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Evaluation of water quality index in sewage fed aquaculture system in a Ramsar site (Nalban East Kolkata Wetland), West Bengal, India

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Abstract
The present study is aimed to investigate the water quality index, using seven important water parameters like pH, dissolved oxygen, electrical conductivity, total alkalinity, total hardness, total dissolved solids and nitrate nitrogen in Sewage fed aquaculture system, Nalban East Kolkata Wetland, West Bengal, India a Ramsar site. The study was carried out for nine months from July 2016 to March 2017. Three sites S1, S2, S3 were selected randomly and monthly water samples were collected. The physico-chemical parameters like pH, dissolved oxygen, electrical conductivity, total alkalinity, total hardness, total dissolved solids and nitrate nitrogen were analysed following the standard procedures (APHA, 2012). Water quality index was calculated by applying weighted arithmetic water quality index. All the physico-chemical parameters except total hardness were within the desirable range for fish culture. The water quality index recorded in S1, S2 and S3 as 141.787 and 197.519, 150.583 and 201.376 and 146.371 and 276.688 respectively, which is unsuitable for human use. The highest value of water quality index was recorded during March, 2017 and lowest during September, 2016. The result indicates the deterioration of water quality which needs continuous monitoring to design the suitable measures for multiple use of this water body.

Keywords: Water quality index (WQI), fish culture, physico-chemical parameters, sewage fed aquaculture system, wetland, weighted arithmetic method

Introduction

Water is a dynamic renewable natural resource. Its availability with good quality and adequate quantity is very important for human life and other purposes. Disposal of partially treated and mostly untreated effluents into rivers and lakes and runoff from urban and agricultural areas are the two main reasons responsible for deterioration of drinking water. Population growth due to rapid industrialization has resulted in the increase of wastewater discharge into the environment. Out of the waste water generated a major portion is supported by the sewage water. Sewage is a complex mixture of natural inorganic and organic materials with a small proportion of man-made substances. Normal domestic and municipal waste water is composed of 99.9% water and 0.1% suspended, colloidal and dissolved solids. Wastewater is characterised with rich total solids, suspended solids, biological oxygen demand, chemical oxygen demand, nitrate, chloride, sodium and potassium contents. Other sewage characteristics include high level of pH value, turbidity, total hardness, colour and coliform count (Alade and Ojoawo, 2009) [1].

In India, West Bengal is well known for sewage fed aquaculture system especially the eastern part of Kolkata which consists of a series of ponds, located in a large wetland area. Since 1929, these wetlands supporting sewage fed fisheries, have recycled wastewater for the production and cultivation of fish, and used for the development of green belt (Jana, 1998) [2]. The presence of different elements originating from domestic and industrial sources has been reported in different compartments of the aquatic environment of these wetlands[3] (Raychaudhury *et al*., 2008) [3]. Waste water, although sufficient as a source of nutrients, can generate problems such as toxicity to fish, accumulation of heavy metals and toxic substances in the muscles of fish, and the potential danger of transmission of pathogens from waste water to handlers and consumers. A Water Quality Index (WQI) is defined as a rating reflecting the composite influence of different water quality parameters on the overall quality of water

(Deininger and Maciunas, 1971; Harkins, 1974; Tiwari and Manzoor, 1988) [4, 5, 6]. In general, water quality indices are divided into five main groups (Sobhani, 2003) [7]:

(A) Public indices: in this category, the indices ignore the kind of water consumption in the evaluation process, such as NSFWQI, Horton [8, 9] (Ott, 1978; Horton, 1965).

(B) Specific consumption indices: in this category, classification of water is conducted on the basis of the kind of consumption and application (drinking, industrial, ecosystem preservation, etc). The most important and applicable of these indices are the Oconer, Oregan and British Columbia indices (DEQ, 2003) [10].

(C) Statistical indices: in these indices statistical methods are used and personal opinions are not considered.

(D) Designing indices: this category is an instrument aiding decision and planning in water quality management projects.

Materials and methods

The present study was carried out in sewage fed aquaculture system (Nalban East Kolkata wetland) of east Kolkata wetland which is located at eastern fringes of Kolkata, West Bengal, India. This East Kolkata Wetland was the largest sewage fed aquaculture system in the world. This area was significant for the use of sewage water, mainly in pisiculture, irrigation, for wastewater aquaculture and harbouring the biological diversity. This wetland lies between latitude 22˚25'– 22˚40' N and longitude 88˚20'–88˚35' E covering an area of 267.45 ha with total 18 ponds. The area under fish culture is 112.16 ha. From that total area a vast perennial lentic water body having around 120 ha was selected for the study. In this system about 600 million litre of sewage and waste water were discharged daily. This wetland acts as a natural sink to solid and soluble wastes which were generated by twelve million inhabitants of the city of Kolkata.


