The Pharma Innovation Journal 2019; 8(5): 724-728

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.03
TPI 2019; 8(5): 724-728

www.thepharmajournal.com
Received: 21-03-2019
Accepted: 25-04-2019

Jayati Adhikary
Aquatic Environment Management Department, West Bengal University of Animal and Fishery Sciences, Kolkata, West Bengal, India

Atanu Maity
Department of Fisheries Economics and Statistics, West Bengal University of Animal and Fishery Sciences, Kolkata, West Bengal, India

Bipul Kumar Das
Aquatic Environment Management Department, West Bengal University of Animal and Fishery Sciences, Kolkata, West Bengal, India

Satarupa Ghosh
Aquatic Environment Management Department, West Bengal University of Animal and Fishery Sciences, Kolkata, West Bengal, India

Prasanna Pal
Animal Physiology Division, ICAR-National Dairy Research Institute, Karnal, Haryana, India

Correspondence
Jayati Adhikary
Aquatic Environment Management Department, West Bengal University of Animal and Fishery Sciences, Kolkata, West Bengal, India

Physicochemical characteristics of a sewage-fed pond of Kolkata, West Bengal

Jayati Adhikary, Atanu Maity, Bipul Kumar Das, Satarupa Ghosh and Prasanna Pal

Abstract
Sewage-fed aquaculture is a popular practice in West Bengal as well as India. But the physicochemical parameters of the pond should be assessed before using it in fish cultivation. So, we conducted a study in a sewage-fed pond of Kolkata, West Bengal to evaluate ten physicochemical characteristics namely temperature, pH, total dissolved solids (TDS), conductivity, total hardness, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), phosphate phosphorus and nitrate nitrogen. The analysis showed that the physicochemical parameters of the pond water were moderate for cultural operation except for TDS (446.69mg/l) and the NO_3-N (0.80mg/l) and PO_4-P (0.21mg/l contents of the pond water were high. But final certification can only be provided after assessing the level of pollutants especially heavy metals.

Keywords: Aquaculture, fish, physicochemical characteristics, sewage-fed pond, sewage treatment

1. Introduction

A huge amount of sewage is generated every day due to domestic, agricultural, industrial or any other commercial activities. These are generally treated for further utilization or discharged into rivers or ocean. One of the best ways of sewage management is to use it for fish cultivation. It contains a lot of nutrients and organic elements that can be a good feed for the fishes. So, sewage fed aquaculture has gained huge popularity in many countries including India. But, before using a sewage-fed water body, it should be examined properly whether it is suitable or not for the culture of fish. The sewage can contain a high level of toxic elements including heavy metals and the physicochemical properties may not satisfy the criteria fish production. This triggered to undertake a study on assessing the physicochemical characteristics of a sewage-fed pond of Kolkata, West Bengal. According to reports Kolkata produces 705.86 Million Liters per Day (MLD) of sewage and can treat only 24% or 172 MLD of sewage [1]. So, every day about 76% of sewage generated from the city is discharged without any treatment. A major amount of sewage is also used in aquaculture. For our experiment, we selected a pond which receives a good amount of sewage from different sources. The objective of the study was to evaluate the physicochemical characteristics (temperature, pH, total dissolved solids etc) of that pond to justify its use in pisciculture.

2. Materials and Methods

2.1 Location of the study area

The study was conducted in a sewage-fed aquaculture pond belonging to ‘The Bonhooghly Fishermen’s Cooperative Society Ltd., located at 22.64^{0}N and 88.38^{0}E in a densely populated area of Kolkata. The lakes of the 'Bonhooghly' and 'Noapara’ receive a huge quantity of sewage coming from the Baranagar Municipality area. This sewage is being used for scientific pisciculture. As there is no sewage treatment plant, only biological treatment with water hyacinth and regular liming enables good fisheries activity.

