was calculated according to Wanielista *et al*. (1997).

Results and Discussion

The study found the range of transparency was 9.0-18.0 cm during monsoon season (Table 1). In post-monsoon and pre-monsoon seasons the river water was so transparent that the transparency was incalculable and during pre-monsoon the river was completely dry at station 1. The transparency of productive water bodies should be at 40 cm or less (Rahman, 1992). Temperature recorded in the river water reflects that it changed with the time of the year as well as with the season. Water temperature was found lower in the post-monsoon than that of monsoon and pre-monsoon season. In most cases, it was just above 30˚C which was within the standard limit for uses of all purposes. Water temperature was found from 20.3-25.5, 29.4-33.0 and 30.8-34.2˚C during post-monsoon, pre-monsoon and monsoon seasons, respectively. The temperature was found 23.5, 31.8 and 32.4˚C over post-monsoon, pre-monsoon and monsoon seasons, respectively (Table 1). An important relationship exists between the dissolved oxygen in a water body and its temperature. Simply, the warmer the water the lesser the dissolved oxygen and vice-versa (EGIS II, 2002).

The TDS concentrations were ranged 221-271, 197-242 and 70-73 ppm in post-monsoon, pre-monsoon and monsoon season, respectively. The total dissolved solid (TDS) was found 240.0, 223.1 and 71.2 ppm over post-monsoon, pre-monsoon and monsoon seasons, respectively (Table 1). The TDS concentrations both in post-monsoon and pre-monsoon seasons were exceeded the standard limit of 165 ppm. It could be due to cut off the river bank for agricultural practices, cultivation in the river bed and along the bank area as well as use of fertilizers and pesticides, and river bank erosion (Huq and Alam, 2005). The EC values are closely related with temperature (Khan *et al*., 2007). The EC was ranged 415-585, 360-450 and 149-196 µs/cm in post-monsoon, pre-monsoon and monsoon season, respectively (Table 1). Due to seasonal variations, all sites showed lower EC value than the standard of 700 µs/cm (EQS, 1997). A positive relation was found between EC and TDS where the EC value increased with increasing the TDS concentration.

According to STOAS (1997), pH values 4 or less and 12 or high cause death to most of the fish species, 6-8 is the range for good growth and reproduction, and pH as low as 5 or as high as 9-11 do not allow fishes to reproduce and cause slow growth. The pH measured in the river revealed that the water was acidic, i.e. pH was lower than 7.0 in the monsoon season. In the post and pre- monsoon seasons, pH was much lower than 7.0 (Table 2). From the investigation, the pH was found 5.5, 5.2 and 6.7 over post-monsoon, pre-monsoon and monsoon seasons, respectively (Table 2). Results of the study indicated that the water was a tendency to become acidic in post- and pre-monsoon, and again become neutral in nature in monsoon season. For sustainability of aquatic life, the pH value should be between 6.0 and 9.0. An alkaline environment with a range of pH between 7.5 and 8.4 is good for the growth of algae and range between 6.0 and 7.2 is optimum for fish eggs (EGIS II, 2002).

According to Rahman (1992), total alkalinity more than 100 mg/l should be present in a highly productive waterbodies. The concentration of alkalinity was found to vary from 500-570, 450-570 and 140-550 mg/l in post-monsoon, pre-monsoon and monsoon season, respectively (Table 2).

Table.1 The physical parameters of the Pungli River water during post-monsoon, pre-monsoon and monsoon seasons

