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Advances in Applied Science Research, 2015, 6(1):15-26

Advances in Applied Science Research
Pelagia Research Library
ISSN: 0976-8610
CODEN (USA): AASRFC

Surface water (Futala Lake) quality and its pollution load in terms of water quality index (WQI)

P. J. Puri[1*], M. K. N. Yenkie[1], D. B. Rana[1], S. U. Meshram[1] and L. S. Awale[2]

[1]Department of Applied Chemistry, LIT, Rashtrasant Tukadoji Maharaj Nagpur University, Nagpur
[5]Department of Chemistry, C. P. & Berar College, Ravinagar, Nagpur

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ABSTRACT

The present work aims at assessing the water quality index (WQI) in the surface water (Futala lake) situated in Nagpur City, Maharashtra India, by monitoring five sampling locations within Futala lake (viz., inlet1, inlet2, centre, corner and outlet) for a period of 3 months from August to October 2013. The surface water samples were subjected to comprehensive physico-chemical analysis involving major cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Fe^{2+},), anions (Cl^{-}, SO_4^{2-}, NO_3^{-}, F^{-}, PO_4^{3-}) besides general parameters (pH, EC, TDS, alkalinity, total hardness, DO, BOD, COD). For calculating the WQI, 14 parameters, namely, pH, electrical conductivity, total dissolved solids, total hardness, alkalinity, calcium, magnesium, sodium, potassium, chloride, sulphate, nitrate, fluorides and iron were considered. It is apparent from WQI values that Futala Lake water with WQI values ranging from 55.81 to 169.37, falls under poor water category. The present study revealed that Futala lake water is polluted (due to surface run-off, washing activities, agriculture run-off, effluents from upstream from surrounding residential area, immersion of idols of God and Goddess during festival season, discharge of domestic sewage (poor) and dumping of garbage) and unsuitable for human consumption also for the survival of life forms unless treated properly. There is need for implementing conservation measures and generating awareness among the people towards the lake which provides livelihood to the people and forms an integral part of the social, economic and cultural life.

Keywords: Physicochemical analysis, WQI, lake, water pollution, festivals.

INTRODUCTION

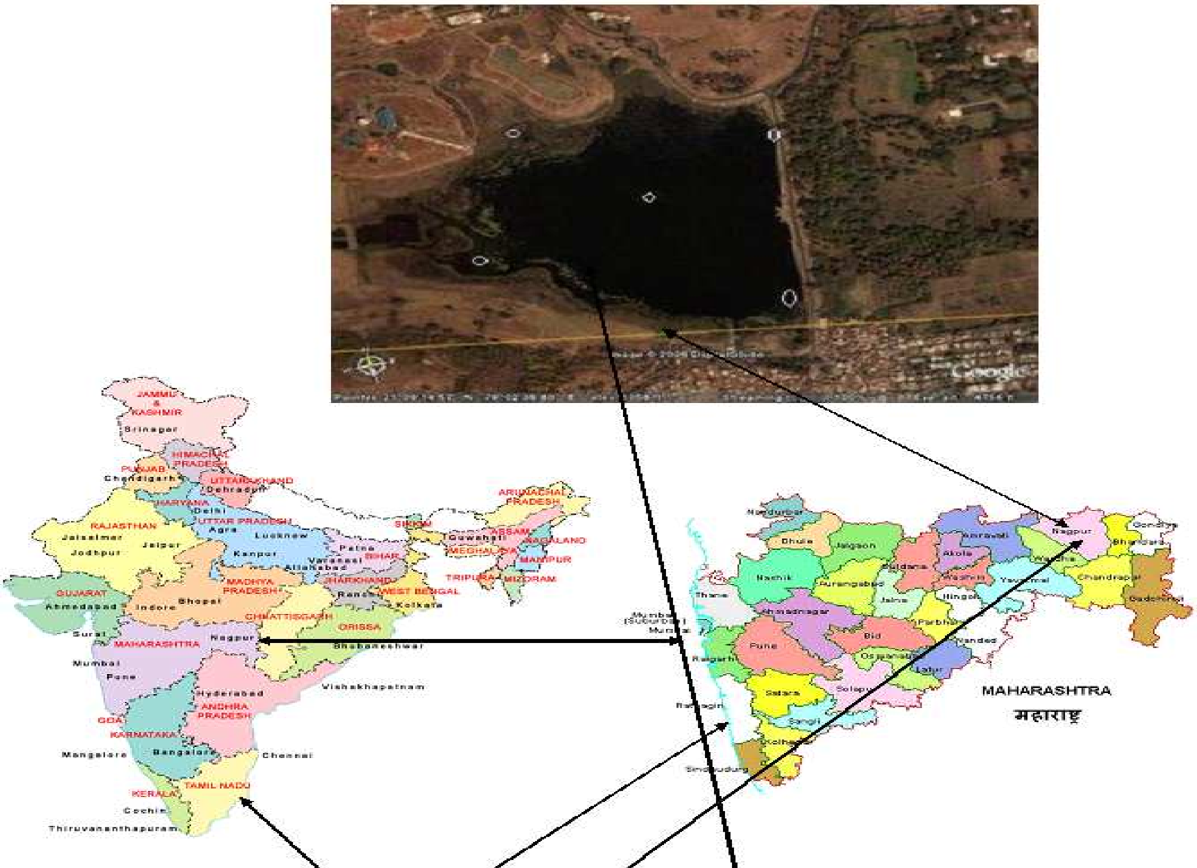
Lakes are important feature of the Earth's landscapes. They are not only a significant source of precious water but provide valuable habitat to plants and animals, enhance the aesthetic beauty of the landscape and offer many recreational opportunities. Lakes are the hub of socio-economic activities of the country. These are dynamic ecosystem that reflects their specific characteristics, variations in climate and biological component.

