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Physicochemical and microbiological evaluation of surface water quality of aquaculture ponds Located in Savar, Dhaka, Bangladesh

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Abstract

Aquaculture is one of the most vital sectors in Bangladesh as it exhibits a major role in nutrition, livelihoods and foreign exchange incomes/earnings every year. However, due to chemical impurities, infectious diseases caused by microorganisms, heavy metal accumulation, and aquaculture in Bangladesh is gradually declining and posing serious health risks. In Savar, which is one of the major industrial zones in Bangladesh, all industrial sewage and wastes severely deteriorate the water quality of the ponds, rivers, lakes and various waterways that are involved in aquaculture/fish culture. Hence, to determine the water quality by assessing different physicochemical and microbiological parameters, water samples were collected from five selected ponds located in Atomic Energy Research Establishment premises, Savar, Dhaka and analyzed according to the standard procedures. The obtained values of temperature, pH, Salinity, TDS, TA, EC, TH, Chloride content, Free CO2, DO, Nitrate and Sulfate were compared with the recommended values of Bangladesh and WHO standard for suitable water quality. Most of the physicochemical parameters exceeded the Standard value. Total Viable Count, Total Coliform and Fecal Coliform Count were also found to be higher than the standard value of WHO indicating fecal contamination of the pond water. Some fish pathogens were also isolated from the ponds. Water quality index (WQI) was calculated for five sampling sites to determine the level of pollution. It was observed that the water quality of the all the ponds reached to critical point of pollution. It is therefore, a high time to take initiatives to save the ponds that are involved in aquaculture from further pollution. The results revealed that the pond waters of five different sites were excessively polluted and unsuitable for fish culture.

Keywords: Aquaculture; Water pollution; Physicochemical parameters; Bacteriological assessment; Water quality index

1. Introduction

Bangladesh is one of the resourceful countries with its extensive range of aquatic bio-diversities and world's leading inland fisheries producers and has a huge water resource all over the country in the form of small ponds, ditches, lakes, canals, small and large rivers, and estuaries covering about 4.34 million hectares (1). Aquaculture and fisheries in Bangladesh is one of the most important potential sectors of the national economy, accounting to 3.69% of national GDP, 23.12% of agricultural GDP and 2.09% of foreign export earnings (2). In Bangladesh no other sector depicted progress prospective more visibly than fisheries. Fish is the second most valuable agricultural crop in Bangladesh and its production contributes to the livelihoods and employment of millions of people(ref). The total fish production in Bangladesh in the fiscal year 2013-14 was estimated as 3.55 million tons, of which 1.96 million tons (55.15%) were obtained from inland aquaculture, 0.99 million tons (28.07%) from capture fisheries and 0.60 million tons (16.78%) from marine fisheries (2) . Bangladesh ranked 5th position in leading aquaculture producing countries in the world just after China, India, Vietnam and Indonesia (3) . Bangladesh produced 30,61,687 ml fish in 2011 of which 15,23,759 mt

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i.e. 49.76% was produced by the aquaculture sector. Bangladesh contributed 2.43% in world total aquaculture production in 2011 (3). Pond culture represents the mainstay of aquaculture in Bangladesh, accounting for 85.8% of the total recorded production and 57.7% of the area under culture (4). As fish is an important component of human foods and animal feeds, fish cultivation is therefore a necessity in order to meet the protein demand of the ever increasing populace in our country. About 10% of the population is dependent directly and indirectly on the fisheries for their living (5). Hence the need for rapid development and proper management of fishery is becoming a necessity in view of the high demand for fish as a relatively cheap source of animal protein Ali (6)(7). Fish supplements to about 60% of our daily animal protein intake.

Water is the most important resource for aquaculture and can be a significant source for contamination. The conditions that fishes are cultured may be potentially stressful, causing existing infections to become more severe and precipitate disease outbreaks which may also compromise the fitness of such fish for human consumption. The mortality of fish due to disease and water pollution constitutes problems to aquaculture development (8). Therefore, for a successful aquaculture venture, maintenance of water quality is very important. Because, the availability of good quality water is an indispensable feature for fish survival, their diversity. Moreover, successful aquaculture and fisheries projects are dependent on several physical, chemical, biological, and microbiological conditions that exist in watercourses and in subsurface aquifers. The relationship between the fish, their biotic and abiotic environments is not an isolated phenomenon; changes of one may reflect and affect the other. Fishes are also dependent on water and atmosphere temperature, pH, dissolved oxygen, alkalinity, salinity, BOD (biological oxygen and demand) and some salts for growth and development. The distribution and size of fish populations are largely determined by the interaction of the fish with the immediate environment which directly impact on pond water quality and indirectly on the whole ecosystem. More so, the placing of fish in fish ponds may expose them to new pathogens. Great loss of fish has been attributed largely to bacterial infections (9).

