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ASSESSMENT OF POND WATER QUALITY OF THAKURGAON SADAR UPAZILA FOR FISH PRODUCTION

M.J. Islam[1*], A. Akter[1], M. Kamrujjaman[2], A. Siddiqa[1], S. Aktar[1]

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Abstract

During dry season, physico-chemical properties of waters from 30 ponds of Thakugaon Sadar Upazila, Thakurgaon, Bangladesh were analyzed for its quality and suitability for aquaculture. The variation in the physico-chemical parameters of the aquaculture ponds above or below standard values has potential effects on the health and productivity of aquaculture. Overall, we found that the pond water were acidic to neutral in nature (pH varied from 6.0 to 7.2) and could be suitable for aquaculture. The dissolved oxygen (DO) concentration was suitable for fish production but more DO level should be present for all aquatic life especially for fish production. Chemical oxygen demands (COD) of all pond waters were within the permissible limits for fish production. The temperature values were remained within the standard values in all the aquaculture ponds. Pond water samples contained Ca^{2+}, Mg^{2+} and Na^{+} as the dominant cations and HCO_3^- and Cl^- were the dominant anions. All samples were within 'soft' class regarding hardness. Based on Zn^{2+}, Mn^{2+}, Fe^{3+}, SO_4^{2-}, NO_3^- and Cl^- all pond water samples were within the 'safe' limit for fish production during dry period.

Keywords: Pond, Water Quality, Fish Production

[1]Department of Agricultural Chemistry, Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200, Bangladesh
[2]Department of Mathematic and Physics, Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200, Bangladesh

*Corresponding author's email: jahid@mail2world.com (M.J. Islam)

Introduction

Water quality describes the chemical, physical, and biological aspects of water, generally in terms of suitability for aquaculture. Water quality is one of the most overlooked aspects of pond management until it affects fish production. Several important variables influence water quality for fish including water temperature, dissolved oxygen, phytoplankton, photosynthesis, pH, carbon dioxide, ammonia, alkalinity and hardness. Each water quality factor interacts with and influences other parameters, sometimes in complex ways. What may be toxic and causes mortalities in one situation can be harmless in another. At present time, surface waters of Bangladesh are polluting by various ways (Islam *et al.,* 2009).

Water quality would be determined by the weathering of bedrock minerals, atmospheric processes of evapotranspiration and deposition of dust and salt by wind, by the natural leaching of organic matter and nutrients from soil, by hydrological factors that lead to runoff, and by biological processes within the aquatic environment that can alter the physical and chemical composition of water. The ionic composition of surface water is governed by exchanges with the underlying geology of the drainage basin and with atmospheric deposition. Global average concentrations of the four major cations (Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+}) and the four major anions (HCO_3^-, CO_3^{2-}, SO_4^{2-}, and Cl^-) in surface water tend to approach patterns in which Ca^{2+} concentrations dominate the cations and HCO_3^- and/or CO_3^{2-} concentrations dominate the anions (Wetzel, 2001). The consequences of eutrophication for humans are bad taste and odour events in public water supplies, and production of cyanobacterial toxins that can threaten animal and human health (Ongley, 1996). Elevated levels of heavy metals in aquatic systems have resulted from a number of land use activities including agriculture, urbanization, impoundments, mining, and industrial activities. Heavy metals effects include reduced growth rates, impaired reproduction, and sometimes death. Bioconcentration and bioaccumulation of these elements in the food chain can put terrestrial consumers, including humans, at risk. In humans, prenatal exposure to high mercury levels, particularly in fish-eating populations, has been associated with developmental problems related to the central nervous system (WHO, 2004). However, it is essential to assess the quality of surface water as well as its suitability for fish production. Therefore, the objectives are to assess the water quality of ponds of Thakurgaon sadar upazila for fish production.

Materials and Methods

Water samples were collected from 30 ponds of Thakurgaon Sadar Upazila between May and June 2012. Table 1 indicates the sampling details of the ponds during the study period. Samples were collected in 10 liter plastic bottles that had been cleaned with hydrochloric acid (1:1) and then rinsed with tap water followed by rinsing with distilled water. Before collecting each sample, plastic bottles were rinsed 3 to 4 times with sample. All reagents used in chemical analysis were of analytical grade. Samples were analyzed in Department of Agricultural Chemistry, Hajee Mohammad Danesh Science and Technology University, Dinajpur.

