Preliminary water quality assessment of Baraila Lake, Vaishali, India

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***Abstract*: Water is one of the most important natural resources on the planet. Quantity and quality of water matters a lot for the biosphere and these are dependent on natural and anthropogenic factors. This study was carried out to assess the preliminary water quality of Baraila lake situated in the heart of Salim Ali Jubba Sahni Bird Sanctuary in Baraila of Vaishali District in the State Bihar, India. It is the largest wetland of Vaishali district present in the Gangetic plain. 11 water parameters for assessment of water quality were identified. The water quality index was calculated by the weighted arithmetic method. Physico-Chemical water quality parameters; pH, TDS, DO, electrical conductivity, hardness, alkalinity, calcium, magnesium, sulphate, nitrate and chloride were included in WQI. The WQI Values (>90) put the water unsuitable for drinking purposes but can be used in irrigation, fishing, industries etc. In order to improve water quality and quantity few recommendations are also suggested.**

***Keywords*: water parameters, water quality index (WQI), Wetland, Baraila Lake, weighted arithmetic method.**

1. INTRODUCTION

Water is one of the basic natural resources which is utilized by almost all living beings. It is present on the surface of the earth as surface water and below the surface as ground water. Water reservoirs on the surface are oceans, rivers, streams, ponds, lakes, glaciers etc. Our blue planet has plenty of water but the fresh water, which is the basic necessity for sustenance, is very scarce. Water resources which we consume in different activities are not simply dihydrogen oxide. Different cations and anions are present in aquatic ecosystems and they are essential for survival of living beings but concentration of these ions has a certain permissible range for their consumption and excessive concentration of different ions causes many issues. Due to continuous increase in population size, changing lifestyle, urban sprawl, industrial demands, intensive agricultural practices, climate change, negligence of proper care of water reservoirs, we are facing scarcity of water across the world.

Socio -economic activities are important parameters to measure the development of any economy. But for many decades, proper inclusion of the concept of sustainability in the development has been lacking and hence the pace of water contamination and deterioration has accelerated. Apart from quantity of water, quality of water is also continuously deteriorating due to anthropogenic activities, industrial and urban sewage discharge, agricultural runoff etc. in the water bodies. Nowadays, quality and quantity of water become an important concern due to a gap in the demand and availability of water. Without water life cannot be sustained while poor quality of water is not only threatening human life but also negatively affects the biodiversity and ultimately the whole ecological balance. Therefore, it is necessary to understand the importance of various water parameters which must be maintained. It is important to examine the suitability of water for human consumption, irrigation, aquatic biodiversity etc.

Water quality index (WQI) is the most effective way to represent the status of water quality of a water body. WQI is a water quality monitoring tool. It is a number which is obtained by integrating different water parameters with appropriate weightage of each parameter. WQI aims at giving a single value to the water quality of a source by translating this list of parameters and their concentration present in a sample into a single value, which in turn provides an extensive interpretation of the quality of water and its suitability for various purposes like drinking, irrigation, fishing etc. [2]. In other words, water quality indices are necessary for simplifying the reporting of complex and communication of water quality data to a single unitless digit which expresses overall water quality.

Although Baraila lake has central importance in the Salim Ali Jubba Sahni Bird Sanctuary, biodiversity of wetland, local ecosystem and local population, but literature survey revealed that very few and limited work on WQI of Baraila lake has been carried out. From this study it has been tried to find the preliminary water quality index of Baraila wetland on the basis of various water parameters which have an important contribution to quality of water by using weighted arithmetic index method.

2. MATERIALS AND METHODS

Study Area

Vaishali

The Baraila wetland is a seasonally flooded area which is located in lower Gangetic plain of Vaishali district, Bihar. Vaishali is a district of Bihar having a great historical importance as credited with being the first republic across the world and birth place of Lord Mahavira, founder of Jainism. The district is spread over 2036 sq. km area and situated north of Patna, capital of Bihar [3]. The projected population of Vaishali district in 2023 is 45.11 lakhs [4]. Since urbanization is less than 10%, agriculture-based economy is prevailing in the district. This district comprises quaternary alluvium plain brought by the Ganga, the Gandak and distributaries of Gandak. In the alluvium plain, there are entisols and inceptisols which are rich in potash and lime.