Additionally, various industrial, municipal, agricultural wastes contaminate the water beyond human consumption and are often responsible for surface water contamination that disrupt the ecosystems and create hazards for aquaculture. The Savar, an urban area of Dhaka, is one of the major industrial zones in Bangladesh, as the country's second largest Dhaka Export Processing Zone (DEPZ) is located there. Furthermore, there are numerous industrial sites along the Dhaka-Aricha Highway. All these industrial activities severely deteriorate water quality of the rivers, lakes, waterways, and wetlands that are either inside or adjacent to Savar industrial areas, thus posing dreadful risks to human health and the environment of the area. For this reason, an investigation was conducted to evaluate the physicochemical and microbial parameters of fishing pond water, collected from various sites of Atomic Energy Research Establishment Area (AERE), Savar. The investigation was aimed to determine the physicochemical properties, the load of microbial pathogens, to identify some fish pathogens and also to determine the water quality index of the fishing ponds of Savar.

2. Material and methods

2.1. Sampling site and water sample collection

Water sample was collected from five selected ponds in Atomic Energy Research Establishment (AERE) premises, Savar, Dhaka. Sampling was performed after ensuring the cleanliness of hands and equipment. Before collecting samples, sample containers were cleaned by detergent solution and then it was treated with 5% HNO3 acid overnight and finally washed with de-ionized water and dried in oven. Followed by repeated washing with sample water to avoid contamination, all the samples were taken with grab sampling. Sample was collected without contact with air and then sealed with Teflon lined caps or aluminum foil to avoid any type of exchange with environment. After sampling, the containers were kept in air tight and labeled properly for identification as DG, NIB (1). NIB (2), TC (1) & TC (2) according to the location site of the ponds in the AERE area. Then the collected water sample was immediately brought into the laboratory for physicochemical and bacteriological analysis. An appropriate amount of water sample was preserved following the standard procedure of American Public Health Association (10). For certain types of analysis, it was necessary to aid in preserving the sample. In this case, nitric acid or sulfuric acid were used by adjusting the pH of the sample. Then, the sample were properly mixed and preserved for further analysis.

2.2. Evaluation of physicochemical properties

Physicochemical parameters such as the pond water color were assessed by visual observation and smell or odor was observed by the nose through sniffing. Temperature and pH of the water samples were recorded using portable laboratory thermometer (Mercury 305 MM thermometer, Zeal, England) and pH meter (HI 2002-02, Hanna instruments, Romania) respectively. Temperature was measured in degree Celsius, and the pH meter was calibrated with standard buffer solution.

Electrical conductivity (EC), Total Dissolved Solid (TDS) and salinity of the samples were measured by HI-2003 Edge® Conductivity meter – Hanna Instruments (HI 2003-02, Romania). Conductivity was measured in µs/ cm by dipping the electrode into a Falcon tube filled with pond water sample. The specific conductivity of the water correlates with the concentration of dissolved minerals which are the total dissolved solids of the sample. TDS was estimated by HANNA instruments by dipping the electrode into the Falcon tube filled with pond water sample. A digital multi range instrument (Model HANNA HI 2003-02, Romania) was used to measured salinity in parts per thousand (ppt) or in % of the water sample by dipping the conductance cell into a beaker filled with water sample from pond water. Dissolved oxygen (DO) of pond water was measured by a dissolved oxygen meter immediately after sample collection. The pond water to be tested was taken in a beaker and the cell was dunked into it and the value shown on the screen of the meter was recorded. Both Nitrate and Sulfate ion were determined by Spectrophotometric methods. Nitrate was determined by Ultraviolet Spectrophotometric Screening Methods and Sulfate was determined by Turbidimetric Methods. Measurement is based on comparison of absorbance of sample with a calibration curve of standard solution. Total Hardness (TH), Total Alkalinity (TA), chloride content and free CO_2 were determined by the titrimetric method. The concentrations of sulfate ion and nitrate ion were determined by using UV-Visible spectrophotometer (T60UV-Visible Spectrophotometer, PG instruments) following the standard procedure of American Public Health Association (10).