Lake pollution is one of the serious environment problems in development and pollutant discharge increase from industry, agriculture. The health of lakes and their biological diversity are directly related to health or almost every component of the ecosystem. According to WHO organization [1], about 80% of all diseases in human beings are caused by water. Once the groundwater and surface water quality is contaminated, its quality can't be restored by stopping the pollutants from the source. It therefore becomes imperative to regularly monitor quality of groundwater and surface water resources and to device ways and mean to protect it. Hence, periodic monitoring and assessment of water quality helps to develop management strategies to control surface water pollution [2] in spite of increasing urbanization and anthropogenic pressure on them. Water quality index (WQI) is one of the most effective tools [3-5] to communicate information on the quality of water to the concerned citizens and policy makers as it is an important parameter for the assessment and management of surface/ground waters. Hence, the present work has been carried out with a focus to evaluate comparatively the prevailing water quality and potability of Futala lake (rainfed lake) by analyzing physico-chemical parameters by estimating WQI.

Study Area

Nagpur city with coordinates of 21º8'55" and 79º4'46"E is second capital of Maharashtra state. Nagpur city is popularly known as orange city, also city of lakes. The city had 10 lakes in the past, but unfortunately only 7 of them are there now. The Futala Lake with a coordinate of 21º8`44``N and 79º03` 48``E is closed water body. The Fulata lake is spread over 60 acres. The Futala Lake is located at the western side of the Nagpur city. The catchment area of dam is 6.475 sq. km. The length of west weir is 8.0m. Futala lake is having capacity to irrigate an area of 34.42 hectors of cultivated agriculture land and Telenkhedi Garden. The initial purpose for irrigating nearby agricultural land was prominent amongst the utilization of Futala lake.

Satellite Image of Futala Lake



Map of India, Maharashtra, Nagpur city, Futala Lake(Study area)

Problem on hand

The Futala lake water is unpotable and now–a-days used for irrigation purpose and for commercial fisheries. It doesn't have self cleaning capacity; hence continuous addition of nutrients through many polluting sources is leading. The watershed of Futala lake is a part of Nag river watershed. Nag River is completely polluted on account of incoming sewage into it. The Four streams are prominent within catchment. The Futala Lake and its environs near Telankhedi Garden on Amravati road, Nagpur, is a picnic spot. It is rainwater impoundment with an area of 26.3 hectors and 5-6 meters deep during monsoon. Futala Lake, too, is facing the threat of eutrophication with weeds covering almost half the lake area already. The sewage is released into Futala Lake without treatment therefore the Futala lake water is polluted at moderate level. In Futala Lake, eutrophication was first seen in some portion towards west, but, almost half of the lake area is covered by weeds, especially on south and north side. Species inside the water start to diminish due to lack of sunlight, even oxygen level in lake water already drastically dropped. Another worry for the lake was, collapse of large portion of embankment towards the bund embankment, constructed with black stone in some time ago, raising the needs for inspection of remaining portion of the embankment. Futala Lake was chosen in this study, since it is heavily influence by human actions leading to domestic and partially agricultural pollution sources. The basic objective of present study is to forearm people by creating awareness also to evolve future strategies for the benefit of mankind and to highlight the basic issues regarding water pollution prevention as well as conservation and management of surface water bodies (Lakes)

MATERIALS AND METHODS

To characterize water quality throughout the main basin of the lakes, five permanent stations for monthly sampling were established and marked within inlet1 S_1, inlet2 S_2, centre S_3, corner S_4, and outlet S_5, regions. Regular samples were collected in sterilized glass bottles for various physicochemical analysis of sample; the pre-cleaned plastic polyethylene bottles were used. Prior to sampling, the entire sampling container's were washed and rinsed thoroughly with lake water to be taken for analysis. The collected surface water samples were collected from these six locations in a 2 L pre-cleaned polyethylene bottles for a period of 3 months from August 2013 to October 2013. Three months continuous monitoring involved comprehensive physico-chemical analyses encompassing estimation of major cations (Ca^{2+}, Mg^{2+}, Na^+, K^+, Fe^{2+}), anions (Cl^-, SO_4^{2-}, NO_3^-, F^-, PO_4^{3-}) besides general parameters (pH, EC, TDS, alkalinity, total hardness, DO, BOD, COD and temperature). In situ parameters like pH, EC, TDS, dissolved oxygen, etc. was measured immediately in the field immediately after sampling. The standard analytical procedures as recommended by the American Public Health Association [6] were employed in the present study (Table 1). The suitability of the surface water from these Futala Lake for drinking, domestic, and irrigation purposes was evaluated by comparing the values of different water quality parameters with those of the Bureau of Indian standards [7] guideline values for drinking water.

Water quality index (WQI) [9]
Water quality index (WQI) is of the most effective tools to communicate information on the quality of water to the concerned citizens and policy makers. The WQI provides a comprehensive picture of the quality of surface/ground water for most domestic uses. WQI is defined as a rating that reflects the composite influence of different water quality parameters [8] WQI is calculated from the point of view of the suitability of surface or groundwater for human consumption. Hence, for calculating the WQI in the present study, 14 parameters namely, pH, electrical conductivity, total dissolved solids, total hardness, alkalinity, calcium, magnesium, sodium, potassium, chloride, sulphate, nitrate, fluorides and iron have been considered (Table 2). There were three steps for computing WQI of a water sample.