Table 1. Information regarding sampling ponds of the Thakurgaon Sadar Upazila under the District of Thakurgaon, Bangladesh; location, depth, and the duration of uses

Sample No.	Sampling sites	Depth (m)	Duration of uses (year)
1-4	Akcha	2.5±0.58	44.25±9.94 (30-52)
5-8	Akhanagor	2.75±0.75	42.50±6.45 (35-50)
9-12	Begunbari	2.50±0.50	59.25±2.50 (52-70)
13-16	Chilarong	2.50±0.75	50.75±4.57 (45-56)
17-20	Gorea	2.75±0.50	36.25±8.54 (25-45)
21-24	Jogonnatpur	2.50±0.70	30.75±10.04 (20-36)
25-28	Jamalpur	2.50±0.50	25.00±2.16 (24-28)
29-30	Mohammadpur	2.75±0.75	32.50±10.60 (25-40)

For assessing the suitability classes for fish cultivation, we measured pH, EC (electrical conductivity), DO, COD_{Mn}, alkalinity, TDS (total dissolved solids), Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Zn^{2+}, Cu^{2+}, Mn^{2+}, Fe^{3+}, CO_3^{2-}, HCO_3^{-}, SO_4^{2-}, NO_3^{-} TN (total nitrogen), NO_2^{-}, NH_3, PO_4^{3-}, TP (total phosphate) and Cl^{-}. Temperature was measured by thermometer. The pH (HANNA pH 211) and electrical conductivity (EC) were determined electrometrically (APHA, 1998). DO was measured by DO meter (Milwaukee MW 600). For COD_{Mn}, 30-mL samples were treated with 5 mN $KMnO_4$ in 1% NaOH for 1 hour at 100°C in an autoclave. A total dissolved solid (TDS) was measured by drying and weighing method. K^{+} and Na^{+} were estimated by flame emission spectrophotometry. Ca^{2+} and Mg^{2+} were analyzed by complexometric titration. Alkalinity was determined by measuring the amount of acid (hydrochloric acid) needed to bring the sample to a pH of 4.5. Chloride was estimated by argentometric titration (APHA, 1998). SO_4^{2-} was determined turbidimetrically. CO_3^{2-} and HCO_3^{-} were analyzed titrimetrically. Zn^{2+}, Cu^{2+}, Mn^{2+} and Fe^{3+} were analyzed by atomic absorption spectrophotometry (APHA, 1998) in the Soil Resources Development Institute, Dinajpur, Bangladesh.

The dissolved inorganic phosphate (DIP) i.e., PO_4^{3-} was analyzed after GF/F filtration (0.45 μm) by applying the molybdenum blue method at 880 nm, according to the American Public Health Association (APHA, 1998). The total phosphorus (TP) was analyzed from the unfiltered sample as the DIP after persulfate digestion and determined after the Mo-blue method, according to APHA (1998). The total N (TN) was determined by the cadmium-reduction method after persulfate digestion, using a flow-injection auto analyzer (SKALAR). The nitrate level was determined with an autoanalyzer by the Cd-reduction method. The Nessler method (Drum *et al.*, 2002) was used for measurement of ammonia. Ammonia-N was measured by colorimetric nesslerization method after distillation of samples. Nitrite-N was determined by colorimetric method after formation of a reddish purple azo dye produced at pH 2.0 to 2.5 by coupling diazotized sulfanilamide with N-(1-naphthyl)-ethylenediamine dihydrochloride (NED dihydrochloride). Nitrate-N was determined by colorimetric method in the ultraviolet range. Calculation of hardness was performed by the following equation of $H_T = 2.5 \times Ca^{2+} + 4.1 \times Mg^{2+}$ (Freeze and Cherry, 1979) where concentrations of ionic constituents are in mg/L.

Results and Discussion

Physico-chemical characteristics of water samples

Summary results from our survey of pond waters are shown in Tables 2, 3 and 4. The water temperatures ranged from 21.5 to 27.6°C and the pH of the samples ranged from 6.0 to 7.2 (Table 2). DO concentrations varied from 6.4 to 8.9 mg O_2/L. In this investigation, the CODMn values of the water samples ranged from 3.2 to 7.9 mg O_2/L ((Table 2). Higher CODMn values indicate that waters of these ponds were to some extent polluted with non-biodegradable chemical pollutants. The EC and TDS ranged from 50 to 490 µS/cm and 32 to 274 mg/L, respectively.