West Bengal Map
Temples
Wild Life
Hills Stations
Beaches
District Head Qtrs
Darjeeling
Jalpaiguri
Cooch Behar
North Dinajpur
Birbhum
Malda
Murshidabad
Birbhum
Bardhaman
Nadia
Purulia
Bankura
Hooghly
Howrah
South 24 Parganas
South Dinajpur
West Midnapore
East Midnapore


SECTOR V
Nicco Park
GP BLOCK
Ring Rd
S1
S2
S3
DHAPA
12

The research work was carried out for nine months (from July 2016 to March 2017). Three sites were selected randomly from the total area. Site 1 (S1) was selected opposite to the inlet of sewage water, whereas Site 2 (S2) was selected in the middle stretch of the water body and Site 3 (S3) was selected near to the inlet of sewage water.

Water samples were collected from three sampling sites separately of the selected water body in labelled and pre-treated polyethylene bottles by random sampling technique taking all the necessary precaution without entrapping any air bubbles and without disturbing the bottom sediment. The parameters like dissolved oxygen, and pH were analysed onsite itself and water samples were brought to the laboratory for further analysis. The physico-chemical parameters such as pH, dissolved oxygen, total alkalinity, total hardness, electrical conductivity, total dissolved solids in triplicate by adapting standard procedures as descripted in APHA (2012) [11], whereas nitrate nitrogen was determined as per USEPA (1971) [12].

In this study for the calculation of water quality index, six important parameters were chosen namely pH, Electrical Conductivity (EC), Total Dissolved Solid (TDS), Total Hardness (TH), Nitrate (NO_3) and Dissolved Oxygen (DO).

The Water Quality Index model developed in the present study consists of 5 steps:

1. Selection of parameters for measurement of water quality.
2. Development of a rating scale to obtain the rating.
3. Estimating the unit weight of each indicator parameter by considering the weightage of each parameter.
4. Determining the sub index value.
5. Aggregating the subindices to obtain the overall WQI.

The calculation of the WQI was done using weighted arithmetic water quality index which was originally proposed by Horton (1965) and developed by Brown *et al.* [13] (1972). The weighted arithmetic water quality index (WQI) is in the following form:

$$WQI = \sum W_i Q_i n_i = 1/ \sum W_i$$

Where, n is the number of variables or parameters, W_i is the relative weight of the i^{th} parameter and Q_i is the water quality rating of the i^{th} parameter. The unit weight (W_i) of the various water quality parameters are inversely proportional to the recommended standards for the corresponding parameters. According to Brown *et al.* (1972) [13], the value of Q_i is calculated using the following equation:

$$Q_i = 100 \{(V_i – V_{id}) / (S_i – V_{id})\}$$

Where, V_i is the observed value of the i^{th} parameter, S_i is the standard permissible value of the i^{th} parameter and V_{id} is the ideal value of the i^{th} parameter in pure water. All the ideal values (V_{id}) are taken as zero for drinking water except pH and dissolved oxygen (Tripathy and Sahu, 2005) [14]. For pH, the ideal value is 7.0 (for natural/pure water) and a permissible value is 8.5 (for polluted water). Therefore, the quality rating for pH is calculated from the following equation:

$$Q_{pH} = 100 \{(V_{pH} – 7.0) / (8.5 – 7.0)\}$$

Where, V_{pH} = observed value of pH.

For dissolved oxygen, the ideal value is 14.6 mg/l and the standard permissible value for drinking water is 5 mg/l. Therefore, its quality rating is calculated from the following equation:

$$Q_{DO} = 100 \{(V_{DO} – 14.6) / 5.0 – 14.6)\}$$

Where, V_{DO} = observed value of dissolved oxygen.

Table 1: Classification of water quality (Q_{DO} as per Brown *et al.*, 1972; Chaterjee and Raziuddin, 2002) [13, 15]

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

Results

pH is the concentrations of hydrogen ions (H+) present in water and is a measure of acidity or alkalinity. It is most important in determining the corrosive nature of water. Lower the pH value higher is the corrosive nature of water. During the study the highest pH of all the sites was recorded as alkaline during October and the lowest as acidic was recorded during the month of February. The minimum and maximum pH at S1, S2 and S3 were recorded as 6.2 ± 0.08 and 8.1 ± 0.08, 6.2 ± 0.08 and 8.47 ± 0.05 and 6.43 ± 0.05 and 8.37 ± 0.45 respectively.

One of the most important critical factor in natural water bodies is the amount of dissolved oxygen. It is regulated by abiotic and biotic factors and susceptible to frequent changes. Dissolved oxygen is a regulator of metabolic processes of both plant and animal communities and acts as an indicator of water quality. Fish cannot survive when DO content is less than 3 mg/l (Kannel *et al.*, 2007) [16]. Banerjea (1967) suggested for a dissolved oxygen level of more than 5 mg/l for average fish production. During the study period the minimum and maximum dissolved oxygen (DO) were recorded at S1, S2 and S3 as 3.97 ± 0.12 mg/l (February) and 7.67 ± 0.25 mg/l (December), 4.23 ± 0.05 mg/l (February) and 8.07 ± 0.09 mg/l (July) and 4.73 ± 0.25 mg/l (February) and 7.93 ± 0.09 mg/l (October) respectively.