Parameters	Sampling sites	Seasons						Standard
		Post-monsoon (Oct. - Jan.)		Pre-monsoon (Feb. - May)		Monsoon (Jun. - Sept.)		
		Avg. (N=3)	R	Avg. (N=3)	R	Avg. (N=3)	R	
Transparency (cm)	1	T	T	NI	T	10.25	9.0 - 18.0	40 or less (Rahman, 1992)
	2	T		T		10.75		
	3	T		T		13.5		
	4	T		T		17.0		
	5	T		T		14.0		
	Mean±SD	T		T		13.1±2.73		
Temperature (˚C)	1	21.0	20.3 - 25.5	NI	29.4 - 33.0	34.2	30.8 - 34.2	20-30 (EQS, 1997)
	2	22.7		31.6		33.8		
	3	25.2		30.4		30.9		
	4	25.2		32.4		31.8		
	5	23.3		32.8		31.5		
	Mean±SD	23.5±1.78		31.8±1.06		32.4±1.47		
EC (µs/cm)	1	546.0	415 - 585	NI	360 - 450	164.7	149 - 196	700 (EQS, 1997)
	2	471.3		427.0		151.3		
	3	437.7		400.0		182.3		
	4	425.7		366.7		160.0		
	5	438.7		447.0		162.3		
	Mean±SD	463.9±48.93		410.2±34.79		164.1±11.35		
TDS (ppm)	1	251.0	221 - 271	NI	197 - 242	70.7	70 - 73	165 (Huq and Alam, 2005)
	2	258.0		232.7		70.7		
	3	229.0		217.7		72.0		
	4	227.7		199.3		70.3		
	5	234.7		242.7		72.3		
	Mean±SD	240.0±13.65		223.1±18.90		71.2±0.89		

Note: Avg. = Average, R = Range, SD= Standard Deviation, T= Transparent, NI= Not Investigated.

Table.2 The chemical parameters of the Pungli River water in post-monsoon, pre- monsoon and monsoon seasons.

Parameters	Sampling sites	Seasons						Standard
		Post-monsoon (Oct. - Jan.)		Pre-monsoon (Feb. - May)		Monsoon (Jun. - Sept.)		
		Avg. (N=3)	R	Avg. (N=3)	R	Avg. (N=3)	R	
pH	1	5.5	5.10 - 5.70	NI	4.90 - 5.45	6.56	6.55 - 6.94	6.5-8.5 (Das, 1997)
	2	5.5		5.0		6.61		
	3	5.6		5.1		6.71		
	4	5.7		5.4		6.81		
	5	5.4		5.3		6.93		
	Mean±SD	5.5±0.11		5.2±0.19		6.7±0.15		
Alkalinity (mg/l)	1	540.0	500 - 570	NI	450 - 570	146.7	140 - 550	> 100 (Rahman, 1992)
	2	560.0		520.0		193.3		
	3	513.3		496.7		380.0		
	4	506.7		473.3		388.3		
	5	523.3		563.3		499.3		
	Mean±SD	528.7±21.55		513.3±38.39		321.52±147.04		
Hardness (mg/l)	1	45.3	28 - 72	NI	40 - 60	34.7	20 - 56	123 (Huq and Alam, 2005)
	2	33.3		42.7		38.7		
	3	38.7		41.3		36.0		
	4	36.0		50.7		33.3		
	5	38.7		52.0		35.3		
	Mean±SD	38.4±4.46		46.7±5.45		35.6±1.99		
Total Nitrogen (ppm)	1	9.8	5.6 - 11.2	NI	5.6 - 16.8	19.8	5.6 - 20.0	1.0 (ECR, 1997)
	2	8.4		7.0		5.6		
	3	8.4		15.4		8.4		
	4	8.4		11.2		8.4		
	5	9.9		8.4		6.95		
	Mean±SD	8.98±0.80		10.5±3.70		9.83±5.69		

Note: Avg. = Average, R = Range, SD= Standard Deviation, NI= Not Investigated.

Post-monsoon and pre-monsoon showed more alkaline water than monsoon season. The river banks were widely used for agricultural practices and during pre-monsoon most of the crops are harvested. A total hardness of 50 mg/l is considered as the dividing line between hardwater and softwater and 15 mg/l or more is suitable for fish culture (Swingle, 1967). All of three seasons showed that the Pungli river water was suitable for fish culture because hardness of all sites were within the standard limit (123 mg/l). The range of hardness of the river water was found to vary from 28-72, 40-60 and 20-56 mg/l in post-monsoon, pre-monsoon and monsoon season, respectively (Table 2). According to the guideline set by EQS (1997), the limit of nitrate (N) is 10 mg/l and in the form NO_3 is 50 mg/l for drinking water, whereas the standard limit of Kjeldahl Nitrogen (total) is 1.0 ppm (ECR, 1997). The result of the study showed that the value of Kjeldahl Nitrogen (total) was highly exceeded the standard level and monsoon season showed the highest concentration compared to post and pre-monsoon period (Table 2). It could be due to wide agricultural practices along the river bank. The excessive nitrogen can cause over-production of planktons and as they die and decompose they use the oxygen and therefore the DO content of water goes down and the oxygen

dependent organisms finally die (EGIS, 2002; Momtaz *et al*., 2010).