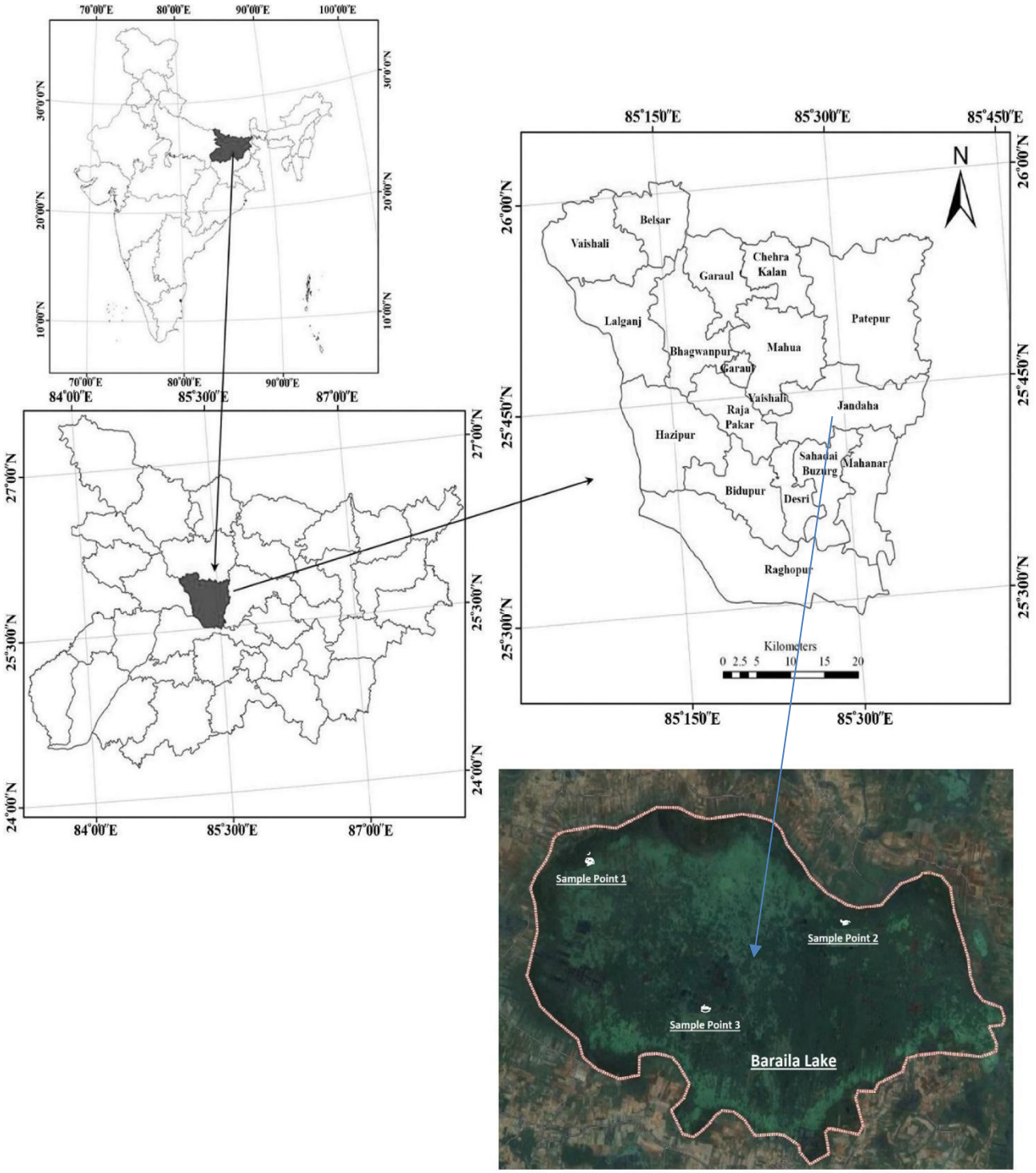
The district has several small patches of area which remain submerged for longer periods. 9036 hectares are wetlands in the district, out of which Baraila lake or wetland is the largest one. In this study Baraila lake and Baraila wetland are used synonymously.