Conductivity (specific conductance) is the ability of water to conduct an electric current. Most dissolved inorganic substances are in the ionized form in water and contribute to conductance. The conductance of the samples gives rapid and practical estimate of the variation in dissolved mineral content of the water supply (Ramachandra *et al.*, 2012) [18]. Freshwater fish generally thrive over a wide range of electrical conductivity. Some minimum salt content is desirable to help fish maintain their osmotic balance (Stone and Thomforde, 2004) [19]. The highest value of electrical conductivity was recorded in the month of February and the lowest was reported in September. The minimum and maximum electrical conductivity (EC) at S1, S2 and S3 were recorded as 888 ± 0 µS/cm and 1263.33 ± 0.94 µS/cm, 945.67 ± 0.94 µS/cm and 1347.33 ± 1.70 µS/cm and 919.67 ± 0.47 µS/cm and 1926 ± 0.38 µS/cm respectively.

The total concentration of bases in water expressed in milligrams per litre of equivalent calcium carbonate ($CaCO_3$) is the total alkalinity (Boyd, 1998) [20]. The total alkalinity or acid combining capacity, is generally due to carbonate and bicarbonates of calcium and magnesium. The presence of carbonates, bicarbonates, and hydroxides are the main cause of alkalinity in natural waters (Rajankar *et al.*, 2009) [21]. Lime leaching out of concrete ponds or calcareous rocks, photosynthesis, denitrification and sulphate reduction is mainly responsible for increasing alkalinity while respiration, nitrification and sulphide oxidation decrease or consume alkalinity (Stumn and Morgan, 1981; Cook *et al*., 1986) [22, 23] and to a lesser degree it increases due to evaporation and decomposing organic matter (Bhatnagar and Devi, 2013) [24]. But if the alkalinity is low, it indicates that even a small amount of acid can cause a large change in the pH (Bhatnagar and Devi, 2013) [24]. The minimum and maximum total alkalinity in the study was recorded at S1, S2 and S3 as 131.33 ± 6.60 mg/l (March) and 362 ± 4.32 mg/l (September), 148.67 ± 12.26 mg/l (March) and 361.33 ± 3.40 mg/l (September) and 122.67 ± 16.76 mg/l (March) and 378.33 ± 4.78 mg/l (July).

The total hardness refers to the concentration of divalent metal ions in water (Paria and Konar, 2000) [25]. It is a measure of the capacity of water to the concentration of calcium and magnesium in water and is usually expressed as the equivalent of $CaCO_3$ (APHA, 2005) [26].The amount of calcium hardness is important in pond fertilization because higher rates of phosphorus fertilizer are required at higher calcium hardness concentrations (Stone and Thomforde, 2004) [19] Calcium and magnesium are essential to fish for metabolic reactions such as bone and scale formation (Bhatnagar and Devi, 2013) [24]. During the study period the minimum and maximum total hardness was recorded at S1, S2 and S3 as 165.33 ± 4.11 mg/l (September) and 295.33 ± 2.50 mg/l (February), 161.33 ± 4.99 mg/l (September) and 383.33 ± 62.36 mg/l (March) and 170 ± 1.63 mg/l (October) and 282.67 ± 7.54 mg/l (March) respectively. Higher values were recorded in the early summer, whereas lower values in late monsoon.

Total dissolved solids is the measure of the combined content of all inorganic and organic dissolved substances in a water sample. It is the aggregated amount of the entire floating suspended solids present in water sample (Sheetal, 2016) [27]. A high concentration of dissolved solids increases the density of water, affects osmoregulation of fresh water organisms, and reduces solubility of gases and utility of water for drinking, irrigational and industrial purposes (Boyd and Tucker, 1998) [28]. Low concentrations of dissolved substances have no significant influence on the water quality but at high concentrations impair the water quality and suitability of water for various applications such as domestic, industrial and agricultural purposes. The minimum and maximum of total dissolved solids were recorded at S1, S2 and S3 from 221.67 ± 8.50 mg/l (December) and 853.33 ± 37.71 mg/l (March), 280 ± 4.08 mg/l (December) and 913.33 ± 49.89 mg/l (August) and 236.67 ± 33 mg/l (November) and 953.33 ± 9.43 mg/l (August) respectively.

The most chemically stable form of nitrogen is nitrate. High nitrate concentration can result in excess algal blooms in water body. Fertilizers, decayed vegetables and animal matter are the principle sources of nitrates in a water body. Nitrate is present in water as a form of nitrogen and it is a vital nutrient for the growth, reproduction and survival of organisms (Adeyemo *et al*., 2008) [29]. The minimum and maximum values of S1, S2 and S3 recorded were 0.16 ± 0 (August) and 0.262 ± 0.018 (November), 0.18 ± 0 (January) and 0.254 ± 0.001 (October) and 0.190 ± 0.002 (October) and 0.408 ± 0.006 (August) respectively. Considerable variations in nitrate concentration were observed in all the sites.