The sulphur concentrations were ranged from 22.68-67.75, 7.61-33.73 and 4.41-6.46 ppm in the post-monsoon, pre-monsoon and monsoon seasons, respectively (Table 3). The monsoon season showed lowest sulphur content compared to post and pre-monsoon period (Table 3). It could be due to considerable surface runoff from agricultural fields to the river water. Phosphorus content in the river water were ranged from 0.40-1.06, 0.10-0.87 and 0.09-0.14 ppm during post-monsoon, pre-monsoon and monsoon respectively, (Table 3) and all were exceeded the standard level 0 ppm (ECR, 1997). Sodium and potassium concentration was below the permissible limit and higher concentration of sodium and potassium was observed in pre-monsoon and post-monsoon compared to monsoon season (Table 3). The lowest concentration of sodium in monsoon was ranged from 6.23-9.74 ppm where as the highest concentration of sodium was ranged from 49.86-79.08 and 46.75-49.08 ppm found in post and pre-monsoon season, respectively. The concentration of potassium in the Pungli River was ranged from 6.64-11.48, 4.03-6.64 and 2.88-3.29 ppm in post-monsoon, pre-monsoon and monsoon seasons, respectively (Table 3).

Adequate DO is necessary for good water quality, survival of aquatic organism and decomposition of waste by microorganism (Dara, 2002; Islam *et al*., 2010; Rahman *et al*., 2012). The DO content was ranged from 3.3-9.8, 4.1-7.3 and 5.71-8.98 mg/l in post-monsoon, pre-monsoon and monsoon seasons, respectively which was favorable for fish and other aquatic organisms (Figure 1). The mean of DO was found 5.81, 5.83 and 7.46 mg/l over post-monsoon, pre-monsoon and monsoon seasons respectively, in the Pungli River. The range of BOD concentration of Pungli river water was found to vary from -1.6 to 11.5, -2.5 to -8.1 and -2.45 to 1.64 mg/l in post-monsoon, pre-monsoon and monsoon season, respectively. Lower BOD values were found in the river among pre-monsoon and monsoon seasons which was

Figure.1 The concentrations of DO in the Pungli River water among three seasons

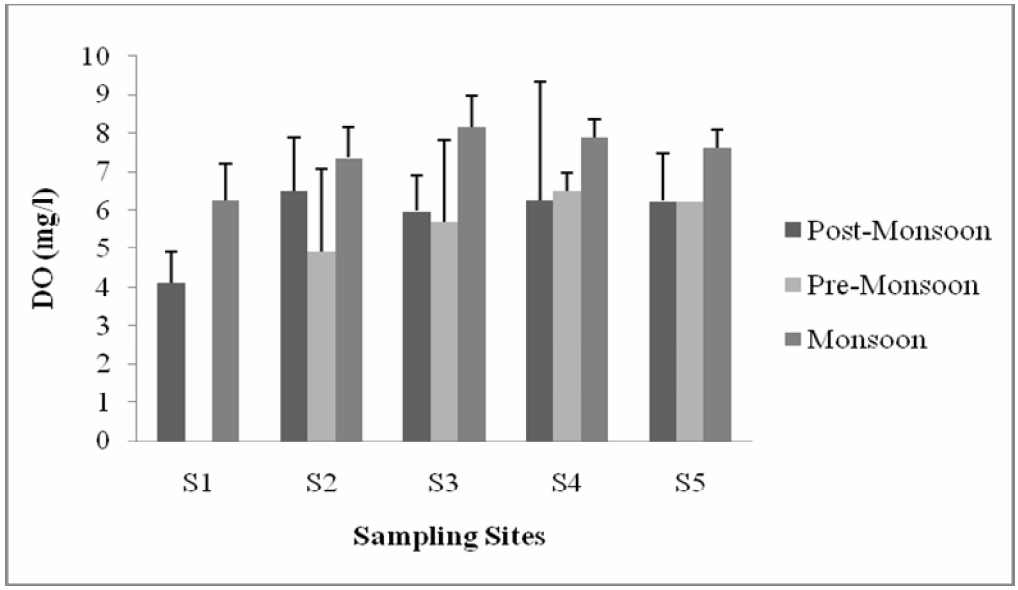
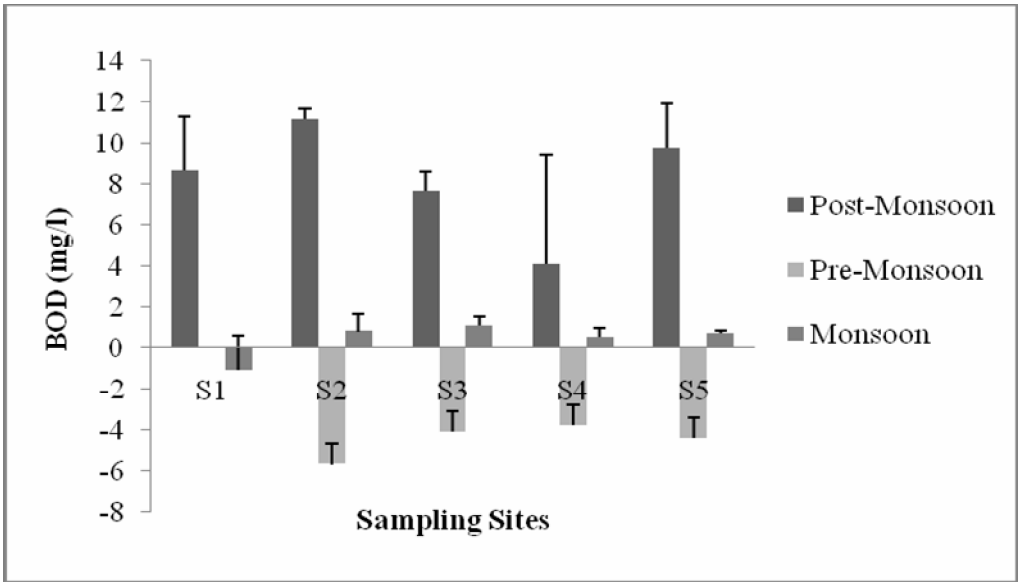