Baraila lake/ wetland

Baraila lake or wetland has an aggregate area of 12.7 square kilometers located in between 25°45’ 58”and 25° 45' 37” north latitude and between 85°31’48” and 85°34’ 50” east longitude [4]. Locally it is also called Baraila tal and it is extended in Patepur and Jandaha block. Due to the ecological importance of this wetland its few parts were declared as sanctuary by the government of Bihar in the year 1997 while the Salim Ali Jubba Sahni Baraila bird sanctuary was published in the Gazette of India in 2016.

The Climatic Condition of the wetland is monsoon type. The winter comes in December and lasts up to February while summer comes in March and lasts up to June. The average annual rainfall in this area is 1168 mm. In winter, temperature ranges between 4℃ to 16℃ and in summer temperature ranges between 40℃. Usually during summer, most of the wetland becomes dry. On the commencement of monsoon, the wetland receives water from the catchment area, Gandak canal, Baya River and Noon River.

Baraila wetland has a great ecological importance. It is the largest wetland of Vaishali district which provides habitats for migratory birds and also various fauna like fish, amphibians, reptiles etc. are present. The water is mainly used for agricultural purposes, fishing, outdoor bathing, and cultural purposes by the population of villages around the wetland.



Sample Collection and analysis

Water samples were collected from 3 locations randomly in February, 2019. Samples were collected in pre-cleaned high density polypropylene bottles. Samples were brought to the laboratory in an ice box and stored at 4°C. Further analysis was carried out within 48 hours. Samples were analyzed for 11 parameters by following standard procedures of the American Public Health Association (APHA 2005) and BIS [6,7]. All experimental glasswares were cleaned with lab grade soap, pre-soaked with 4% nitric acid followed by rinsing with deionised water.

Water Quality Index (WQI)

Water quality index was calculated to address potability and pollution present in Baraila wetland. For the calculation of WQI, Standards of drinking water quality recommended by World Health organization (WHO), Bureau of Indian standard (BIS) and Indian Council of Medical Research (ICMR) were used. The Weighted Arithmetic Index was used for assessing WQI. Following are the different steps in the calculation of WQI: -

I. Selection of water parameters for measures of water quality and development of quality rating for nth parameter.

$$q_n = [v_n - v_i]/[s_n - v_i] \times 100$$

where qn= Quality rating for the nth parameter
vn= Observed value of nth parameter
vi= Ideal value of nth parameter
sn= standard permissible value of nth parameter

II. Unit weight (Wn) was calculated. Its value was inversely proportional to the standard permissible value of the corresponding nth parameter.

$$wn \ \alpha \ 1/sn$$
$$wn = k/s_n$$

III. Determination of sub index value Wnqn for each parameter.
IV. Aggregation of unit weight of all parameters W_n
V. Aggregation of Sub-indices $\sum W_n q_n$
VI. Calculation of WQI

$$WQI = \sum W_n q_n / \sum W_n = W_1 q_1 + W_2 q_2 + .../W_1 + W_2 + ...$$

In the present study, WQI is Calculated by the arithmetic weighted index method as described by Brown et al. (1972) [8].

Table l : WQI range, status and possible use of water (Brown et al. 1972)

Sl. No.	WQI	Water Quality Status (WQS)	Possible Uses
1.	0-25	Excellent	Drinking, Irrigation, Industrial
2.	26-50	Good	Drinking, Irrigation, Industrial
3.	51-75	Poor	Irrigation and Industrial
4.	75-100	Very Poor	Irrigation
5.	Above 100	Unsuitable for drinking and fish culture	Proper treatment required before use.