According to the results shown in tables and figure the water quality index from weighted arithmetic index (WAI) method was calculated in all the three sites for nine months from the experimental area. In S1 the WQI level ranged from 141.787 to 197.519 while in the S2 the index level varied from 150.583 to 201.376 and in S3 WQI index level recorded between 146.371 and 276.688. The highest value of WQI was recorded during March and lowest value was reported during the month of September in all the three sites.

Table 2: Water quality parameters and their assigned standard values and unit weights

Parameters	Standard values (S_i)	Unit weight (W_i)
pH	8.5	0.2190
Electrical conductivity (EC)	300	0.371
Total dissolved solids (TDS)	500	0.0037
Total alkalinity (TA)	120	0.0155
Total hardness (TH)	300	0.0062
Nitrate (NO_3)	45	0.0412
Dissolved oxygen (DO)	5	0.3723
		$\sum W_i$=1.0289

Table 3: Observed values of Sewage fed aquaculture system (Nalban East Kolkata wetland) water quality

S1	pH	EC	TDS	TA	TH	NO_3	DO
July	7.167	1123.333	740.000	331.000	178.333	0.181	6.267
August	7.133	1001.000	800.000	353.667	192.000	0.160	6.367
September	7.167	888.000	566.667	362.000	165.333	0.183	7.333
October	8.100	1034.667	413.333	234.667	175.000	0.232	7.567
November	7.967	1078.000	346.667	272.000	188.000	0.262	7.600
December	7.800	1006.000	221.667	250.667	194.000	0.210	7.667
January	7.667	1172.667	353.333	186.000	252.667	0.170	6.333
February	6.200	1170.667	553.333	158.000	295.333	0.232	3.967
March	7.600	1263.333	853.333	131.333	288.667	0.213	5.500
S2							
July	7.467	1163.000	646.667	356.000	180.667	0.225	8.067
August	7.317	1145.000	913.333	348.667	192.000	0.227	5.933
September	7.467	945.667	753.333	361.333	161.333	0.221	8.000
October	8.467	1157.000	381.667	259.667	172.000	0.254	7.667
November	7.633	1126.333	3203.000	229.333	196.667	0.216	6.867
December	7.400	1107.000	280.000	269.333	188.667	0.190	7.967
January	7.567	1197.667	333.333	178.333	246.333	0.180	6.567
February	6.200	1192.667	633.333	160.667	272.667	0.253	4.233
March	7.367	1347.333	760.000	148.667	383.333	0.187	6.367
S3							
July	7.600	1101.667	580.000	378.333	177.333	0.270	7.567

August	7.500	1153.333	953.333	350.667	190.667	0.408	5.933
September	7.133	919.667	653.333	365.333	171.000	0.240	7.033
October	8.367	1101.667	388.333	273.000	170.000	0.190	7.933
November	7.200	1134.667	236.667	248.000	190.667	0.246	6.400
December	7.133	1215.000	255.000	295.333	204.000	0.210	6.000
January	7.400	1274.667	323.333	123.667	223.333	0.179	6.100
February	6.433	977.333	606.667	151.333	267.333	0.258	4.733
March	7.867	1926.000	860.000	122.667	282.667	0.207	6.600

Table 4: Quality rating (Q_i) of Sewage fed aquaculture system (Nalban East Kolkata wetland) water quality

S1	pH	EC	TDS	TA	TH	NO_3	DO
July	11.111	374.444	148.000	275.833	59.444	0.403	86.806
August	8.889	333.667	160.000	294.722	64.000	0.356	85.764
September	11.111	296.000	113.333	301.667	55.111	0.407	75.694
October	73.333	344.889	82.667	195.556	58.333	0.515	73.264
November	64.444	359.333	69.333	226.667	62.667	0.581	72.917
December	53.333	335.333	44.333	208.889	64.667	0.467	72.222
January	44.444	390.889	70.667	155.000	84.222	0.377	86.111
February	-53.333	390.222	110.667	131.667	98.444	0.516	110.764
March	40.000	421.111	170.667	109.444	96.222	0.473	94.792
S2							
July	31.111	387.667	129.333	296.667	60.222	0.500	68.056
August	21.111	381.667	182.667	290.556	64.000	0.504	90.278
September	31.111	315.222	150.667	301.111	53.778	0.491	68.750
October	97.778	385.667	76.333	216.389	57.333	0.565	72.222
November	42.222	375.444	64.000	191.111	65.556	0.479	80.556
December	26.667	369.000	56.000	224.444	62.889	0.421	69.097
January	37.778	399.222	66.667	148.611	82.111	0.400	83.681
February	-53.333	397.556	126.667	133.889	90.889	0.561	107.986
March	24.444	449.111	152.000	123.889	127.778	0.416	85.764
S3							
July	40.000	367.222	116.000	315.278	59.111	0.600	73.264
August	33.333	384.444	190.667	292.222	63.556	0.907	90.278
September	8.889	306.556	130.667	304.444	57.000	0.533	78.819
October	91.111	367.222	77.667	227.500	56.667	0.421	69.444
November	13.333	378.222	47.333	206.667	63.556	0.547	85.417
December	8.889	405.000	51.000	246.111	68.000	0.467	89.583
January	26.667	424.889	64.667	103.056	74.444	0.398	88.542
February	-37.778	325.778	121.333	126.111	89.111	0.573	102.778
March	57.778	642.000	172.000	102.222	94.222	0.461	83.333