Table.3 The nutrients concentrations of the Pungli River water in post-monsoon, pre-monsoon and monsoon seasons.

Parameters	Sampling sites	Seasons						Standard
		Post-monsoon (Oct. - Jan.)		Pre-monsoon (Feb. - May)		Monsoon (Jun. - Sept.)		
		Avg. (N=3)	R	Avg. (N=3)	R	Avg. (N=3)	R	
Sulphur (ppm)	1	67.713	22.68 - 67.75	NI	7.61 - 33.73	5.866	4.41 - 6.46	-
	2	50.563		29.929		4.921		
	3	48.908		27.957		5.197		
	4	36.338		17.075		4.803		
	5	24.084		25.985		4.724		
	Mean±SD	45.52±16.38		25.24±5.67		5.10±0.46		
Phosphorus (ppm)	1	0.698	0.40 - 1.06	NI	0.10 - 0.87	0.120	0.09 - 0.14	0 (ECR, 1997)
	2	0.415		0.638		0.108		
	3	0.552		0.296		0.101		
	4	0.830		0.238		0.125		
	5	0.902		0.437		0.089		
	Mean±SD	0.679±0.20		0.402±0.18		0.109±0.01		
Sodium (ppm)	1	78.691	49.86 - 79.08	NI	46.75 - 49.08	9.349	6.23 - 9.74	200 (ECR, 1997)
	2	61.161		48.695		9.349		
	3	62.329		47.137		8.375		
	4	58.239		47.915		6.622		
	5	50.642		47.526		6.817		
	Mean±SD	62.21±10.28		47.82±0.67		8.10±1.33		
Potassium (ppm)	1	10.670	6.64 - 11.48	NI	4.03 - 6.64	3.186	2.88 - 3.29	12 (ECR, 1997)
	2	6.845		6.039		2.981		
	3	7.949		5.536		2.878		
	4	8.354		4.932		3.289		
	5	7.147		4.832		3.289		
	Mean±SD	8.193±1.51		5.330±0.56		3.124±0.19		

Note: Avg. = Average, R = Range, SD= Standard Deviation, NI= Not Investigated.