2.2 Collection of samples

The study was carried out only for a period of six months from January 2014 to June 2014. Water samples were separately taken from every sampling site in labeled and pretreated polyethylene bottles by random sampling technique taking all the necessary precautions not to entrap any air bubbles and without disturbing the bottom sediment. The samples were taken fortnightly at 1st day and 15th day of a month containing 12 sampling days.

The sampling days were denoted as D_1 to D_{12} starting from 1st January 2014 to 30th June 2014 respectively.

2.3 Temperature
The surface water temperature was recorded by using mercury in glass thermometer (0 to 50^{0}C). It was immersed at surface level for five minutes. Then the temperature of the water was recorded from the thermometer and expressed as ^{0} C [2].

2.4 pH
The pH of water samples was measured at the spot following the electrometric method. The pH of the water was measured in the laboratory by using a digital pH meter (Systronics: Model No. MK-VI) [2].

2.5 Total dissolved solids
Total dissolved solids (TDS) of water samples were estimated following the gravimetric method [3]. For the estimation, properly dried and clean beakers were weighted. Then, 50 ml of water samples filtered for TDS was taken in separate beakers and placed in a hot air oven at 103 to 105^0 C for drying. After 24 hours of drying, the weight of each beaker with solid residue was taken. The weight difference of the beaker was used to calculate the total dissolved solids of the sample and expressed as mg/l.

$$\text{Total dissolved solids (mg/l)} = \frac{(\text{A-B}) \times 1000}{\text{Sample volume (ml)}}$$

Where,
A= weight of the dried residue (mg) + dish (mg)
B= weight of the dish (mg)

2.6 Conductivity
The conductivity of the water sample directly measured by a conductivity meter (Systronics, Model-306) and expressed as mS/cm.

2.7 Total hardness
The hardness of water samples was estimated by a titrimetric method using 0.01N of EDTA (Ethylene diamine tetra acetic acid) solution as a titrant and Eriochrome Black-T as an indicator after ammonification of water sample by ammonium buffer and expressed in mg/l as $CaCO_3$ [3].

2.8 Dissolved oxygen [3].
Dissolved oxygen was estimated by Winkler's Iodometric method. DO in the water sample was fixed by adding manganese sulfate ($MnSO_4$) and alkaline potassium iodide (KI) solution. The obtained precipitation was dissolved by concentrated sulfuric acid (H_2SO_4). The solution was then titrated against 0.025 (N) sodium thiosulphate ($Na_2S_2O_3$) solutions using the starch solution as an indicator till blue colour turn into the colourless sample and expressed in mg/l.

$$\text{Dissolve oxygen (mg/l)} = \frac{(\text{N}\times\text{S})}{\text{V}} \times 1000$$

Where,
N = Strength of $Na_2S_2O_3$
S = Volume of $Na_2S_2O_3$ consumed (ml)
V = Volume of sample (ml)

2.9 Biochemical oxygen demand (BOD)
Biochemical Oxygen Demand (BOD) is the amount of oxygen required by the microorganisms to decompose the organic matter in the water and it is also a measure of biologically decomposable organic matter under aerobic condition. It was estimated following the Iodometric method [3]. For the estimation of BOD, water samples were filled in airtight 150 ml BOD bottles. Then, the samples were incubated for five days in a BOD incubator at 20±2 ^{0}C.In some cases where BOD values expected to be more, samples were dilute to 85% to 90% using distilled water before incubation. DO of the samples were measured initially and after 5 days of the incubation period, following the Iodometric method. In the case of dilution, DO of the dilution water during the initial and after the incubation periods were also estimated following the same procedure. The BOD of the sample was calculated by the following formula:

a) BOD (mg/l) = D_1-D_2 (in case of undiluted sample)
b) BOD (mg/l) = {(D_1-D_2)-(C_1-C_2)} × dilution factor (in case of dilution)

Where,
D_1 = Initial DO of the sample
D_2=DO of the sample after 5 days of incubation
C_1= Initial DO of the dilution water
C_2=DO of the dilution water after 5 days of incubation
Dilution factor=Total volume of the sample after dilution (ml)/Original volume of the sample