Table 5: Parameters wise calculated values of water quality $w_i \times q_i$

S1	pH	EC	TDS	TA	TH	NO_3	DO
July	2.433	138.919	0.548	4.275	0.369	0.017	32.318
August	1.947	123.790	0.592	4.568	0.397	0.015	31.930
September	2.433	109.816	0.419	4.676	0.342	0.017	28.181
October	16.060	127.954	0.306	3.031	0.362	0.021	27.276
November	14.113	133.313	0.257	3.513	0.389	0.024	27.147
December	11.680	124.409	0.164	3.238	0.401	0.019	26.888
January	9.733	145.020	0.261	2.403	0.522	0.016	32.059
February	-11.680	144.772	0.409	2.041	0.610	0.021	41.237
March	8.760	156.232	0.631	1.696	0.597	0.020	35.291
S2							
July	6.813	143.824	0.479	4.598	0.373	0.021	25.337
August	4.623	141.598	0.676	4.504	0.397	0.021	33.610
September	6.813	116.947	0.557	4.667	0.333	0.020	25.596
October	21.413	143.082	0.282	3.354	0.355	0.023	26.888
November	9.247	139.290	0.237	2.962	0.406	0.020	29.991
December	5.840	136.899	0.207	3.479	0.390	0.017	25.725
January	8.273	148.111	0.247	2.303	0.509	0.016	31.154
February	-11.680	147.493	0.469	2.075	0.564	0.023	40.203
March	5.353	166.620	0.562	1.920	0.792	0.017	31.930
S3							
July	8.760	136.239	0.429	4.887	0.366	0.025	27.276
August	7.300	142.629	0.705	4.529	0.394	0.037	33.610
September	1.947	113.732	0.483	4.719	0.353	0.022	29.344
October	19.953	136.239	0.287	3.526	0.351	0.017	25.854
November	2.920	140.320	0.175	3.203	0.394	0.023	31.801
December	1.947	150.255	0.189	3.815	0.422	0.019	33.352
January	5.840	157.634	0.239	1.597	0.462	0.016	32.964
February	-8.273	120.864	0.449	1.955	0.552	0.024	38.264
March	12.653	238.182	0.636	1.584	0.584	0.019	31.025

Table 6: Water quality index for all three sites and nine months of Sewage fed aquaculture system (Nalban East Kolkata wetland)

Months	Sites		
	S1	S2	S3
July	173.853	176.349	172.983
August	158.653	180.220	183.891
September	141.786	150.582	146.370
October	170.094	189.910	180.998
November	173.734	177.734	173.812
December	162.113	167.710	184.661
January	184.676	185.260	193.169
February	172.428	174.115	149.513
March	197.518	201.375	276.688

Discussion

Rout (2011) [30] recorded maximum pH of 8.27 ± 0.01 during November from different East Kolkata wetlands and Sheetal *et al*. (2016) [31] recorded high pH which during summer and low pH during winter season from lentic ecosystems of East Kolkata which are in correlation with the present findings. Rokade and Ganesh wade (2005) [32] observed high fluctuations in the pH ranging from 6.0 to 8.4 in a polluted lake at Aurangabad, Uttar Pradesh. Popa *et al*. (2012) [33] observed that the wastewater collected at a polluted site was slightly alkaline showing the range of 6.8 and 8.3. The desirable range for pond pH is 6.5-9.5 and acceptable range is 5.5-10.0 (Stone and Thomforde, 2004) [19]. As per Bhatnagar and Devi (2013) [24] the desirable range of pH for fish culture is 6.5-9.0. The water with pH values ranging from about 6.5-9.0 at day break is most suitable for fish production (Sheetal, 2016) [27]. During the present investigation the recorded pH range is within the desirable limit so it can be stated that this water body is suitable for fish culture.