a. Each of the chemical parameters was assigned a weight (w_i) based on their perceived effects on primary health and their relative importance in the overall quality of water for drinking purposes (Table 2). The highest weight of 5 was assigned to parameters which have the major effects on water quality and their importance in quality (viz, NO_3^-, F^- and TDS) and a minimum of 2 was assigned to parameters which are considered as not harmful (Ca^{2+}, Mg^{2+}, K^+).
b. Computing the relative weight (W_i) of each parameter using Eq. 1. Table 2 present the weight (w_i) and calculated relative weight (W_i) values for each parameter.
c. A quality rating scale (q_i) for each parameter is computed by dividing its concentration in each water sample by its respective standard according to the guidelines laid down by BIS (1998) and then, the result was multiplied by 100 using Eq. 2. Finally, for computing the WQL, the water quality sub-index (SI_i) for each chemical parameter is first determined, which is then used to determine the WQI as per the Eqs. 3 and 4.

$$W_i = \frac{w_i}{\sum_{n=1}^{n} w_i} \quad (1)$$

Where Wi is the relative weight, w_i is the weight of each parameter and n is the number of parameters.

$$q_i = \left(\frac{C_i}{S_i}\right) x100 \quad (2)$$

where q_i = quality rating, C_i = concentration of each chemical parameter in each water sample in mg/L, S_i = Indian drinking water standard (BIS 1998) for each chemical parameter in mg/L except for conductivity (µS/cm) and pH.

$$SI = Wiqi \quad (3)$$

$$\text{WQI}= \sum_{i=1}^{n} SI_i \quad (4)$$

where SI_i is the sub-index of ith parameter; qi is the rating based on concentration of ith parameter and n is the number of parameters.

Table 1: Analytical methods adopted with the BIS desirable and Permissible limits [7-9]

Sl. No.	Characteristics	Analytical method	Unit	BIS limits (1998)	
				Desirable	Permissible
1.	pH	Electrode	-	6.5-8.5	6.5-8.5
2.	Electrical conductivity (EC)	Conductivity meter	µS/cm	2,000	3,000
3.	Total dissolved solids (TDS)	Conductivity-TDS meter	mg/L	1,000	2,000
4.	Total Alkalinity (TA)	Titrimetric	mg/L	200	600
5.	Total hardness (TH)	EDTA titrimetric	mg/L	300	600
6.	Dissolved Oxygen (DO)	Modified Winder's method	mg/L	6.0	NA
7.	Biochemical oxygen demand (BOD)	Modified Winder's method	mg/L	3.0	6.0
8.	Chemical oxygen demand (COD)	Closed reflux method	mg/L	NA	NA
9.	Calcium (as Ca^{2+})	EDTA titrimetric	mg/L	75	200
10.	Magnesium (as Mg^{2+})	EDTA Titrimetric	mg/L	20	100
11.	Potassium (as K^{+})	Flame photometric	mg/L	10	10
12.	Chlorides (Cl^{-})	Argentometric titration	mg/L	250	1,000
13.	Nitrates (as NO_3^{-})	Ion selective electrode (ISE)	mg/L	45	45
14.	Fluoride (as F^{-})	Ion selective electrode (ISE)	mg/L	1.0	1.5
15.	Phosphates (as PO_4^{3-})	Stannous chloride	mg/L	0.3	0.3
16.	Sulphates (as SO_4^{2-})	Barium chloride	mg/L	200	400

Table 2: The weight and relative weight of each of the physico-chemical parameters used for WQI determination [9]

Parameters	BIS desirable limit (1998)	Weight (w_i)	Relative weight (W_i)
pH	8.5	3	0.698
Electrical conductivity	2,000	3	0.0698
Total dissolved solids	1,000	5	0.1163
Total alkalinity	200	2	0.0465
Total harness	300	3	0.0698
Calcium	75	2	0.0465
Magnesium	30	2	0.0465
Sodium	100	3	0.0698
Potassium	10	2	0.0465
Chloride	250	3	0.0698
Sulphate	200	3	0.0698
Nitrate	45	5	0.1163
Fluoride	1	5	0.1163
Iron	0.3	2	0.0465
	-	$\Sigma w_i = 43$	$\Sigma W_i = 1.000$

RESULTS AND DISCUSSION

The study reveals a clear picture of Futala Lake water status at different sites during the different months and is tabulated in Table 1,2,3. Based on the results of physico-chemical analyses, irrigation quality parameters like sodium absorption ratio (SAR), percent sodium (% Na) were also calculated. The suitability of the surface water from Futala lake for drinking, domestic, and irrigation purposes was evaluated by comparing the values of different water quality parameters with those of the Bureau of Indian standards (BIS 1998) guideline values for drinking water. The higher concentration of some parameters is due to heavy pollution load due to idol immersion activities during festival season (Aug-Oct months) resulting in deterioration of natural water body. Futala Lake is affected by several sources of pollution including washing of clothes, animals, vehicles and even bathing. These activities lead to pollution of the lake by soaps, detergents and organic matter, and are taking place almost all around the lake. The lake area is also misused as public toilets leading to unhygienic environment and increasing the organic load in the lake. To the south of the lake, its banks are used as crematorium. Dumping of garbage and other wastes around the lake is taking place, which not only pollutes the lake but also spoils its beauty. Cattle grazing can be seen to the west and north of the lake. The volume of the Futala lake is decreasing due to the accumulation of silt coming from the run off. There are a number of upcoming layouts (residential area) around the lake, which may affect the water both quantitatively and qualitatively. Futala Lake is used as a repository for human wastes and also for irrigation water purpose. Development activities discharged of nutrients and growth of population has caused changes in mentioned lake ecosystem. Massive blooms of algae have developed, water born diseases have increased in frequency and water hyacinth has started chocking important water ways and landings as well as water supply intakes.