Table 2: Permissible limits of water parameters [8,9]

Sl. No.	Parameters	Permissible Limit	Source
1.	pH	6.5-8.5	BIS
2.	TDS	500(mg/L)	BIS
3.	DO	5(mg/L)	BIS
4.	Conductivity	400 (µS/L)	WHO
5.	Hardness	300 (mg/L)	BIS
6.	Alkalinity	200 (mg/L)	BIS
7.	Magnesium	30 (mg/L)	BIS
8.	Calcium	75 (mg/L)	BIS
9.	Nitrate	45 (mg/L)	BIS
10.	Sulphate	200 (mg/L)	BIS
11.	Chloride	250 (mg/L)	BIS

RESULT AND DISCUSSION

Water quality is defined as those physical, chemical or biological characteristics of water by which users evaluate the acceptability of water [9]. Different physico–Chemical water quality parameters; pH, electrical conductivity, total dissolved solids (TDS), dissolved oxygen (DO), hardness, alkalinity, magnesium, calcium, nitrate, sulphate and chloride were analyzed and accordingly water quality index (WQI) was also calculated.

Water Quality Parameters

I. pH, Electrical Conductivity, TDS and DO

pH: The pH of water is a very important water parameter concerning water quality as it determines the solubility and availability of other chemicals present in the water. The pH of water is the indicator of acidic or alkaline status of water which ranges from 0 to 14. Moderate pH was present at all the sites of Baraila lake. It ranges from 7.62 to 7.85. Moderate pH is good for survival of wetland ecosystems.

Electrical Conductivity: Pure water is an insulator of electric current. The presence of ions in water makes conducting. Electrical conductivity of water is a measure of its capacity to conduct electric current. It varies directly with the temperature and it is proportional to its dissolved inorganic salts [10]. It can measure contaminants in water. Electrical conductivity values vary from range 336-339µS /cm. The permissible limit of electrical conductivity is 400 µS/cm. Conductivity is below the permissible limit but is not low enough, so reflects contaminants in the wetland.

DO: DO is that indicator of water quality which determines the metabolism of all life forms present in the water body. DO in water depends on the physical, chemical and biochemical activities in the water. It is also dependent on temperature and rate of photosynthesis. In this study, the value of DO ranges from 4.98 mg/L to 5.5 mg/L while the permissible limit is 5.0 mg/L.

TDS: TDS are the portion of volatile and non-volatile solids present in water. It depends on geographical parameters, agricultural activities, soil erosion, pollutants etc. The value of TDS ranges from 162 mg/L to 163 mg/L which is far below the permissible limit, 500 mg/L.

II. Total Hardness and Alkalinity

Total Hardness: Hardness in water is the traditional way to measure the capacity of water to react with soap. The principal hardness causing ions are alkaline earth metals; calcium and magnesium. Hardness in water of Baraila lake ranges from 168 mg/L to 173 mg/L while the permissible limit is 300 mg/L.

Alkalinity: Although many materials contribute to the alkalinity of water, the major portion of alkalinity in aquatic ecosystems is bicarbonate, carbonate and hydroxide. Alkalinity of water acts as a buffer to resist acid. Thus, alkalinity in measure of the buffer capacity of aquatic ecosystems. Alkalinity of Bariala lake was found between 198 mg/L to 214 mg/L while the permissible limit is 200 mg/L.

III. Water chemistry of ions

Cations and anions play an important role in hydrochemistry as together they form salts and thus are responsible for water types in the water body. The maximum permissible limit of cations; Ca^{++} and Mg^{++} ions are 75 mg/L and 30 mg/L respectively while the maximum permissible limits of anions; NO_3^-, SO_4^{--} and Cl^- ions are 45 mg/L, 200 mg/L and 250 mg/L respectively.

Magnesium: Magnesium is the 8th most abundant element on the earth crust. It is an important nutrient for all organisms. The source of this ion may be sediment water interaction and anthropogenic factors like domestic waste. It was found from the range 24.29 mg/L to 34.78 mg/L. In BLS-2, the value of concentration of Mg^{++} is high due to anthropogenic activities. Magnesium salts have a laxative effect particularly when present as magnesium sulphate .

Calcium: Calcium is an important nutrient for all organisms and its high concentration does not cause any adverse effect on organisms apart from hardness. Water with high calcium content is undesirable for household uses such as washing, bathing and laundering because of consumption of more soap and other cleaning agents [11]. Calcium was present in Baraila lake between the range of 22.44 mg/L to 32.34 mg/L.