2.10 Chemical oxygen demand (COD) [3]
The Chemical Oxygen Demand (COD) is a measure of the total amount of oxygen, which is required to completely oxidize all of the organic matter in the sample water. For the estimation of COD following the oxidation-reduction titrimetric method [4], 10 ml of water sample was taken in a conical flask. Then 5 ml of 0.25 N$K_2Cr_2O_7$ (Potassium Dichromate) solution was added to it followed by 15 ml of concentrated H_2SO_4 (Sulphuric Acid). After shaking well, the conical flask with the sample was covered by a watch glass and digested in a hot water bath (103^{0}C-105^{0}C) for 30 minutes. The sample was taken out from the water bath after digestion and was diluted by adding 15 ml of distilled water. The diluted sample was then titrated against 0.2N Fe_2 (NH_4) SO_4 (Ferrous Ammonium Sulphate) using phenanthroline indicator until the solution becomes a light green colour. A blank was also prepared using 10 ml distilled water instead of the sample and running simultaneously as identical manner. The volume of ferrous ammonium sulfate consumed by the sample and by the blank during titration was recorded and COD was calculated by the following formula:

Chemical Oxygen Demand (mg/l) = {(B-S) ×S×N×800}/V

Where,
B=Volume of Fe_2 (NH_4) SO_4 solution consumed by the blank (ml)
S= Volume of Fe_2 (NH_4) SO_4 solution consumed by the sample (ml)
N=Strength of Fe_2 (NH_4) SO_4 solution
V= Volume of water sample (ml)

2.11 Phosphate phosphorus
The phosphorus of the pond was estimated Spectrophotometric

ally by stannous chloride method [3]. The 10 ml of water sample was taken in a 25 ml test tube. Then two drops of phenolphthalein indicator were added to it to check the sample. If the sample turned pink then the strong acid solution (H_2SO_4+HNO_3) was added to discharge the colour. Then 0.4 ml ammonium molybdate and 1 or 2 drops of stannous chloride were added and then mixed thoroughly. Then the blue colour was developed in the sample. After 10 min, but before 12 min, the absorbance was taken in a spectrophotometer at 690 nm wavelength. A standard curve was prepared by using the value of various known concentrations of the standard phosphate solution (KH_2PO_4). The phosphate-phosphorus concentration of the water sample was calculated from the standard curve and was expressed as mg/l.

2.12 Nitrate nitrogen
Nitrate Nitrogen of pond was estimated by brucine method. First 10 ml sample was taken in a conical flask. Then 10 ml sulfuric acid solution (4:1) was added to the sample and mix well by shaking while cooling in flowing water. After cooling the sample, 0.5 ml brucine in sulfanilic acid solution was mixed by shaking. Then the sample was heated 25 minutes at 100^0 C in the water bath. After that, the sample was placed in a cool water bath maintained 10^0-20^0 C. Yellow colour was developed in the sample. Then the absorbance of the sample was taken in a spectrophotometer (Systronics: Model No. MK-166) at 410 nm wavelength. The NO_3-N was calculated from the standard curve prepared by plotting the absorbance with their respective known concentration of NO_3-N obtained through the same procedure and expressed as mg/l. A standard curve was prepared by using the value of various known concentrations of the standard nitrate solution potassium dihydrogen phosphate (KH_2PO_4). The nitrate-nitrogen concentration of the water sample was calculated from the standard curve and was expressed as mg/l.

2.13 Statistical analysis
The data generated from the study were tested for significance of variance by single-factor ANOVA (Analysis of Variance) with replication as per the structure of the data. The graphical presentation of the data was also made. All the statistical analysis and graphical presentation were done with the help of Microsoft Excel 2007.