Table 3 : Water quality data collected and average pollution load from five studied points in Futala Lake during the month of August 2013

	Sites				
Parameters	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**
pH	7.8	7.9	8.1	7.8	7.7
EC	530	470	380	498	588
TDS	320	260	310	288	410
TH	178	198	280	228	310
Alkalinity	145	190	210	180	194
PO_4^{3-}	0.03	0.03	0.012	0.08	0.24
Ca^{2+}	35.21	49.46	30.51	27.54	48.34
Mg^{2+}	10.02	12.24	18.32	21.10	7.06
Na^{+}	12.36	18.24	25.21	14.0	38.21
K^{+}	3.21	4.81	4.81	5.34	9.38
Cl^{-}	36.28	40.28	35.71	42.72	66.24
SO_4^{2-}	20.24	30.14	16.24	10.27	28.42
NO_3^{-}	6.81	0.92	6.88	8.38	9.24
F^{-}	1.34	2.31	3.0	2.18	1.44
Fe^{2+}	0.72	0.34	0.38	0.46	0.88
DO	4.2	3.9	4.5	4.8	3.9
BOD	16	20	18	16	14
COD	70	110	66	84	140
WQI	55.81	63.17	75.83	65.6	72.32
%Na	20.32	21.54	31.97	20.59	37.10
SAR	2.60	3.29	5.10	2.84	7.26

All values are expressed in mg/L except pH, Conductivity (µmhos/cm), WQI, SAR and % Na

Table 4: Water quality data collected and average pollution load from five studied points in Futala Lake during the month of September 2013

	Sites				
Parameters	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**
pH	8.2	8.1	8.0	8.4	8.2
EC	698	728	616	750	734
TDS	420	322	386	392	428
TH	210	264	314	240	346
Alkalinity	154	180	246	210	228
PO_4^{3-}	0.05	0.08	0.06	0.12	0.22
Ca^{2+}	54.31	60.81	68.42	72.8	68.34
Mg^{2+}	18.28	9.34	14.82	28.16	27.18
Na^{+}	14.21	20.16	32.23	16.24	42.18
K^{+}	4.22	3.89	4.72	7.89	10.12
Cl^{-}	64.32	50.24	38.76	56.12	74.34
SO_4^{2-}	38.12	68.32	36.14	50.62	64.76
NO_3^{-}	6.12	1.92	10.21	4.16	7.12
F^{-}	1.98	3.0	2.72	4.89	3.0
Fe^{2+}	1.89	2.16	3.0	4.51	3.0
DO	2.0	1.8	2.5	2.0	2.6
BOD	24	30	32	38	48
COD	84	142	78	110	152
WQI	88.72	104.34	120.92	169.37	131.3
%Na	15.61	21.40	26.82	12.98	28.53
SAR	2.36	3.40	4.53	2.29	10.6

All values are expressed in mg/L except pH, Conductivity (µmhos/cm), WQI, SAR and % Na

pH

pH is a numerical expression that indicates the degree to which water is acidic or alkaline, with the lower pH value tends to make water corrosive and higher pH provides taste complaint and negative impact on skin and eyes [10]. pH below 6.5 starts corrosion in pipes. The decrease in pH values during the month August to October is mainly related to the high bicarbonate content, while the uptake of CO_2 by phytoplankton decreasing as a result of increasing in the concentration of HCO_3^- [11]. The mean pH of Futala lake water was 7.7 to 8.1 (August, 2013); 8.1 to 8.4 (September, 2013) and 7.8 to 8.1 (October, 2013) respectively.

Total dissolved solids (TDS)

Total dissolved solids (TDS) mainly consists of inorganic salts such as carbonates, bicarbonates, chlorides, sulphates, phosphates and nitrates of calcium, magnesium, sodium, potassium, iron etc. and small amount of organic matter [12]. Due to immersion of idols along with worship materials into Futala lake, TDS values increased in the month of September. The average concentration of total dissolved solid in Futala Lake water was 260 mgL^{-1} to 410

mgL^{-1} (August, 2013); 322 mgL^{-1} to 428 mgL^{-1} (September, 2013) and 320 mgL^{-1} to 430 mgL^{-1} (October, 2013) respectively.

Table 5: Water quality data collected and average pollution load from five studied points in Futala Lake during the month of October – 2013

	Sites				
Parameters	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**
pH	8.1	8.0	7.9	7.9	7.8
EC	630	750	650	740	700
TDS	430	390	284	320	382
TH	220	250	382	284	394
Alkalinity	160	182	340	172	186
PO_4^{3-}	0.12	0.14	0.12	0.08	0.18
Ca^{2+}	32.64	54.34	60.32	66.14	60.32
Mg^{2+}	12.72	13.54	14.26	18.32	22.36
Na^{+}	14.28	24.33	40.26	20.21	46.34
K^{+}	3.12	2.78	1.89	4.36	3.22
Cl^{-}	68.62	56.34	40.72	64.36	79.18
SO_4^{2-}	34.18	52.12	68.32	70.26	60.24
NO_3^{-}	2.18	3.0	3.0	1.58	3.48
F^{-}	1.76	2.00	2.84	3.0	1.32
Fe^{2+}	1.44	2.32	2.54	3.28	2.14
DO	2.2	1.9	2.8	2.2	2.8
BOD	20	24	24	30	42
COD	74	68	58	120	112
WQI	75.01	95.59	115.14	124.13	91.33
%Na	22.75	25.61	34.49	18.54	35.02
SAR	3.0	4.18	6.59	3.11	7.21

All values are expressed in mg/L except pH, Conductivity (µmhos/cm), WQI, SAR and % Na

Dissolved oxygen (DO)
It is an important which is essential to the metabolism of all aquatic organism that posses aerobic respiration [13]. DO levels in lakes vary according to their trophic level and depletion of DO in water probably is the most frequent result of water pollution [14]. Dissolved oxygen is the maximum concentration of oxygen that can dissolve in water. As a function of water temperature, it may vary from place to place and time to time. It fluctuate seasonally, daily and with variation in water temperature [15], mainly due to consumption of DO owing to respiration by aquatic animals, decomposition of organic matter, and various chemical reactions. The average concentration of dissolved oxygen in Futala lake water was 3.9 mgL^{-1} to 4.8 mgL^{-1} (August, 2013);1.8 mgL^{-1} to 2.6 mgL^{-1} (September, 2013) and 1.9 mgL^{-1} to 2.8 mgL^{-1} (October, 2013) respectively.