2.3. Water Quality Index (WQI)

Water quality index (WQI) is a dimensionless number that combines multiple water quality parameters into a single number by normalizing values to subjective rating curves (11). Conventionally it has been used for evaluating the quality of water for water resources such as rivers, streams and lakes. WQI is a single value indicator to the water pollution, which integrates the data pool generated after collecting due weights to the different parameters. Conventionally it has been used for evaluating the quality of water for water resources such as rivers, streams and lakes. WQI is a single value indicator to the water pollution, which integrates the data pool generated after collecting due weights to the different parameters. Several researchers have worked on this concept and presented examples with case scenarios in the literature (12)(13).

So, WQI was calculated to determine the overall quality of the pond water from five sampling sites in Atomic Energy Research Establishment, Savar. Several parameters like pH, TDS, EC, Total Alkalinity, Total Hardness, Chloride, DO, Nitrate and Sulfate were considered to find out the WQI of the water (14).

2.4. Microbiological Analysis of water samples

The presence of the Total Viable Count was determined by standard plate count (SPC) using nutrient agar media employing pour plate technique (15).To determine the total coliform count and fecal coliform count, the most probable number method (MPN) was employed following the standard procedures (ref). The total count was multiplied by the respective dilution factor to get the result. The calculated result was expressed as colony forming unit (cfu/ml) per ml of water.

2.5. Identification of pathogens from water samples

The isolation and identification procedures of microorganisms were carried out on the basis of standard microbiological methods. For isolation of the pathogenic bacterial isolates, serial dilution plating method by was employed using Nutrient agar (NA) as growth media. Colonies with distinct morphologies were then separated and purified by repeated streaking on NA media. Finally, purified bacterial isolates were transferred on agar slants and preserved for identification. Aliquots from MPN analysis tubes showing characteristics or features of presence of coliform and fecal coliform were transferred to streak plates containing Mac Conkey Agar (MCA), Brilliant Green Agar (BGA) and Bismuth Sulfate Agar (BSA) medium. The colonies exhibiting growth characteristics of Coliform and fecal coliform on the mentioned media were isolated and purified. Bacterial isolates including coliform and fecal coliform bacteria were analyzed by the standard cultural, morphological, and physiological and biochemical characteristics. The isolates were then identified up to species based on the critical comparison of the observed characteristics with the description of bacterial strains given in Bergey's Manual of Determinative Bacteriology, 8thed (16).

3. Results

3.1. Physicochemical properties

A number of physicochemical parameters were investigated to assess the water qualities of five ponds, located in Atomic Energy Research Establishment, Savar, and Dhaka. The Sample coding, numbering and labeling is indicated in table 1.

The Color and the odor indicate the initial status of water. So, at first, the colors of the water were observed visually from the five sampling sites (Fig.1). The abundance of phytoplankton and zooplankton is responsible for the determination of colour of an aquatic body and Green, bluish green/ brown greenish color of water that indicate good plankton population hence, good for fish health (17). The obtained result for colors is shown in table 2. The water of all the sampling sites were odorless.