Sondhia (2008) [34] studied the impact of sewage water on water quality at Nalban sewage fed fisheries and observed the DO range of 2.5 to 10.8 mg/l. Similarly, Popa *et al*. (2012) [33] studied the level of wastewater pollution and recorded the DO values between 0.96 and 11.33 mg/l. Ahmad *et al*. (2011) [35] also analysed the physico-chemical properties in sewage fed pond of Aligarh (UP), India and observed the range from 1.6 to 9.2 mg/l. The above findings of several workers are in agreement with the present findings. The desirable range of DO for fish culture is 5 mg/l (Bhatnagar and Devi, 2013) [24] and acceptable concentrations range for DO is 5-15 mg/l (Boyd, 1998) [20]. During the present study do recorded in the month of February is below 5 mg/l which indicates that in this period the fish survive but grow slowly and will be sluggish (Bhatnagar *et al*., 2004) [37]. The DO level may be improved by reducing the organic load through better sewage treatment practices. But the DO recorded in acceptable range in remaining period indicating the suitability of water body for fish culture.

Rajagopal *et al*. (2010) [38] also recorded low value during September and this might be due to high temperature, less solubility and high degradation of organic substances. The similar results have been reported from the findings of Moundiotiya *et al*. (2004) [38] and Mishra and Tripathi (2008) [39]. Gaikwad *et al*. (2008) [39] stated that the dilution of solid substance in turn reduces the electrical conductivity value. Harney *et al*. (2013) [40] and Kedar *et al*. (2008) [41] also reported low conductivity during monsoon season in Yedshi Lake in Mangarulpir tehsil of Washim district, Maharashtra. In the present study EC recorded in S1 ranged from 888 ± 0 µS/cm to 1263.33 ± 0.94 µS/cm, for S2 it varied from 945.67 ± 0.94 µS/cm to 1347.33 ± 1.70 µS/cm and in S3 it was recorded between 919.67 ± 0.47 µS/cm and 1926 ± 0.38 µS/cm. Benit and Roslin (2015) [42] observed the conductivity from wastewater collected from different stations of Nagercoil Town, Kanyakumari District, Tamil Nadu and recorded in range between 650 and 2390 µS/cm. Sheetal *et al*. (2016) [31] recorded EC in the range of1254 ± 2.60 to 2423.7 ± 1.74µS/cm during the month of February. Increasing levels of conductivity and cations are the products of decomposition and mineralization of organic materials (Abida and Harikrishna, 2008) [43]. According to Stone and Thomforde (2004) [19] recommended the desirable range 100-2000 µS/cm and acceptable range 30-5000 µS/cm for pond fish culture. The present findings are within the desirable limit so it is suitable for the fish culture.

Harney *et al*. (2013) [40] reported that, the total alkalinity was maximum in monsoon in Pindavani pond. Rout (2011) [30] recorded the total alkalinity from different East Kolkata wetlands as 128 ± 1.63, 141.50 ± 1.91 and 148.50 ± 1.29 mg/l in the month of March which are in agreement with the present findings. Anupama *et al*. (2016) [44] also found the similar range of total alkalinity varying from 342.67 ± 2.31 to 422 ± 2 mg/l which is might be due to pollution of organic and inorganic matter (Phillips, 1977) [45]. Water bodies having total alkalinity above 50 ppm can be considered productive (Hazarika, 2004) [54]. The desirable range and acceptable range for fish culture is 25-100 mg/l and 50-200 mg/l respectively (Bhatnagar and Devi, 2013) [24]. The ponds with a total alkalinity above 20 mg/l can produce an abundance of fish and other aquatic creatures and if the alkalinity is below 20 mg/l, liming is necessary (Boyd, 1998) [20]. Bhatnagar *et al*. (2004) [37] suggested that <20 mg/l indicates poor status of water body, 20-50 mg/l shows low to medium, 80-200 mg/l is desirable for fish and >300 mg/l is undesirable due to non-availability of CO_2. The present result is within the acceptable limit which is indicative of good pond productivity.

Solanki *et al*. (2014) [47] also recorded the highest values of total hardness during the month of March in Bellal Lake, Bodhan, Andhra Pradesh. The higher values of total hardness in the present study might be due to evaporation of water and addition of calcium and magnesium salts (Solanki *et al*., 2014) [47]. This is also supported by Bagde and Varma (1985) [48]. Sugunan *et al*. (2000) [49] reported that the average total hardness of water in the beels of West Bengal vary between 56.4 and 372.20 mg/l which is comparable to the present findings. Kumar *et al*. (2008) [50] observed the minimum hardness in the month of September in sewage-fed wetland, Khodiyar, Gujarat, where they observed the minimum value of hardness to be 279.3 mg/l in the month of September. Rout (2011) [30] also recorded the total hardness ranging between 119 ± 1.15 and 390 ± 8.16 mg/l in different lentic water bodies of West Bengal. Increase in total hardness during the months of February and March has been reported by Anupama *et al*. (2016) [44]. In the present investigation, the rainfall lowered hardness for as indicated by the sudden drop from 165.33 ± 4.11 to 192 ± 1.63 mg/l in S1, 161.33 ± 4.99 to 192 ± 1.63 mg/l in S2 and in S3 reduced from 171 ± 0.81 to 190.67 ± 0.94 mg/l. The recommended ideal value of hardness for fish culture in the range of 30-180 mg/l (Santhosh and Singh, 2007) [51]. According to Bhatnagar *et al*. (2004) [37] hardness values less than 20 mg/l causes stress, 75-150 mg/l is optimum for fish culture and >300 mg/l is lethal to fish life as it increases pH, resulting in non-availability of nutrients. The total hardness observed in the present investigation is beyond the optimum range for fish culture. This might be due to the heavy influx of sewage into the water body and it can be controlled by following the suitable chemical treatment.