Biochemical oxygen demand (BOD)
BOD and COD are important parameters that indicate contamination with organic wastes. Biochemical oxygen demand (BOD) is the amount of oxygen required by bacteria while stabilizing decomposable organic matter under aerobic conditions [16]. It is required to assess the pollution of surface and ground water contamination occurred due to disposal of domestic and industrial effluents. According to WHO drinking water standard, BOD should not exceed 6 mg/L. The average concentration of biochemical oxygen demand in Futala lake water was 14.0 mgL^{-1} to 20.0 mgL^{-1} (August, 2013); 24.0 mgL^{-1} to 48.0 mgL^{-1} (September, 2013) and 20.0 mgL^{-1} to 42.0 mgL^{-1} (October, 2013) respectively.

Chemical oxygen demand (COD)
Chemical oxygen demand (COD) determines the oxygen required for chemical oxidation of most organic matter and oxidizable inorganic substances with the help of strong chemical oxidant. In conjunction with the BOD, the COD test is helpful in indicating toxic conditions and the presence of biologically resistant organic substances. [17] The average concentration of chemical oxygen demand in Futala lake water was 66.0 mgL^{-1} to 140.0 mgL^{-1} (August, 2013); 78.0 mgL^{-1} to 152.0 mgL^{-1} (September, 2013) and 58.0 mgL^{-1} to 120.0 mgL^{-1} (October, 2013) respectively. The higher values of COD indicate increase in organic pollution due to increase household waste water and waste discharges.

Total Alkalinity (TA)
Alkalinity is a measure of the ability of water to neutralize acids. It is due to the presence of bicarbonates, carbonates and hydroxide of calcium, magnesium, sodium, potassium and salts of weak acids and strong bases as borates, silicates, phosphates, etc. Large amount of alkalinity imparts a bitter taste, harmful for irrigation as it damages soil and hence reduces crop yields [18]. The average concentration of total alkalinity in Futala lake water

was 145 mgL^{-1} to 210 mgL^{-1} (August, 2013); 154 mgL^{-1} to 246 mgL^{-1} (September, 2013) and 160 mgL^{-1} to 340 mgL^{-1} (October, 2013) respectively.

Calcium and magnesium (Ca^{2+} and Mg^{2+})

The distribution of calcium and magnesium concentrations in the water of Futala lake were highly fluctuations during different periods. The average concentration of calcium in Futala lake water was 27.54 mgL^{-1} to 49.46 mgL^{-1} (August, 2013);54.31 mgL^{-1} to 72.84 mgL^{-1} (September, 2013) and 32.64 mgL^{-1} to 66.14 mgL^{-1} (October, 2013) respectively. The average concentration of magnesium in Futala lake water was 7.06 mgL^{-1} to 21.10 mgL^{-1} (August, 2013); 9.34 mgL^{-1} to 28.16 mgL^{-1} (September, 2013) and 12.72 mgL^{-1} to 22.36 mgL^{-1} (October, 2013) respectively.

Sodium and potassium (Na^{+} and K^{+})

Since natural levels of sodium and potassium ions in soil and water are very low their presence might indicates lake pollution caused by human activities. Sodium is often associated with chloride. It finds its way into lakes from road salt, fertilizers, human and animal waste. Soil retains sodium and potassium to a greater degree than chloride or nitrate. The sodium and potassium values overtime can mean there are long term effects caused by pollution. The average concentration of sodium in Futala lake water was 18.24 mgL^{-1} to 38.21 mgL^{-1} (August, 2013); 14.21 mgL^{-1} to 42.18 mgL^{-1} (September, 2013) and 14.28 mgL^{-1} to 46.34 mgL^{-1} (October, 2013) respectively. The average concentration of pottasium in Futala lake water was 3.21 mgL^{-1} to 9.38 mgL^{-1} (August, 2013); 4.22 mgL^{-1} to 10.12 mgL^{-1} (September, 2013) and 1.89 mgL^{-1} to 4.36 mgL^{-1} (October, 2013) respectively.

Chloride (Cl^{-})

Chloride occurs in all types of natural waters. The high concentration of chloride is considered to be an indication of pollution.[19] The sewage water and industrial effluent are rich in chloride and hence the discharge of these wastes results in high chloride level in surface water.[20] The average concentration of chloride in Futala lake water was 35.71 mgL^{-1} to 66.24mgL^{-1} (August, 2013); 38.76 mgL^{-1} to 74.34 mgL^{-1} (September, 2013) and 40.72 mgL^{-1} to 79.18 mgL^{-1} (October, 2013) respectively.

Sulphate (SO_4^{2-})

Sulphate in lake water is primarily related to the types of minerals found in the water shed and acid rain. Industries and utilities that burn coal releases sulphur compounds into the atmosphere that are carried into the lakes by rain fall. The high concentration of sulphate induce diarrhea.[21] The average concentration of sulphate in Futala lake water was 10.27 mgL^{-1} to 28.42 mgL^{-1} (August, 2013); 36.14 mgL^{-1} to 68.32 mgL^{-1} (September, 2013) and 34.18 mgL^{-1} to 68.32 mgL^{-1} (October, 2013) respectively.