Figure.2 The concentrations of BOD in the Pungli River water among three seasons



suitable for fisheries production (Figure 2). Unpolluted waters typically have BOD values of 2 mg/l or less (chapman, 1992). The BOD content of water samples collected from all sampling sites in the river bank reflects that among three seasons, post-monsoon season exceed the standard value. When BOD level is high, DO level decrease because the oxygen available in the water is being consumed by the bacteria (Sawyer *et al*., 2003). Since less DO is available in the water, fish and other aquatic organisms may not survive. If there is no organic waste present in the water, there would not be as many bacteria present to decompose it and thus the BOD will tend to be lower and the DO level will tend to be higher (Rahman *et al*., 2012). Lower BOD values were found in the river which was suitable for fisheries production (Figure 2).

The variations of heavy metal concentrations as well as cadmium and copper in the Pungli river water were mainly due to different collection spots and seasons. All the concentrations of Cd were higher than the standard level 0.005 mg/l (ECR, 1997). Phosphoric fertilizers are widely regarded as being the most ubiquitous source of Cd contamination of agricultural soils (Alloway, 1995). Paints and dyes are used for cloth manufacturing along the river. These could be the main reason of excessive concentration of Cd in the studied river water which is the responsible factor for fish die. The mean of Cadmium (Cd) was found 0.209, 0.238 and 0.013 mg/l over post-monsoon, pre-monsoon and monsoon seasons respectively (Figure 3). The Standard Deviation (SD) was found 0.028, 0.022 and 0.033 and Standard Error (SE) was 0.007, 0.006 and 0.009 among three seasons, respectively. The range of Copper concentration was 0.02 to 0.03, 0.02 to 0.03 and -0.08 to -0.20 mg/l during post-monsoon, pre-monsoon and monsoon seasons, respectively. In all the sampling sites, the concentration of Cu was lower than the Standard limit of 1.0 mg/l (ECR, 1997) among three seasons (Figure 4). In

this respect, the river of Pungli was not polluted in terms of copper concentrations.

In compliance to the objective of the study, water quality investigated from the Pungli River especially in context of aquatic environment. It was observed that the temperature is increasing gradually in the study period. The dissolved oxygen (DO) content is suitable in all sampling sites among three seasons in the Pungli River. The biochemical oxygen demand (BOD) is suitable except post-monsoon season. From the present investigation, it was observed that the contents of Kjeldahl Nitrogen (total), Phosphorus, and Cadmium in water samples exceeded the standard values. Moreover, pH was decreased, and TDS was increased in both post and pre-monsoon seasons. The excessive presence of Nitrogen and Phosphorus made the river prone to eutrophication, which ultimately resulted into degradation of water quality as well as the aquatic environment. Nutrients from induced fertilizers, human activities and other animal wastes were the main causes of this problem. The investigation of ammonium ion, nitrite, nitrate, phosphate, the content of phytoplankton, zooplankton, microbiological parameters such as total coliforms and fecal coliforms and assessment of present indigenous fish species and fisheries were not possible due to insufficient laboratory facilities.. In this regard, a similar study will be carried out in near future. To recover the soundness of aquatic environment of the Pungli River for aquatic organisms as well as fisheries, it is needed to raise awareness regarding