3. Results
3.1 Temperature
The temperature of pond water showed significant variation ($P<0.05$) in between the different months of study. The average monthly water temperature gradually increased from the month of January 2014 (27^0C) to May 2014 (32^0C). The fluctuation of temperature was very less (31.92^0C to 30^0C) between March and June of the year 2014. The highest average temperature (32.93^0C) recorded during the last week of April and the lowest average temperature (26.5^0C) recorded during the last week of January. The temperature of the water was inversely correlated ($P<0.05$) with the NO_3-N content. This indicates that the temperature is influencing the NO_3-N content in the water.

3.2 pH and conductivity
Significant variation ($P<0.05$) of pH was observed in between the months of the study. The pH 6.90 was the lowest value in the month of June and pH 7.73 was the highest value in the month of March. The conductivity of water of sewage-fed pond varied from1.31 to 1.43 mS/cm with a maximum value at 1.43 mS/cm in February and May and the minimum value at 1.31 mS/cm in March.

3.3 DO, BOD, COD, TDS and hardness
The DO, BOD and COD varied significantly ($P<0.05$) in between the months of study, but the level of those parameters was under the permissible limit of freshwater fish culture (Fig 1). The fluctuation of DO varied in between 3.73 mg/l (April) and 5.61 mg/l (March and June). The BOD content varied from 10.8 mg/l in January to 16.9 mg/l in March. The maximum BOD recorded during the months of March. The lowest BOD obtained at D_1 (January) followed by D_4 (February). The maximum COD observed at D_6 (38.6 mg/l) and immediately it was reduced fall at D_7 (29.0 mg/l). The water was turbid and rich in total dissolved solids (TDS) (Fig 2). The TDS varied from 436 mg/l (May) to 455 mg/l (April) and it significantly varied ($P<0.05$) in between the months of the study. The maximum hardness of the water observed during the months of March (301.67 mg/l). The lowest hardness of water recoded during the month of January (221.67 mg/l) (Fig 2).

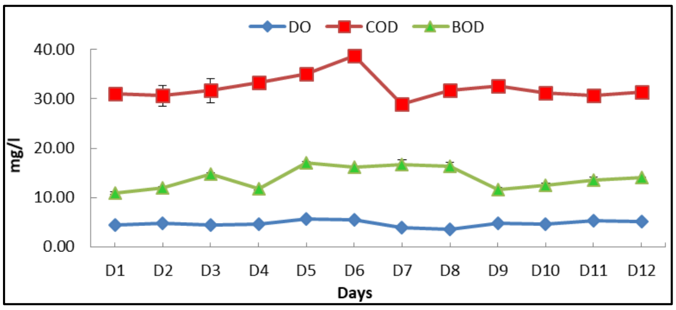

Fig 1: Variations of DO, BOD and COD in the water of a sewage-fed aquaculture pond (mean ± SD, n=3)

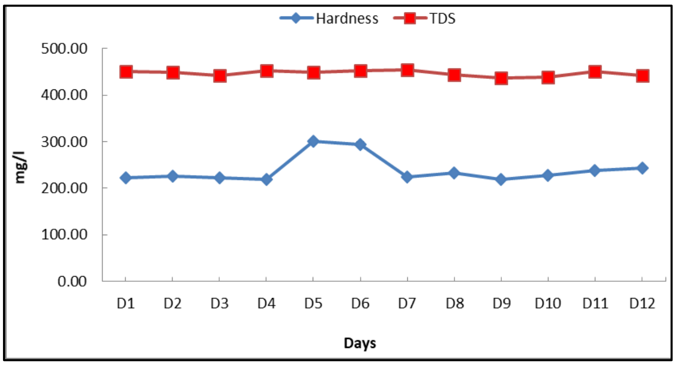

Fig 2: Variations of Hardness and TDS in the water of a sewage-fed aquaculture pond (mean ± SD, n=3)

3.4 Phosphate phosphorus and nitrate nitrogen
A significant variation ($P<0.05$) of PO_4-P and NO_3-N observed in between the months of the study (Fig 3). The 0.16 mg/l was the lowest PO_4-P content in the month of June and 0.24 mg/l was the highest PO_4-P content in the month of March. The NO_3-N content of water of sewage-fed pond varied from 0.66 to 0.90mg/l with maximum value in March and the minimum value in June.