Nitrate (NO_3^{-})

The higher values recorded during cold period and it may be attributed to the oxidation of ammonia by nitrifying bacteria and biological nitrification [22]. The higher concentration of nitrate causes Methaemoglobinemia in infants [23]. The average concentration of nitrate in Futala lake water was 0.92 mgL^{-1} to 9.24 mgL^{-1} (August, 2013); 1.92 mgL^{-1} to 10.21 mgL^{-1} (September, 2013) and 1.58 mgL^{-1} to 3.48 mgL^{-1} (October, 2013) respectively.

Total hardness (TH)

Total hardness, a measure of the quality of water supplies, is governed by the content of calcium and magnesium salts combine with carbonate and bicarbonate and with sulphates, chorides and other anions of mineral acids. However total hardness is used to classify water as soft or hard. It is suggested that the total hardness of 50 mg/L of $CaCO_3$ is equivalent to the dividing line between soft and hard water and the water having hardness $\geq$ 15 mg/L is suitable for growth of fishes. Also water with $<$ 5 mg/L $CaCO_3$ is not at all suitable for fish growth.[24] The average concentration of total hardness in Futala lake water was 178 mgL^{-1} to 310 mgL^{-1} (August, 2013); 210 mgL^{-1} to 346 mgL^{-1} (September, 2013) and 220 mgL^{-1} to 394 mgL^{-1} (October, 2013) respectively. Maximum hardness was observed during August due to immersion of idols and minimum values were observed in September due to dilution effect of rain water.

Fluoride(F^{-})

The recommended limit of fluride as per WHO are 1.5 mg/L and 1-1.5 as per IS. Values over 1.5mg/L may cause dental fluorosis or mottling of permanent teeth in children between the ages of birth to 13 years. [12] The average concentration of fluoride in Futala lake water was 1.34 mgL^{-1} to 2.31 mgL^{-1} (August, 2013); 1.98 mgL^{-1} to 4.89 mgL^{-1} (September, 2013) and 1.32 mgL^{-1} to 3.0 mgL^{-1} (October, 2013) respectively.

Iron (Fe^{2+})
Exposure to a combination of water and oxygen causes iron to deteriorate; the casing and pipes contain iron, the acquaintance leads to this deterioration. The average concentration of iron in Futala lake water was 0.34 mgL^{-1} to 0.88 mgL^{-1} (August, 2013); 1.89 mgL^{-1} to 4.51 mgL^{-1} (September, 2013) and 1.44 mgL^{-1} to 3.28 mgL^{-1} (October, 2013) respectively.

Total Phosphate (TP)
Phosphate constitutes important nutrients essential for the growth of organisms. Phosphate occurs in natural water in low quantity as many aquatic plants absorb and store phosphate many times their actual immediate needs.[26] Household detergents, domestic sewage, leaching of phosphate fertilizers may be reason for phosphate level increase in Futala Lake. The high values of phosphate are mainly due to rain, surface water runoff, agriculture runoff and washing activities could have also contributed to the inorganic phosphate content.

Table 6: The classification of lakes on the basis of total phosphate.[26]

Sr. No.	Trophic status	Values of PO_4^{3-} in mg/L
1	Oligotrophic	< 0.005
2	Mesotrophic	0.005 to 0.01
3	Mesoeutrophic	0.01 to 0.03
4	Eutrophic	0.03 to 0.1
5	Hypereutrophic	>0.1 mg/L

The trophics status of Futala lake as per the above classification varies from mesotrophic to hypereutrophic during different months. Increase phosphate concentration beyond 0.2 mg/L increases the growth of phytoplanktons. The average concentration of phosphate in Futala lake water was 0.03 mgL^{-1} to 0.24 mgL^{-1} (August, 2013); 0.05 mgL^{-1} to 0.22 mgL^{-1} (September, 2013) and 0.12 mgL^{-1} to 0.18 mgL^{-1} (October, 2013) respectively.

Electrical conductivity (EC)
Electrical conductivity of water is a direct function of its total dissolved salts and is used as an index to represent the total concentration of soluble salts in water [27]. Excess EC leads to scaling in boilers, corrosion and quality degradation of the product. Conductivity value of Futala Lake water were well within the permissible limit of 3,000 µS/cm. Relatively higher EC values were recorded in the Futala Lake water, attributed to the high degree of anthropogenic activities such as waste disposal, sewage inflow, immersion of idols and agricultural runoff [28] Classification of water based on Electrical conductivity (EC) illustrates that the Futala lake water belongs to medium salinity class (water C2) The mean conductivity values in Futala lake was 380 μmhos/cm to 588 μmhos (August, 2013); 616μmhos/cm to 750 μmhos (September, 2013) and 630 μmhos/cm to 740 μmhos (October, 2013) respectively.