Nitrate: Nitrate nitrogen is the highest oxidized form of nitrogen in water [12]. Large concentrations of nitrate cause serious health hazards to livestock and humans. The sources of nitrate in water bodies are livestock waste, agricultural waste, anthropogenic source of sewage, fertilizer etc. The concentration of NO_3^- present in Baraila lake range from 0.53mg/L to 1.23 mg/L.

Sulphate: Sulphate ions have an important role in hydrochemistry of water bodies. Sulphate ions are converted into sulphide ions by biochemical process which turns to hydrogen sulphide and creates odour problems in the water body. The source of sulphate ions are domestic sewage waste, industrial waste etc. The range of concentration of $SO_4^{--}$is between 4.12 mg/L to 7.69 mg/L which are within the permissible limit.

Chloride: Chloride in the form of Cl^- is present in water. It is generally associated with sodium. Chloride is one of the major anions present in water and its reasonable concentration is not harmful to humans. It has importance in metabolic activities in the human body. High concentration of chloride may damage metallic pipes and also harm growth of plants. The value of Cl^- present in range 41.8 mg/L to 43.9 mg/L which is far below of permissible limit.

WQI: Water quality index of Baraila Lake was calculated. It ranges from 90.36 - 97.36 which shows that the water is not suitable for drinking purposes.

Table 3: The water Quality Index of Barela Lake Site-1 (BLS-1)

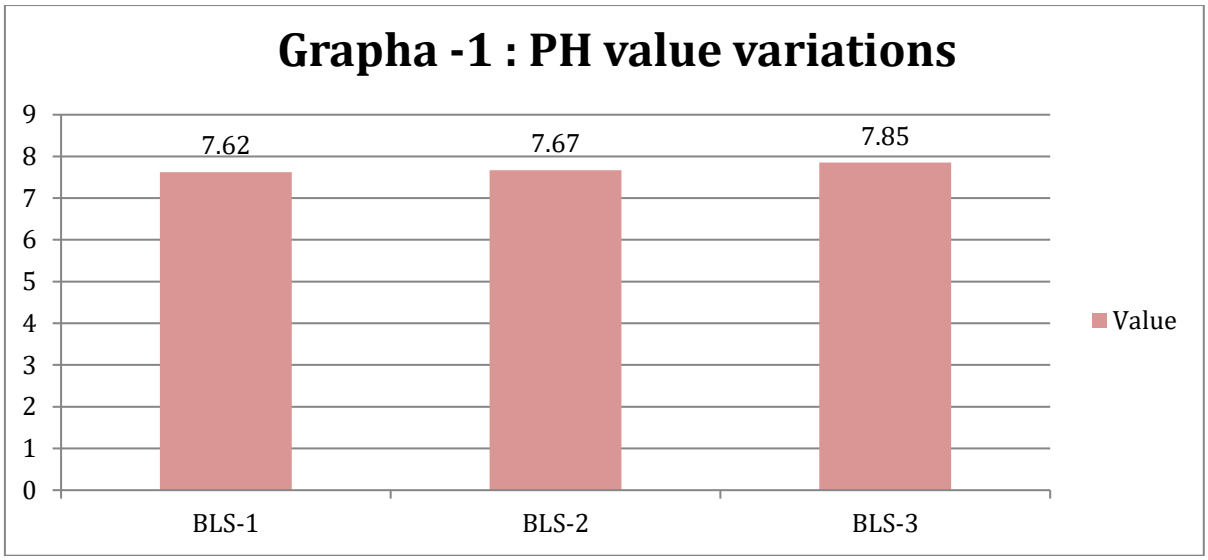
SL. No	Parameters	Vn	Sn	qn	Wn	qnWn	WQI
1	pH	7.62	7.5	101.6	0.31497	32.00	**92.39**
2	TDS	162	500	32.4	0.0047	0.1523	
3	DO	5.2	5	104	0.4725	49.19	
4	Conductivity	337.3	400	84.325	0.0059	0.4975	
5	Hardness	168	300	56	0.00787	0.4407	
6	Alkalinity	198	200	99	0.0118	1.1682	
7	Magnesium	29.15	30	97.17	0.0787	7.647	
8	Calcium	22.44	75	29.92	0.03149	0.9422	
9	Nitrate	1.23	45	2.73	0.0525	0.1433	
10	Sulphate	7.69	200	3.845	0.0118	0.0454	
11	Chloride	43.90	250	17.56	0.0094	0.1658	