Table 2. pH, EC, DO, TDS, CODMn, alkalinity and hardness of surface water of Thakurgaon Sadar Upazila during the study period

	Temp (°C)	pH	DO mgO$_2$/L	COD$_{Mn}$ mgO$_2$/L	EC µS/cm	TDS mg/L	Alkal mg/L	Hardn mg/L
Min	21.5	6.0	6.4	3.2	50	32	18	28
Max	27.6	7.2	8.9	7.9	490	274	88	212
Mean	25.3	6.5	7.7	5.6	145	89	32	70
SE(±)	0.3	0.1	0.1	0.3	16	9	3	8

Phosphate (PO_4^{3-}) level of water samples was in between 0.011 and 0.270 mg/L (Table 3). Nitrite-nitrogen values ranged between 0.01 and 0.10 mg/L while nitrate levels in surface water varied from 3.64 to 10.50 mg/L. On the other hand extensive epidemiological data support the current guideline values for NO_3^--N of 10 mg/L (WHO, 2004). Higher concentrations of NO_3^--N and trace amount of ammonia nitrogen were noticed in all ponds. As most of the study areas were in intensive irrigation, the fertilizers used for agriculture may be the source for the elevated concentration of nitrate in a few locations (Chandna *et al.*, 2010). During the present study, major chemical contents such as NO_3^--N, NO_2^--N and phosphorus values were within suitable level from pollution point of view. The TN: TP ratios ranged from 10~98:1. A recent mathematical model has suggested that the origin of Redfield's N: P = 16 (Redfield *et al.*, 1963) could be the consequence of the most advantageous ratio of protein: RNA under optimal growth conditions for microbes and algae (Loladze and Elser, 2011).

Concentrations of Na^+ and K^+ ranged from 0.12 to 1.82 meq/L and 0.06 to 0.87 meq/L, respectively. K^+ concentrations were generally lower than Na^+ concentrations. Ca^{2+} and Mg^{2+} were major cations in pond water and ranged from 0.20 to 3.89 meq/L and 0.85 to 4.25 meq/L, respectively (Table 4). An appreciable amount of HCO_3^- was present in all water samples, though CO_3^{2-} was negligible in most cases. The concentrations of HCO3- were from 0.85 to 6.20 meq/L while Cl^- and SO_4^{2-} concentrations ranged from 0.55 to 2.10 meq/L and 0.03 to 1.67 meq/L, respectively (Table 3). The order of the relative abundance of major cations, expressed in percent of meq/L, was $Mg^{2+} > Ca^{2+} > Na^+ > K^+$ while that of the anions was $HCO_3^- > Cl^- > SO_4^{2-}$. The concentration of earth alkalis elements (Ca and Mg) represents 75% of total cations; this shows a high rock/water interaction in dry season. Fe^{3+}, Cu^{2+}, Zn^{2+} and Mn^{2+} concentrations varied from 0.11 to 0.23 mg/L, 0.004 to 0.047 mg/L, 0.033 to 0.659 mg/L and 1.00 to 1.42 mg/L, respectively (Table 4). Hardness varied from 28 to 212 mg/L (Table 2).

Suitability based on pH, alkalinity and hardness for fish production

In the study area, the pH range recorded from 6.0 to 7.2. The pH of 6.o to 8.5 is acceptable for most pond life (Alabaster and Lloyd, 1980). Fish can become in stress in water with a pH ranging from 4.0 to 6.5 and 9.0 to 11.0. Long term conditions above 9.0, can cause kidney damage to the fishes. When pH rises over 11, the gills, lens and cornea of fish eyes are destroyed (Jhingran, 1988). Lower pH increases the toxicities of hydrogen sulphide (H_2S), copper and other heavy metals to fish.