Sheetal *et al*. (2016) [27] reported the TDS ranging from 827.31 to 2165.68 mg/l from East Kolkata wetlands. In the present study the TDS were reported high values during monsoon and drastically reduced in winter and shows the increment of dissolved solids towards the late winter. The maximum total dissolved solids were recorded in the month of monsoon period, which might be due to solid wastes getting washes into water bodies with the rain water (Abbasi and Vinithan, 1999) [52]. The high value of total dissolved solids during rainy season may be due to addition of domestic waste water, garbage and sewage in the natural water body (Verma *et al*., 2012) [53]. Increased high concentration of total dissolved solids increases the nutrient status of water body which was resulted into eutrophication of aquatic bodies as suggested by Singh and Mathur (2005) [54]. In the present study, total dissolved solids were very high throughout the study which might be due to organic matter, salt, silts, cations and debris (Sheetal, 2016) [27]. Abir (2014) [69] reported the maximum TDS during summer and least during winter in Rudrasagar Wetland, Tripura. Shinde *et al*. (2010) [70] also reported the maximum TDS during monsoon season (59.17 ± 439.8mg/l) in Savangi dam, Aurangabad. Sanyal *et al*. (2015) [71] showed distinct seasonal trend in TDS with the maximum value during monsoon which observed in different sewage-fed wetlands in Kolkata Metropoliton area. All the findings were in accordance with the present findings.

Sheetal (2016) recorded the nitrate nitrogen from different lentic ecosystem of Eastern Kolkata which varied from 0.12 ± 0.02 mg/l to 1.05 ± 0.06 mg/l which agreed with the present study. Kumar *et al*. (2008) [72] observed nitrate nitrogen ranging from 0.17 to 0.49 mg/l in sewage fed wetlands, Khodiyar, Gujarat. Rokade and Ganeshwade (2005) was also found the nitrate at the range of 0.5 to 1.012 from Salim Ali Lake at Aurangabad, Uttar Pradesh. The maximum value for nitrate nitrogen was recorded in the month of August and minimum in the month of October for S3 which might be due to surface runoff during monsoon period as this site receives much surface runoff. Lower values observed during post monsoon as the waters gets settled. Sheetal *et al*., (2016) observed the maximum nitrate nitrogen during the monsoon season in different lentic ecosystems of Eastern Kolkata. Milli *et al*. (2017) [73]; Shinde *et al*. (2010) [74] and Abir (2014) [55] also observed the maximum value of nitrate nitrogen during the month of August. The maximum value was observed in August by Sivakumar and Karuppaswamy (2008) [56] and similarly, Manjare *et al*. (2010) [57] from Maharashtra recorded the maximum value in the month of July (monsoon) and minimum in the month of November (winter). According to Anderson *et al*. (1998) [58], higher concentration might be due to influx of nitrogen rich flood water and bring about large amount of sewage. The rainy season was the period with the highest nitrate nitrogen concentration which supports the formation of blooms. Higher nitrate levels are not good for aquatic life (Garg *et al*., 2006) [59]. During the present study in S1 the nitrate was recorded the maximum value as 0.018 ± 0.262 (November) and the minimum value as 0 ± 0.16 (August). The present findings are correlated with the findings of Shyamsunder (1998) [60], who reported that maximum nitrate in winter. Anupama *et al*. (2016) [44] found low levels of nitrate nitrogen in the month of August from a wastewater body, West Bengal. They also recorded high level nitrate nitrogen during September and low level during January from other lentic ecosystem, these findings are in agreement with the present study. According to Stone and Thomforde (2004) [19] nitrate is relatively nontoxic to fish and not cause any health hazard except at exceedingly high levels (above 90 mg/l). Santhosh and Singh (2007) [51] described the favourable range of 0.1 mg/l to 4.0 mg/l in fish culture water. The acceptable concentration range of nitrate nitrogen is 0.2-10 mg/l (Boyd, 1998) [20]. The nitrate nitrogen reported during the present study is in the favourable range for the fish culture.