Table 7: Classification of irrigation water based on electrical conductivity[9]

Sl. No.	Type of water	Suitability for irrigation
1.	Low salinity water (Cl) conductivity between 100 and 250 µS/cm	Suitable for all types of crops and all kinds of soil. Permissible under normal irrigation practices except in soils of extremely low permeability
2.	Medium salinity water (C2) conductivity between 250 and 750 µS/cm	Can be used, if a moderate amount of leaching occurs. Normal salt tolerant plants can be grown without much salinity control
3.	High salinity water (C3) conductivity between 750 and 2,250 µS/cm	Unsuitable for soil with restricted drainage. Only high-salt tolerant plants can be grown
4.	Very high salinity (C4) conductivity more than 2,250 µS/cm	Unsuitable for irrigation

Irrigational quality parameters
Sodium absorption ratio (SAR)
If the SAR ratio of the water samples in the study area is less than 10, it is excellent for irrigation purposes. The SAR values for each water sample was calculated using the following equation[29]

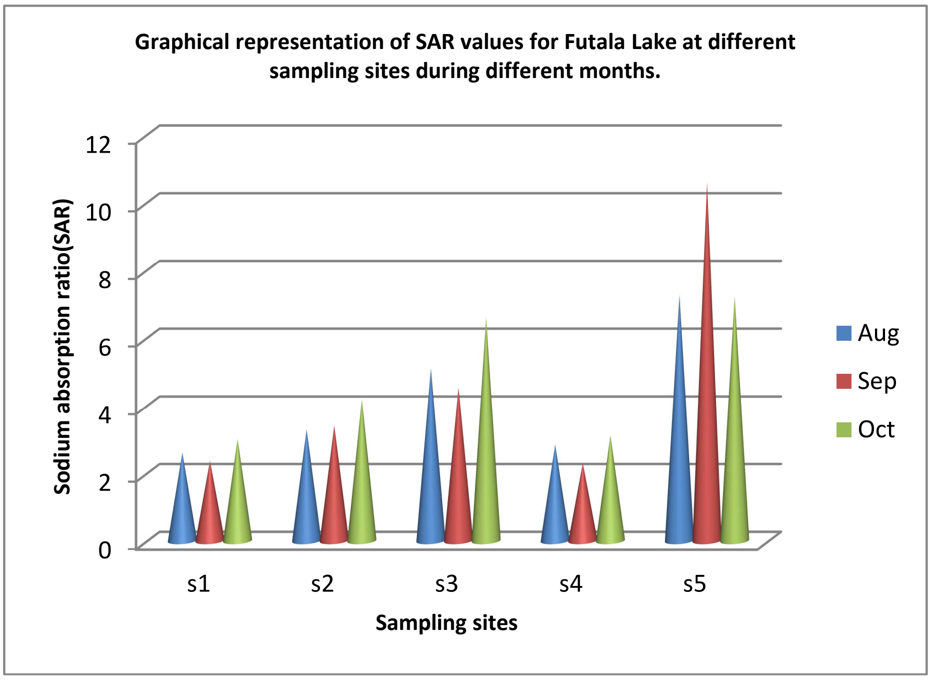
$$SAR = \frac{Na^+}{\sqrt{\frac{(Ca^{2+} + Mg^{2+})}{2}}}$$

According to classification given in Table 7, Futala lake water showed mean SAR value below 10, indicating that lake waters are simply good (S2) for irrigation.

Table 8: Classification of irrigation water based on SAR[29]

Sl. No.	Type of water and SAR value	Quality	Suitability for irrigation
1.	Low sodium water (S1) SAR value: 0-10	Excellent	Suitable for all types of crops and all kinds of soils, except for those crops, which are sensitive to sodium.
2.	Medium sodium water (S2) SAR value: 10-18	Good	Suitable for coarse textured or organic soil with good permeability. Relatively unsuitable in fine textured soils.
3.	High sodium water (S3) SAR value: 18-26	Fair	Harmful for almost all types of soil; Requires good drainage, high leaching gypsum addition
4.	Very high sodium water (S4) SAR value: above 26	Poor	Unsuitable for irrigation

SAR values indicated that Futala Lake water is simply good (S2) for irrigation while electrical conductivity values classified this lake water as medium salinity (C2) category. According to % sodium class, the Futala Lake water is simply good for irrigation purpose. The average concentration of sodium absorption ratio in Futala lake water was 2.60 to 7.26 (August, 2013); 2.36 to 10.6 (September, 2013) and 3.0 to 7.21 (October, 2013) respectively. On the basis of values obtained for SAR Futala lake water can be classified as medium sodium water (S2) SAR values: 10-18, good, suitable for coarse texture or organic soil with good permeability. Relatively u nsuitable in fine textured soil.



Percent sodium(%Na)

It has been widely recommended that the percentage of sodium in irrigation water should not exceed 50-60, in order to avoid its deleterious effects on soil. When the percent sodium exceeds 60, the water is considered to be unsuitable for irrigation purposes. It is considered, that water is of class I quality if the % sodium is less than 30%, class II quality if the % sodium is between 30 and 75, and of class III quality if it is more than 75. Percent sodium can be determined using the following formula:

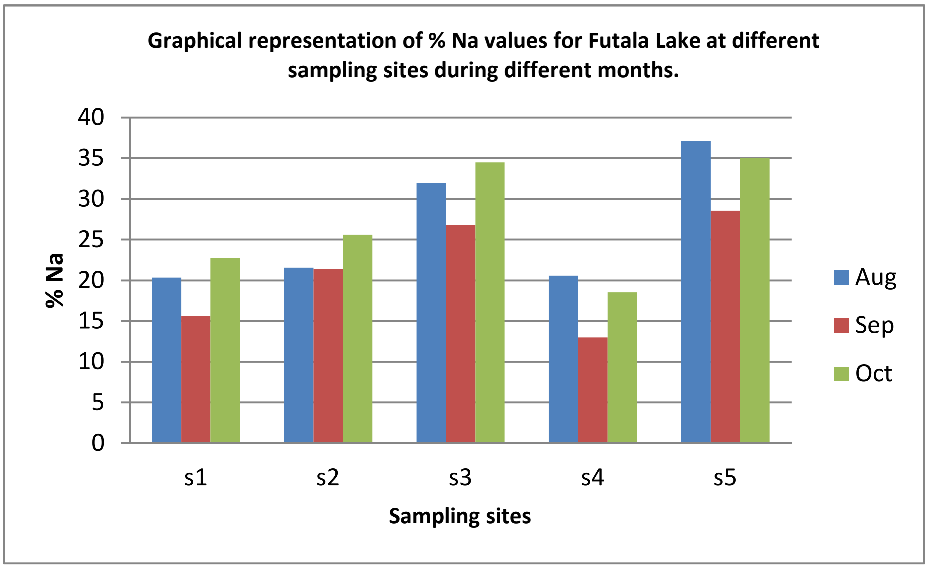
$$\%Na = \frac{Na}{(Ca + Mg + K + Na)} \times 100$$