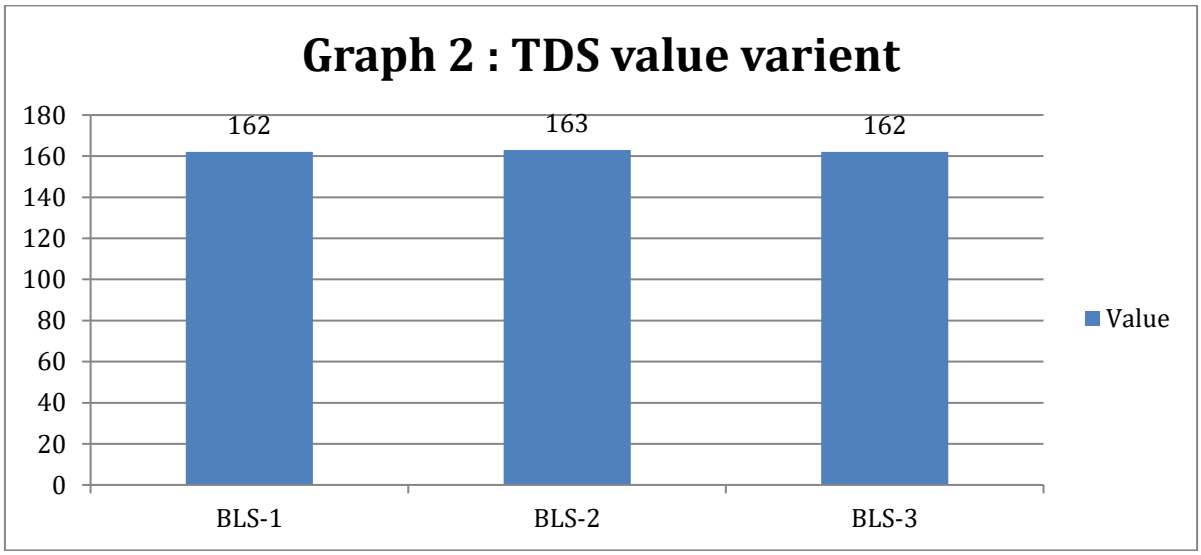
Table 4: The water Quality Index of Barela Lake Site-2 (BLS-2)