Figure.3 The concentrations of Cd in the Pungli River water among three seasons

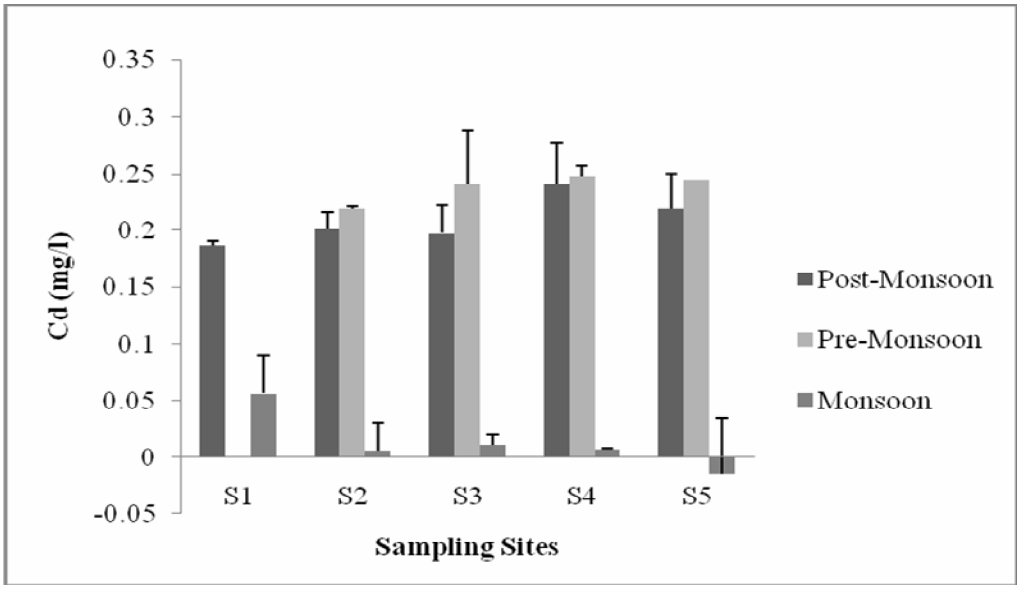
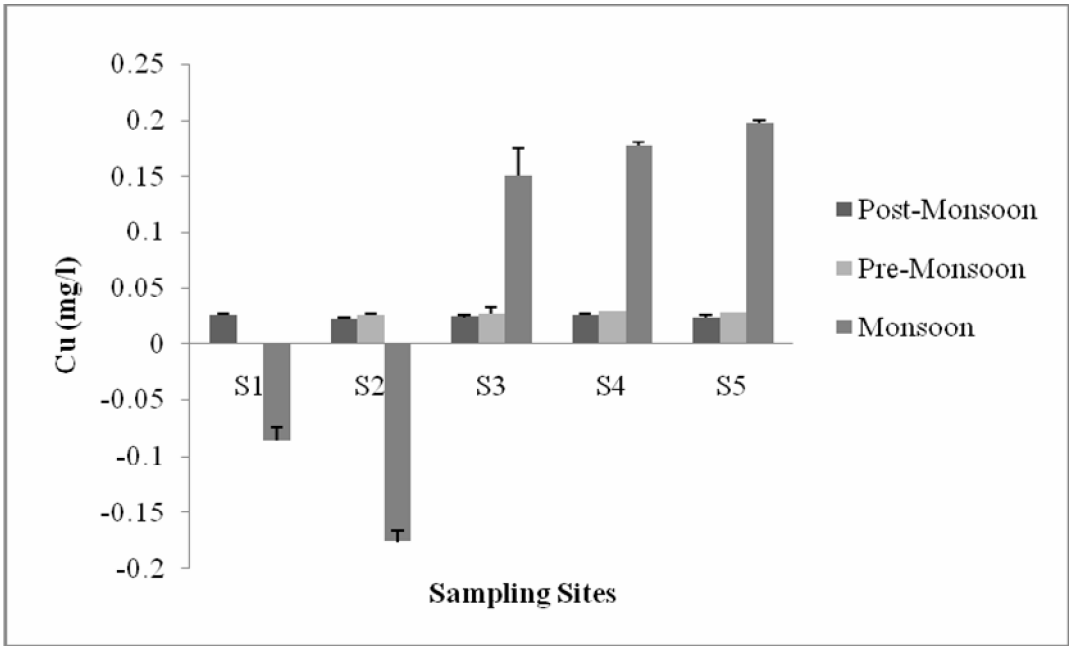


Figure.4 The concentrations of Cu in the Pungli River water among three seasons.



the water quality problems through different forms of education, monitoring and research. Necessary initiative should take against river bank erosion, use of excessive fertilizers and pesticides to improve the overall quality of the river for sustainable management.

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References

Akhteruzzaman, M., A.H.M. Kohinoor, M.S. Islam and Modak, P.C. 1998. Observations on the induced breeding of indigenous small fish Bhagna (*Cirrhinus reba* Ham.) in Bangladesh. Progre. Agri. 9(1-2): 281-284.

Alloway, B.J., 1995. Heavy metals in soil. 2nd edition, Blackie Academic and Professional, Chapman and Hall, UK.

Chapman, D., 1992. Water quality assessment. Published on behalf of UNESCO/WHO/UNEP Chapman and Hall, London-Newyork-Tokyo-Melborn-Madras.

Dara, S.S., 2002. A text book of environmental chemistry and pollution control. S. Chand and Company Limited, New Delhi,pp. 216.