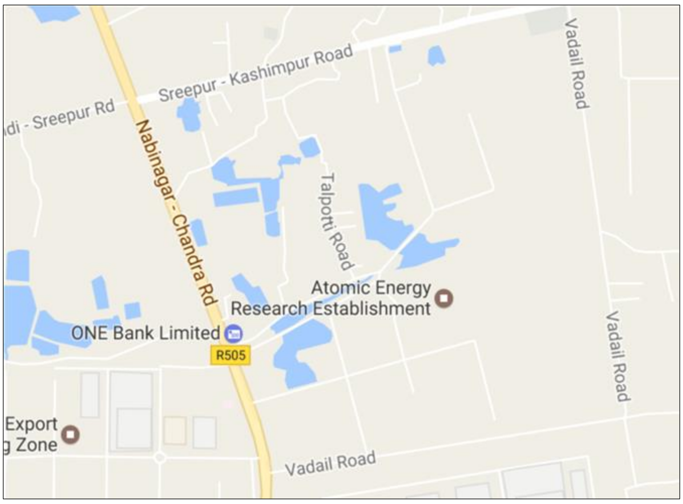

Figure 1 Different Sampling Sites of AERE

Table 1 Sample coding, numbering and labeling

Sample No.	Sample ID	Date	Time	Location
1	DG	15/11/16	12.40 pm	D.G. office
2	NIB (1)	15/11/16	12.51 pm	NIB (near left side)
3	NIB (2)	15/11/16	1.00 pm	NIB (near right side)
4	TC (1)	15/11/16	1.10 pm	Training Centre (near left side)
5	TC (2)	15/11/16	1.15 pm	Training Centre (near right side)

Table 2 Water color of five different sampling sites of Savar

Water samples	Color
DG	Light greenish
TC (1)	Light greenish
TC (2)	Turbid
NIB (1)	Greenish
NIB (2)	Greenish

Different other major physicochemical parameters were also determined to assess the quality of pond water of the five sampling sites and assembled in Table 3.

Table 3 Physicochemical parameters of the pond water body

Sr. No	Parameters	Sample 1 (DG)	Sample 2 (TC-1)	Sample 3 (TC-2)	Sample 4 (NIB-1)	Sample 5 (NIB-2)	Standard
1	pH	7.46	7.67	7.15	7.37	7.32	6.5-8.5
2	Electrical conductivity	249	159	161.7	250	110	300
3	TDS	124.8	79.5	80.9	125.3	55.4	500
4	Total Alkalinity	55	38.5	35.75	49.5	27.5	120
5	Total Hardness	102	68	56	100	42	300
6	Chloride	21.3	23.075	17.75	19.52	19.525	250
7	Nitrate	1.5180	1.659	2.7260	1.5070	1.030	45
8	Sulphate	3.9140	4.2	8.1950	0.7760	8.3280	150
9	Dissolved oxygen	1.6	1.9	2.1	1.5	1.1	5.00

The pH of natural waters is greatly influenced by the concentration of carbon dioxide which is an acidic gas (18) and increases the amount of acidity that affects fish culture. That is why, pH value was determined. The pH values obtained in the study ranged from 7.15 to 7.67 (Table 3). The change of temperature affects the metabolism and physiology and ultimately affects the fish culture and production. The results obtained from the study showed temperature values ranging from 26-27.6°C (Table 3). Fish are sensitive to the salt concentration of their waters that affects the density and growth of aquatic organism's population(19). In this research work, the salinity values ranged from 0.2-0.5% and the TDS values ranged from 55.4-124.8 mg/L. Conductivity of water depends on its ionic concentration (Ca^{2+}, Mg^{2+}, HCO_3^-, CO_3^-, NO_3^- and PO_4^-), temperature and on variations of dissolved solids. High values of conductivity are an indication of pollution. The conductivity values of pond water in the study ranged from 110-250μs/cm. Total hardness of water is the parameter used to describe the effect of dissolved minerals (mainly Ca and Mg) which is attributed to the presence of bicarbonates, sulphates, chlorides and nitrates (Singh 2010, Ezekiel 2011). So, this parameter has a great importance on fish culture. Total hardness ranged from 42-102 mg/L in this investigation. The alkalinity of the samples was determined and it ranged from 27.5-55 mg/L in pond water. The free CO_2 values obtained in the study ranged from 1.27-1.68 mg/L. The DO values obtained from this study ranged between 1.1-2.1 mg/L and nitrate values ranged from 4.3-5.7 mg/L. The obtaining results in the study ranged from 17.75-23.075 mg/L. Sulphate is known as one of the least toxic anions. Sulphate may occur in water as a result of industrial discharge. Water samples investigated had sulphate values ranging from 2.25 mg/L to 4.50mg/L.