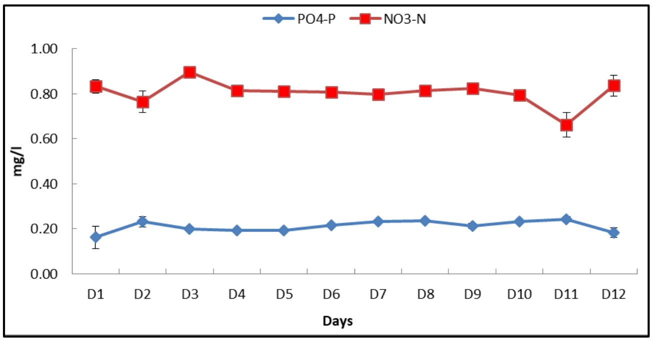

Fig 3: Variations of PO_4-P and NO_3-N in the water of a sewage-fed aquaculture pond (mean ± SD, n=3)

4. Discussion

Most of the physicochemical parameters of water were optimum for fish culture. But, the average dissolved oxygen content was somewhat low (4.77±0.629 mg/l). Sometimes it was 3.73±0.161mg/l in April which was alarming for the survival of fish. The pH, Conductivity and temperature of the water were acceptable for fish culture. BOD and COD of the water were also within the permissible limit but high TDS (436-450mg/l) may be created some problem particularly for the penetration of light into the water column. Thereby it may be hampered the productivity of the water and interfered in the microbial degradation of the organic matter. The important nutrients like phosphate-phosphorus and Nitrate-nitrogen were also within the permissible limit and indicated its productivity.

Temperature is the most important factor in the water, which has enormous significance as it regulates various physicochemical as well as biological activities [5]. The average monthly water temperature gradually increased from the month of January 2014 (27^0C) to May 2014 (32^0C). The fluctuation of temperature was very less (31.92^0C to 30^0C) between March and June of the year 2014. The highest average temperature (32.93^0C) recorded during the last week of April and the lowest average temperature (26.5^0C) recorded during the last week of January. An increasing trend of temperature from the month of February to June was may be due to the cloudy and humid weather and due to the onset of summer. Saha and coworkers (1990) also observed the variation of temperature in between 23.0^0C to 30.2^0C and 24.3^0c to 31.5^0C respectively in Kulia beel [6]. Rana and core searchers (1990) also reported the water temperature at the surface of the water bodies varied between 24.7^0C to 32.2^0C in Kulia beel [7]. The changes in the water temperature were directly related to the sunshine and followed closely the changes in the atmospheric temperature. The higher temperature was observed because of the clear atmosphere, greater solar radiation and due to low water level [8]. The present study is in agreement with this observation.

The pH is one of the most important factors that serve as an index to assess the quality of an aquatic ecosystem for pollution. In the present study pH 6.90 was the lowest value in the month of June and pH 7.73 was the highest value in the month of March. There is very less fluctuation of pH throughout the study period, which may be due to the buffering capacity of the system. Generally, the normal range of pH of inland waters varies between 6.0 to 9.0.

Dissolved oxygen (DO) is an important critical factor in natural waters both as a regulator of metabolic processes of plant and animal community and as an indicator of water quality. In the present study, the DO contents varied between 3.73mg/l (April) and 5.61mg/l (March and June). The maximum DO of the water body was utilized towards the decomposition process of organic matters of the sewage-fed pond. The concentration of DO is directly proportional to the atmospheric pressure and inversely proportional to the temperature. A minimum DO value of 1.8mg/l and maximum 4.40mg/l in the sewage-fed fish pond was reported by Chattopadhyay *et al*. (1988) which is comparable to the present findings [9].