Das, B., 1997. Fisheries resources management in Bangladesh. Bangla Academy, 153-155 pp.

ECR., (Environment Conservation Rules). 1997. Ministry of Environment and Forest, Government of the People's

Republic of Bangladesh.

EGIS II., (Environment and GIS Support Project for Water Sector Planning). 2002. Water quality approach: Draft Final Report. Ministry of Water Resources, Government of the People's Republic of Bangladesh.

Ehiagbonare, J.E., and Ogunrinde, Y.O. 2010. Physico-chemical analysis of fish pond water in Okada and its environs, Nigeria. African. J.Biotechnol. 9(36): 5922-5928.

EQS., (Environmental Quality Standard). 1997. Environmental Quality Standard. Bangladesh Gazette, Ministry of Environment and Forest, Government of the People's Republic of Bangladesh.

Haque, M.I., 2008. Water resources management in Bangladesh. Anushilan, Chuadanga and Dhaka, pp. 24-84.

Hussain, M.G., and Mazid, M.A. 2001. Genetic improvement and conservation of crap species in Bangladesh. Bangladesh Fisheries Research Institute and International Center for Living Aquatic Resources Management, Bangladesh, pp. 74.

Huq, S.M.I. and Alam, M.D. 2005. A handbook of analyses of soil, plant and water. BACER DU, University of Dhaka, Bangladesh, pp.246.

Islam, M.S., Suravi and Meghla, N.T. 2010. Investigation on water quality in the Ashulia beel, Dhaka. Bangladesh J. Fish. Res. 14(1-2): 55-64.

IUCN.,(International Union for Conservation of the Nature). 1998. List of threatened animals of Bangladesh. *In*: Special workshop on Bangladesh Red Book of Threatened Animals, Dhaka, pp. 13.

Khan, M.A.I., A.M.M.M. Hossain, M.E. Huda, M.S. Islam and Elahi, S.F. 2007. Physico-chemical and biological aspects of monsoon waters of Ashulia for economic and aesthetic applications: preliminary studies. Bangladesh. J. Sci.Indus. Res. 42(4): 377-396.

Momtaz, H., A.K.M.R. Alam and Hoque, S. 2010. A comparative study of phytoplankton diversity in relation to water quality of migratory birds visiting and non-visiting wetlands of Savar. Bangladesh J. Environ. Res. 8: 31-38.

Mustafa, M.G., and Brooks, A.C. 2009. A comparative study of two seasonal flood plain aquaculture systems in Bangladesh. Water Policy 11(1): 69–79.

Rahman, M.S., 1992. Water quality management in aquaculture. BRAC Prokashana, Bangladesh, pp. 84.

Rahman, A.K.M., M.A. Sattar, M.A. Baten and Hossain, M.A. 2005. Contamination of River waters. Bangladesh. J. Environ.Sci. 11(2): 319-322.

Rahman, A.K.M.L., M. Islam, M.Z. Hossain and Ahsan, M.A. 2012. Study of the seasonal variations in Turag river water quality parameters. African. J. Pure. Appl.Chem. 6(10): 144-148.

Sattar, M.A. and Rahman, M.M. 1987. Techniques of soil analysis. Pak Press, Mymensingh, Bangladesh, pp.87-124.

STOAS., 1997. Fish farming in tropical fresh water ponds. Foundation for the Development of Agricultural Education and Training, Wageningen, the Netherlands.

Sawyer, C.N., P.L. McCarty and Parkin, G.F. 2003. Chemistry for Environmental Engineering and Science. 5th edition, McGraw-Hill, New York.

Stanitski, C.L., L.P. Eubanks, C.H. Middlecamp and Pienta, N.J. 2003.

Chemistry in Context: Applying Chemistry to Society. 4th edition, Boston: McGraw-Hill.

Swingle, H.S., 1967. Standardization of chemical analyses for waters and pond muds. FAO Fish. Report. 4(44): 397-421.

Trivedy, R.K., and Goel, P.K. 1984. Chemical and biological methods for water pollution studies. Environmental publications, KARAD, pp.42-74.

UNEP (United Nations Environment Programme). 2001. Bangladesh: State of Environment 2001, Dhaka, Bangladesh.

Wanielista, M., R., Kersten and Reaglin, R. 1997. Hydrology: Water Quantity and Quality Control. 2nd edition, John Wiley and Sons.