3.2. Variation of WQI in pond water

The present study used a simple modified WQI (14) considering local environments and hydrology of the Pond water in AERE area to determine the pollution load and its suitability for various purposes. In this study, for the calculation of water quality index, nine important parameters were chosen. The WQI has been calculated by using the standards of drinking water quality recommended by the World Health Organization (WHO), Bureau of Indian Standards (BIS) and Indian Council for Medical Research (ICMR). The weighted arithmetic index method (Brown et al, 1999) has been used for the calculation of WQI of the Waterbody. Further, quality rating or sub index (q_n) was calculated using the following expression;

$$q_n = 100[V_n - V_{io}] / [S_n - V_{io}]$$

(Let there be *n* water quality parameters and quality rating or sub index (q_n) corresponding to n^{th} parameter is a number reflecting the relative value of this parameter in the polluted water with respect to its standard permissible value)

Where,

q_n = quality rating for the nth water quality parameter

V_n= Established value of the n^{th} parameter at a given sampling station

S_n= standard permissible value of the nth parameter

V_{io}= Ideal value of the nth parameter in pure water. (*i.e.*, 0 for all other parameters except the parameter pH and Dissolved oxygen (7.0 and 14.6 mg/l respectively)

Unit weight was calculated by a value inversely proportional to the recommended standard value S_n of the corresponding parameter

W_n= K/S_n

The overall WQI was calculated by aggregating the quality rating with the unit weight linearly

WQI =$\sum Wnqn/ \sum Wn$

The correlation of water quality index level and water quality status is mentioned in Table 3.

Table 4 Water quality index (WQI) and status of water quality according to Chatterji and Raziuddin (20)

Water quality index level	Water quality status
0-25	Excellent water quality
26-50	Good water quality
51-75	Poor water quality
76-100	Very poor water quality
>100	Unsuitable for drinking

In the current investigation, the WQI was calculated for five different samples and mentioned in the Table 5.

Table 5 Variation of WQI values of five water samples

Sample No.	WQI Value
Sample 1(DG)	84.93
Sample 2 TC(1)	74.08
Sample 3 TC(2)	57.5
Sample 4 NIB(1)	84.07
Sample 5 NIB(2)	67.92

3.3. Microbiological properties of the pond water

Water bodies usually consist of a wide variety of microorganisms, some of which are pathogenic and some of which are not. Some of the non-pathogenic microorganisms may lead to problems in water supplies such as unpleasant taste and odour which may serve as indicator of safety. The principal concern for microbiological quality of water, however, is the potential of contamination by pathogens. Such pathogenic contaminants include bacteria, helminths, protozoa and viruses and most of these organisms are derived from faeces (21). Indicator organisms, usually bacteria, are practically used to analyze the microbiological quality of drinking water. Among such indicators the most commonly ones are thermotolerant (fecal) coliforms or *E. coli*. In addition to the above mentioned indicators of bacteriological water quality, the broader groups of coliforms known as total coliforms are also used in monitoring the water quality program (22) (WHO 1995). In addition, the fecal pollution or contamination can generate a significant threat to the entire aquatic ecosystem of the ponds along all other water bodies and the consumers.

Microbiological quality of water is therefore a critical parameter to measure health risks, as contaminated water is a key source of various infectious diseases. So, microbial count of water can often be considered as one of the important criteria to assess the water quality. Hence, the pond waters were tested to detect the presence of coliform and fecal coliform including other pathogenic bacteria in the pond water. Microbial analysis of pond waters in our study is shown in table 6.

Table 6 Bacteriological analysis of different pond water samples

Samples	Total viable count (TVC)	Total Coliform Count (TCC)	Total Fecal coliformCount (TFC)
Sample 1 (DG)	2.5×10^7 CFU/ml	1.2×10^3 CFU/ml	1.0×10^3 CFU/ml
Sample 2 TC(1)	1.8×10^5 CFU/ml	2.4×10^3 CFU/ml	2.9×10^4 CFU/ml
Sample 3 TC(2)	3.1×10^5 CFU/ml	1.6×10^2 CFU/ml	1.3×10^4 CFU/ml
Sample 4 NIB(1)	1.3×10^6 CFU/ml	1.1×10^3 CFU/ml	1.7×10^4 CFU/ml
Sample 5 NIB(2)	1.7×10^4 CFU/ml	2.4×10^3 CFU/ml	1.1×10^4 CFU/ml

3.4. Identification of pathogens

The microorganisms isolated from the ponds were *E.coli, Salmonella typhi, Staphylococcus aureus, Klebsiella pneumoniae* and which may pose a threat to the health of the fishes and consumers.

4. Discussion

The main goal of the present study was to analyze different physico-chemical and microbiological parameters of water from 5 selected ponds of Savar with a view to determining the suitability of pond water for fish culture.