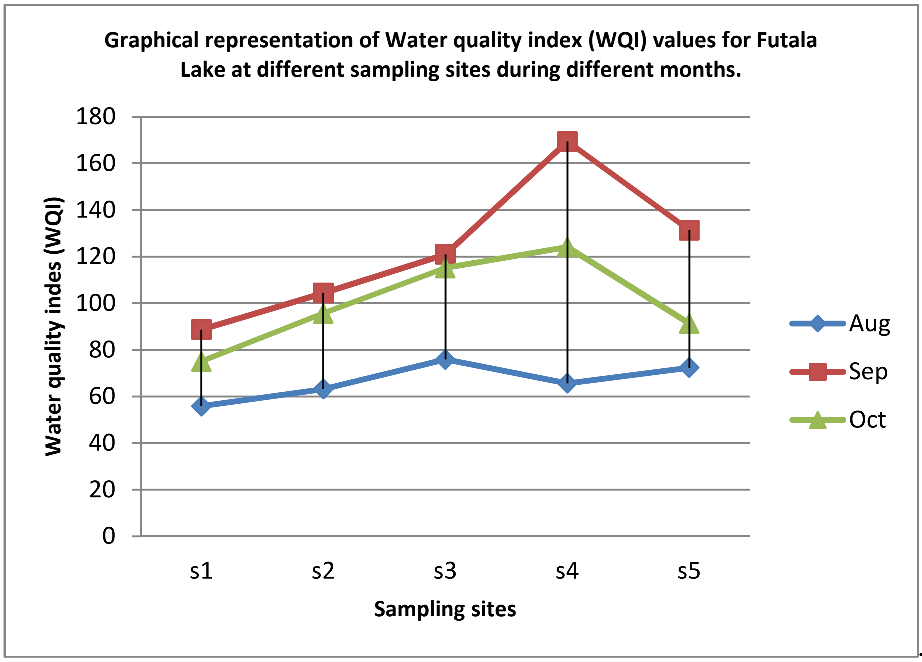
Where the concentration of Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} are expressed in milliequivalents per litre (epm or meq/L). Soil permeability has been found to be affected by high sodium ratio. Water quality reflected by sodium percentage values can be categorized as shown in Table 9.

Table 9: Sodium percent water class [30]

Sodium (%)	Water class
<20	Excellent
20-40	Good
40-60	Permissible
60-80	Doubtful
>80	Unsuitable

The average concentration of % sodium in Futala lake water was 20.32 mgL^{-1} to 37.10 mgL^{-1} (August, 2013); 12.98 mgL^{-1} to 28.53 mgL^{-1} (September, 2013) and 18.54 mgL^{-1} to 35.02 mgL^{-1} (October, 2013) respectively. On the basis of average values for %Na in Futala lake , it is simply good, permissible for irrigation purpose.





Water quality index(WQI)

A water quality index is a means to summarize large amounts of water quality data into simple terms for reporting to management and the public in a consistent manner.

Table 10: Water quality status based on water quality index.[9]

Water Quality Index	Water Quality Status
WQI<50	Excellent Water Quality
50>WQI<100	Good Water Quality
100>WQI<200	Poor Water Quality
200>WQI<300	Very Poor Water Quality
WQI>300	Unfit for drinking

The average concentration of water quality index in Futala lake water was 55.81 to 75.83 (August, 2013); 88.72 to 169.37 (September, 2013) and 75.01 to 124.13 (October, 2013) respectively. The average values of WQI calculated for Futala lake shows given lake water quality is poor.

Hence, the analysis revealed that the surface water of Futala lake needs some degree of treatment before usage and it is essential to protect them from the perils of contamination.

CONCLUSION

Rainfall, slope and land use pattern influence the level of soil erosion and release nutrients into lake water bodies. Total nitrogen fluctuation may be due to microbial utilization as well as due to the varying agricultural inflows. Electrical conductivity classified Futala lake to be medium salinity class. In the present study, it is found that water quality problems associated with Futala Lake includes severe dissolved oxygen depletion, poor water clarity, and high level of algae growth, blue green algae blooms and dense beds of aquatic microphytes. The quality of Futala Lake water is no longer good to support micro flora and fauna also in terms of fish productivity. The present study revealed that Futala lake water is polluted (due to surface run-off, washing activities, agriculture run-off, effluents from upstream from surrounding residential area, immersion of idols of God and Goddess during festival season, discharge of domestic sewage (poor) and dumping of garbage) and unsuitable for human consumption also for the survival of life forms unless treated properly. Therefore pollution parameters must be regularly monitored and evaluated according to aquatic living and local regulations. The suggested measures to improve the lake water quality includes total ban on the activities (including idols immersion) that causes pollution. Awareness, proper understanding, planning and management of environmental resources is essential to prevent environment degradation of these resources.

Acknowledgement
The author is thankful to the Director, Laxminarayan Institute of Technology, RTM Nagpur University, Nagpur for providing necessary facilities for carrying out laboratory work.

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