Alkalinity found to range from 18 to 88 mg/L. Alkalinity is water's ability to resist changes in pH and is a measure of the total concentration of bases in pond water including carbonates, bicarbonates, hydroxides, phosphates and borates. A suitable range of alkalinity is 50 to 300 ppm (APHA, 1998; Boyd and Tucker, 1992). In the study area, hardness ranged from 28 to 212 mg/L. Calcium and magnesium are essential to fish for metabolic reactions such as bone and scale formation. Total alkalinity was high and total hardness was low, pH was risen to extremely high levels during periods of rapid photosynthesis. Desirable level of total hardness and total alkalinity for fish culture generally was fallen within the range of 20-300 ppm. Total alkalinity and total hardness raised by liming (Joseph *et al.*, 1993).

Suitability based on temperature, DO, TDS and heavy metals for fish production

In the study area, the temperature recorded to range from 21.5-27.6°C. However, the ideal range of temperature is between 20°C-25°C and the acceptable range is 2°C-30°C (Alabaster and Lloyd, 1980). In study area it was recorded that water temperature increased in the pond water,, the toxicity of ammonia was increased and the amount of dissolved oxygen decreased. Water temperature influenced the onset of fish spawn, aquatic vegetation growth and the biological demand for oxygen in ponds. In addition, plants and animals used more oxygen due to increased respiration rates. These factors commonly resulted in less available oxygen for fish during the study period.

The value of DO of the study area varied from 6.4 to 8.9 mg/L (Table 2). This range was suitable for fish culture in the study area (Jhingran, 1988). He found that growth and production is optimum at more than 5 mg/L in pond culture. Above 5 mg/L, almost all aquatic organisms can survive indefinitely, provided the allowable limits of other environmental parameters. Higher concentrations of phosphorus, nitrogen and iron can occur in the deeper portions of ponds when anoxic conditions convert bound and solid forms in sediments into soluble forms thus released into the water column.

Total dissolved solids (TDS) ranged from 32 to 274 mg/L (Table 2). The high amount of dissolved solids in water increases the water density; it influences osmoregulation of freshwater organisms and reduces solubility of gases. In the study area, Fe content varied from 0.11 to 0.23 mg/L and was within the limit of the Department of Environment (DOE, 2003). The concentration of Cu and Mn of the study area were also within the limit of DOE (2003). The content of Zn ranged from 0.033 to 0.659 mg/L. The maximum recommended concentrations of Fe, Cu, Zn and Mn are 2.0, 0.5, 5.0 and 5.0 mg/L, respectively (DOE, 2003).

Suitability based on ammonia, nitrite, nitrate, chlorine and phosphorus concentrations

In the study area, the concentrations of ammonia varied from 0.23 to 2.72 mg/L (Table 3). According to Alabaster and Lloyd (1980), ammonia poisoned fish congregates close to the water surface, gasp for air and are restless. In some cases, hemorrhages occur mainly at the base of the pectoral fins. Fishes are able to withstand levels of unionized ammonia of up to 0.6 to 2 mg/L for only short periods (Alabaster and Lloyd, 1980).

In the study area, the concentrations of nitrite ranged from 0.01 to 0.10 mg/L. Nitrite can be deadly, particularly to the smaller fishes, in concentrations as low as 0.25 ppm. Vamos and Szollozy (1974) documented that in nitrite poisoned fish, a brownish colour of blood on the gills is indicative of the increase of methaemoglobin, as nitirite bound to haemoglobin giving rise to methaemoglobin that reduces the oxygen transporting capacity of the blood.

Concentrations of nitrate from zero to 200 ppm are acceptable. The NO_3^- concentration in the water samples of the study area ranged from 3.64 to 10.50 mg/L (Table 3) which were slightly higher than the limit of 5 mg/L (UCCC, 1974) that may be due to continuous uses of nitrogenous fertilizers for agricultural field crops.

Table 3. TN: TP and anionic constituents of pond water of Thakurgaon Sadar Upazila during the study period

	NH_3 Mg/L	NO_2^- mg/L	NO_3^- mg/L	TN mg/L	Cl^- Meq/L	HCO_3^- meq/L	SO_4^{-2} meq/L	TP mg/L	PO_4^{-3} mg/L	TN: TP
Min	0.23	0.01	3.64	5.65	0.55	0.85	0.03	0.081	0.011	10
Max	2.72	0.10	10.50	14.25	2.10	6.20	1.67	0.84	0.27	98
Mean	1.24	0.04	6.66	9.05	1.03	2.71	0.31	0.27	0.05	49
SE(±)	0.10	0.004	0.28	0.38	0.06	0.27	0.07	0.04	0.01	4.76

Even in very small concentrations of chlorine (< 0.5 mg/L), it burns the edges of the gills of fish and kills the beneficial nitrifying bacteria in the pond. The Cl concentration was much lower than the DOE standard. All the chloride (Cl^-) values were within the permissible limits of 200 mg/L (Gupta, 2005). The buccal spasm hinders respiration, so that the fish suffocate and ultimately dies (Bohl, 1989).