Several workers worked on the water quality index of different types of water bodies as discussed. Shekar *et al*. (2015) [61] calculated the values of water quality index from weighted arithmetic index (WAI) method of Gidadakonenahalli Lake and recorded as 849.01 which is above 100 and the water quality rating of the lake is unfit and it is concluded to be severely polluted. Shankar and Sanjeev (2008) [63] assessed the water quality index for the ground waters of an Industrial area in Bangalore and recorded the value up to 300. Khan (2011) [64] also estimated the WQI for Municipal Water Supply of Attock City, Punjab and recorded the value up to 142. Singh and Kamal (2014) [63] calculated the water quality index of biotreated sewage water for four months which ranging from 171.79-115.5. Boah *et al*. (2015) [65] analysed the water quality index of Vea Dam in Upper East Region of Ghana and the value was recorded as 54.21 which falls within 51-75 of the classification of water quality based on weighted arithmetic WQI method and concluded that untreated water from the Vea dam is of poor quality. Alobaidy *et al*. (2010) [66] evaluated the WQI of Dokan Lake Ecosystem, Kurdistan Region, Iraq and the values ranged from 53.18 during 2000 to 101.26 during 2009 and therefore categorized into "Good water" during 1978, 1979, 1980, 1999, 2000, 2008 to "Poor water" during 2009. The water quality index of urban water body of Shimoga town, Karnataka (receives domestic waste and drainage waste) were calculated in different seasons of study period i.e rainy season, winter season and summer season are 96, 101.7 and 106.3 respectively, which indicate the poor quality of water (Yogendra and Puttaiah, 2008) [67]. The WQI values in the Pariyej Lake, Gujarat are reported to be less than 75 (67.201, 68.43 and 70.37) for different season indicating that the water quality is poor and not totally safe for human consumption (Thakor *et al*., 2011) [68]. The WQI for all samplesin and around mining talukas of Goa, were found in the range of 34 to 107, most of the water samples were found within Good to moderate categories (Singh and Kamal, 2014) [63]. Bora and Goswami (2016) [69] resulted that the WQI scores shows very poor to unsuitable quality of water samples in almost all the seven sampling sites along the Kolong River and it is found to be most deteriorated during monsoon season with an average WQI value of 122.47 as compared to pre-monsoon and post-monsoon season having average WQI value of 85.73 and 80.75, respectively. All the above findings were in agreement with the present work. Throughout the study period the water quality index level was above 100 which indicated that the water is unsuitable for drinking (Chaterjee and Raziuddin, 2002) [13]

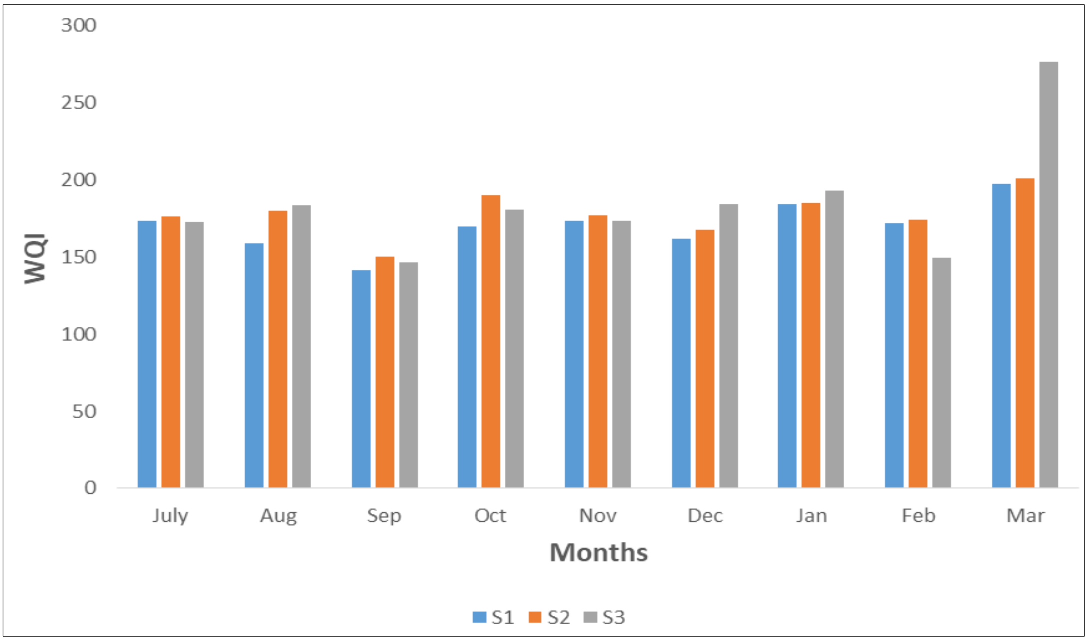

Fig 4: Monthly variation of water quality index in three sites of the sewage fed aquaculture system during the study period.

Conclusion

Our present study pertaining to water quality rating clearly shows that the status of the water body is eutrophic and it is unsuitable for human uses. But the physico-chemical properties except total hardness of the study area are within the desirable limit for fish culture. Based on the keen observations, it can be concluded that the largest sewage fed wetland is suitable of fish culture, but the water quality is deteriorating from time to time due to the inflow of sewage water, anthropogenic activities, industrial effluent, lack of proper sanitation, and urban runoff. Hence highest priority should be given to water quality monitoring to obtain necessary information to design specific pollution prevention programs and to determine the suitability of this largest sewage fed wetland for multiple uses.

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