BOD and COD are the parameters to assume a very high significance because they give an idea of the quantity of biodegradable organic matters present in an aquatic system, which are subjected to aerobic and anaerobic decomposition by microorganisms. These are the reliable parameters for judging the extent of pollution in water [10]. In the present investigation, the BOD contents varied from 10.8 mg/l in January to 16.9 mg/l in March. The maximum BOD recorded during the months of March. The lowest BOD obtained at January followed by February. The maximum COD observed at D_6 (38.6mg/l) and immediately it was reduced at D_7 (29.0mg/l). This study also revealed a high value of COD with respect to BOD, which is in agreement with Oguanrombi and Onuoha (1982) who reported that the COD values higher than BOD values when organic matter contains a large amount of biological resistant substances [11]. Abbasi and Vinithan (1999) observed BOD ranging from 0.3 to 7.2 mg/land COD ranging from 0.8 -76 mg/l in water bodies of Pondicherry [12]. According to some researchers, the most significant source of BOD and COD are the industrial effluent [13]. Both the parameters showed higher value might be due to high organic matter and high algal blooms respectively [13]. Higher BOD value was observed in the pre-monsoon season due to the higher microbial activity due to high temperature.

Total dissolved solids (TDS) in water were mainly composed of inorganic and organic matters present in the aquatic system. In water total dissolved solids and suspended solids mainly composed of carbonates, bicarbonates, chlorides, phosphates and nitrates of calcium, magnesium, sodium, potassium and organic matters, silts and other particles. The concentration of which will indicate the type of pollution. During the present study, the TDS varied from 436 mg/l (May) to 455 mg/l (April) and it significantly varied ($P<0.05$) in between the months of the study which might be due to the excessive discharge of wastes, clay, silts from the adjoining area through sewage water. Mishra and Saksena (1991) encountered high values of TDS due to organic matter, silts, debris etc [10]. According to Rao *et al*. (1982), the increase in TDS level was due to the industrial and domestic discharge [13]. The high value of TDS will reflect a greater amount of ions in water [14]. The TDS value was observed in high concentration during the monsoon period, which might be due to the addition of solids from runoff water.

Nutrients are the major abiotic factors, which influence the components of the ecosystem. The role and importance of nitrogen and phosphorus in aquatic productivity have been recognized and widely studied. Nitrogen, a major constituent of protein, occupies a predominant place in the aquatic ecosystem. However, a relatively minor constituent of phosphorus is often considered as the most critical single element in the maintenance of aquatic productivity. Nitrate-nitrogen is one of the most important nutrients in an aquatic ecosystem. In the present study, a significant variation of PO_4-P and NO_3-N ($P<0.05$) observed in between the months of the study. The 0.16mg/l was the lowest PO_4-P content in the month of June and 0.24mg/l was the highest PO_4-P content in the month of March. The NO_3-N content of water of sewage-fed pond varied from 0.66 to 0.90mg/l with maximum value in March and the minimum value in June. According to a study in Kerala, the chief sources of nitrate are domestic sewage, agricultural run-off, metabolic waste of aquatic community and dead organisms and the low values of nitrate might be due to the insufficiency in the system to biologically oxidized ammonia to increase the nitrate levels [15]. Saha and coworkers (1990) reported that the nitrate-nitrogen content of Kulia beel varied from 0.08 to 1.8mg/l during 1981and 1982 [6]. Mishra and Saksena (1991) pointed out the major source of phosphate in water as domestic sewage, agricultural effluent with fertilizers, industrial wastewater etc [10].

5. Conclusion

The critical analysis of these physicochemical parameters of water indicates that the pond is ideal for fish culture apparently. The NO_3-N (0.80mg/l) and PO_4-P (0.21mg/l contents of the pond water were found high. But the metal contents in the fish tissues, water and sediment samples should also be assessed before using it for pisciculture. The quality production of fish from sewage-fed aquaculture pond is only possible when the source of sewage water is free from any toxicant. The source of sewage water may be treated properly before using for sewage-fed aquaculture.

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