The total phosphorus content of the study area ranged from 0.081 to 0.840 mg/L (Table 3), these high levels of phosphate originated from municipal wastewater discharges from nearby locality or from sediments of ponds. The increase in nutrients of water was spurted in algal productivity i.e., eutrophication. Bird droppings, natural run-off, fall of leaves and twigs from surrounding vegetation, continuous discharge of domestic waste, bathing, washing were principal sources of N, P, K in the wastewater of the study area.

Correlations among the parameters

The correlation matrix of 14 parameters, for the 30 samples in the study area is shown in Table 5. There were few significant relationships among the measured concentrations. The high correlations between Cl^- and Ca^{2+}(r=0.86), Cl^- and Mg^{2+} (r=0.80), alkalinity and hardness (r=0.89), and Cl^- and Na^+ (r=0.54) indicating that they most likely derive from the same source of water (Table 5). For most of the ions however, there were no significant correlation between them. The high correlation between EC and TDS (r=0.99) reflects the interdependency of these measurements as general measures of the amount of total dissolved solutes.

Table 4. Cationic composition of pond water samples of Thakurgaon Sadar Upazila

	Ca^{2+} Meq/L	Mg^{2+} meq/L	Na^+ meq/L	K^+ meq/L	Cu^{2+} mg/L	Zn^{2+} mg/L	Mn^{2+} mg/L	Fe^{3+} mg/L
Min	0.20	0.85	0.12	0.06	0.004	0.033	1.00	0.11
Max	3.89	4.25	1.82	0.87	0.047	0.659	1.42	0.23
Mean	1.21	1.98	0.70	0.38	0.028	0.136	1.25	0.15
SE(±)	0.15	0.16	0.08	0.05	0.002	0.04	0.02	0.01

Table 5. Correlation matrix of the physico-chemical characteristics of pond water

	Temp	EC	TDS	Cl	HCO_3	SO_4	NO_3	Ca	Mg	Na	K	TP	Alka	H_T
Temp	1.00													
EC	-0.04	1.00												
TDS	-0.03	0.99	1.00											
Cl	-0.04	0.42	0.39	1.00										
HCO_3	0.19	0.33	0.34	-0.05	1.00									
SO_4	0.20	0.09	0.09	0.09	0.15	1.00								
NO_3	-0.01	0.14	0.16	0.04	-0.04	-0.26	1.00							
Ca	0.09	0.30	0.28	0.86	0.18	0.28	0.09	1.00						
Mg	-0.24	0.52	0.50	0.80	0.17	0.06	-0.12	0.58	1.00					
Na	0.34	0.40	0.37	0.54	0.29	0.47	0.07	0.57	0.27	1.00				
K	0.31	0.15	0.12	0.45	0.15	0.20	0.03	0.53	0.07	0.44	1.00			
TP	0.02	0.17	0.14	0.15	-0.13	-0.02	0.17	0.18	-0.06	0.13	0.33	1.00		
Alka	-0.05	-0.06	0.01	0.25	0.16	0.17	0.34	0.42	0.03	0.31	0.26	0.10	1.00	
H_T	0.02	-0.02	-0.04	0.37	0.28	0.22	0.34	0.54	0.19	0.45	0.26	0.07	0.89	1.00

Values are significant at p =0.05 where r ≥ 0.36

Conclusions

Nitrate shows an elevated concentration in most of the ponds. Fertilizer application in agricultural fields and decay of organic matter are the probable origin of these nitrate concentration. These anions and cations concentrations might be helpful for algal production. Based on different water quality parameters, we concluded that all the pond water samples of the Thakurgaon Sadar Upazila, Bangladesh were suitable for fish production. These results illustrate the necessity of improving our knowledge of pond water quality in the study area. Especially for fish production, continued monitoring of physical, chemical and biological indicators of water quality is needed.

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