According to Meade (1989) physico-chemical parameters such as alkalinity, dissolved oxygen, total hardness pH and temperature are the most common water quality characteristics that will influence fish health and growth. The changes of temperature might cause variation in water density, salinity and dissolved oxygen. For sustaining aquatic life, the temperature is within 20 to 30°C. In our study, the temperature was ranged between26-27.6 °C. So, the investigated temperature was within the permissible limit for aquaculture. According to Meade (1989), the recommended pH for aquaculture ranges from 6.5 to 8.0. The result of our investigation was within this similar pH ranges. The result was also agreed by other workers (23). So, it was estimated that the ponds have suitable pH ranges for fish culture. A maximum value of 400 ppm of total dissolved solids is permissible for diverse fish population. In this analysis, the TDS values of water samples ranged from 55.4-125.3 ppm which were below the permissible limit of aquaculture. According to APHA (10). Conductivity outside the range between 150 and 500 µs/cm of inland fresh waters indicate that, the water is not suitable for certain species of fish or macro-invertebrates. So, in our study, the conductivity of water was within preferable range. DoF (1996) reported that the range of dissolve oxygen suitable for fish culture is 5 mg/l to 8 mg/l. So, DO values (1.6, 1.9, 2.1, 1.5 and 1.1 mg/L) lower than the acceptable value indicated that the water was not fit for fish culture. According to Ekubo and Abowei (24), the ideal level of CO_2 in fishponds is less than 10 mg/L. So, the ponds (free CO_2ranged from 1.27-1.68 mg/L) were agreeable for fish culture. The alkalinity values in the pond water were found 55, 38.5, 35.6, 49.5 and 27.5 mg/L respectively that were the permissible limit of aquaculture according to Bhatnagar and Devi, 2013.The concentration of hardness ranged from 42-102 mg/L considered as soft to moderately hard according to Kannan (1991). The nitrate value in our study ranged between 4.3-5.7 ppm. Scanthosh and Singh, 2007, gave the favorable range of 0.1mg/L to 4.00 mg/L. So, the nitrate value in the pond water exceeded the permissible limit of aquaculture. As a result, the pond water may result in eutrophication. The chloride values range 21.3-23.1 mg/L is similar to the findings of Anny *et al.* (2017) (23). So, the ponds are suitable for fish culture. The Water Quality Index obtained for the water body were found 84.93,74.08, 57.5, 84.07 and 67.92 respectively in which sample 1 and 4 indicate very poor quality of water and sample 2,3 and 5 indicate poor quality of water. The range of salinity is between 0.2-0.5 percent in the pond water.

Microbial analyses of the water collected from the different fish ponds revealed a high microbial load and varied within the ponds. The coliform and fecal coliform growth was also observed. In the study, the highest load of total viable bacteria (2.5×10^7 CFU/ml) was found in sample 1. This high bacterial load of water indicates that a huge number of bacteria was present in water and deteriorated the water quality in a great extent. The total coliform count observed throughout the study period were always much higher than the standard values of EQSB (Environmental Quality Standard for Bangladesh), Department of Environment, Government of the People's Republic of Bangladesh (1991). The values were due to water temperature which was optimum for bacterial growth and also due to the organic matter load found within pond water resulting from the diet used in feeding the fish. The persistence of pathogens in the water environment also is considered as one of the crucial factors for infection transmission in terms of acute outbreaks of disease. Thus, the pond water has become an ideal culture medium for the proliferation of bacterial pathogens causing bacterial infection in fish and an important cause of food poisoning (25). The microorganisms isolated from the ponds were *E.coli, Salmonella typhi, Staphylococcus aureus, Klebsiella pneumoniae* which may show a threat to the health of the fishes, aquatic systems and the consumers.

5. Conclusion

From the investigation, the physicochemical, bacteriological parameters and water quality index of the ponds in AERE area could be scrutinized and it can be concluded that the Dissolved oxygen was below the permissible limit of aquaculture and nitrate exceeded the permissible limit that result in eutrophication in the pond water. However, other physicochemical parameters were in the range of standards. On the other hand, it is evident from the present study that the water bodies were highly contaminated by bacteria. Presence of coliforms indicates fecal contamination. So, the ponds were not fit for fish culture.

Compliance with ethical standards

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Disclosure of conflict of interest

There is no conflict of interest.

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