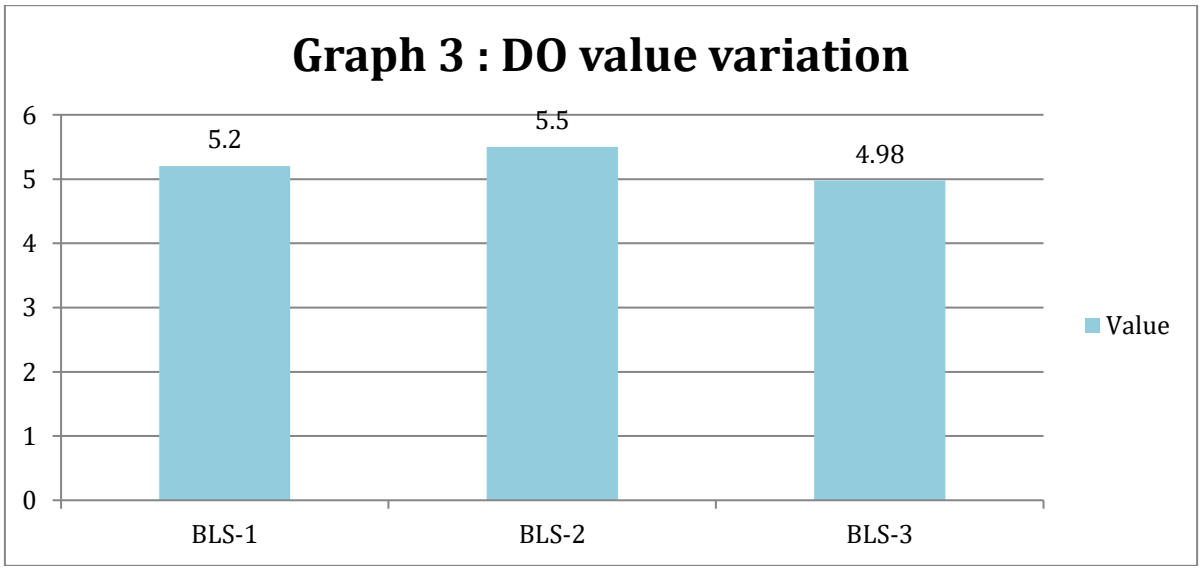
Sl. No	Parameters	Vn	Sn	q_n	Wn	q_nWn	WQI
1	pH	7.76	7.5	103.47	0.31497	32.59	**97.36**
2	TDS	163	500	32.6	0.0047	0.1532	
3	DO	5.5	5.0	110	0.4725	51.975	
4	Conductivity	339	400	84.75	0.059	0.3230	
5	Hardness	172	300	57.33	0.0079	0.4512	
6	Alkalinity	214	200	107	0.0118	1.263	
7	Magnesium	34.78	30	115.93	0.0787	9.124	
8	Calcium	28.86	75	38.48	0.0315	1.212	
9	Nitrate	0.66	45	1.47	0.0525	0.0772	
10	Sulphate	4.13	200	2.065	0.0118	0.0244	
11	Chloride	43.90	250	17.56	0.0094	0.1658	

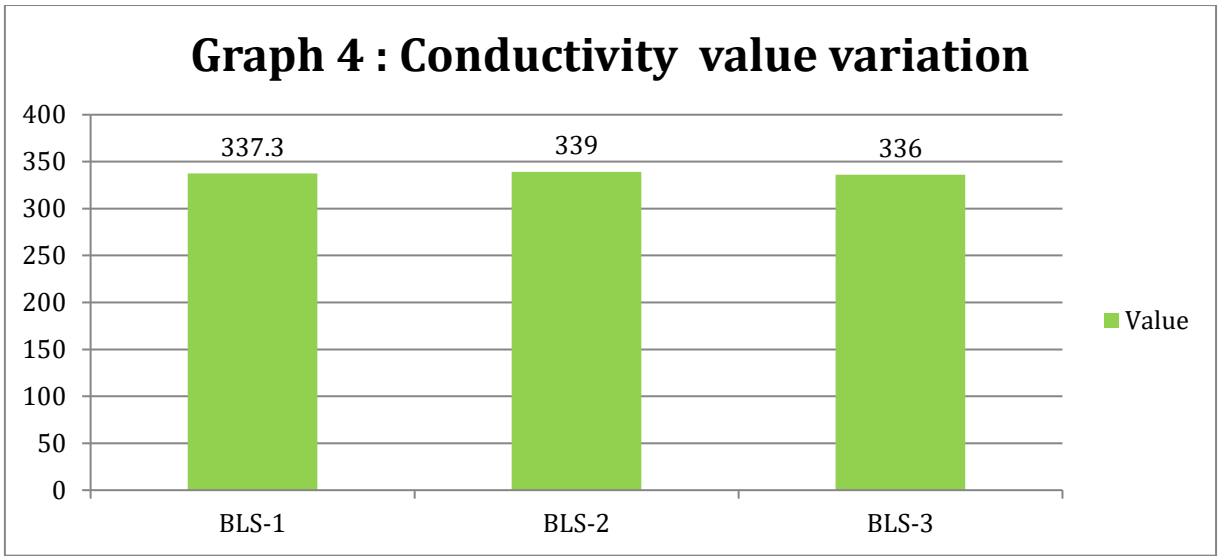
Table 5: The water Quality Index of Barela Lake Site-3 (BLS-3)

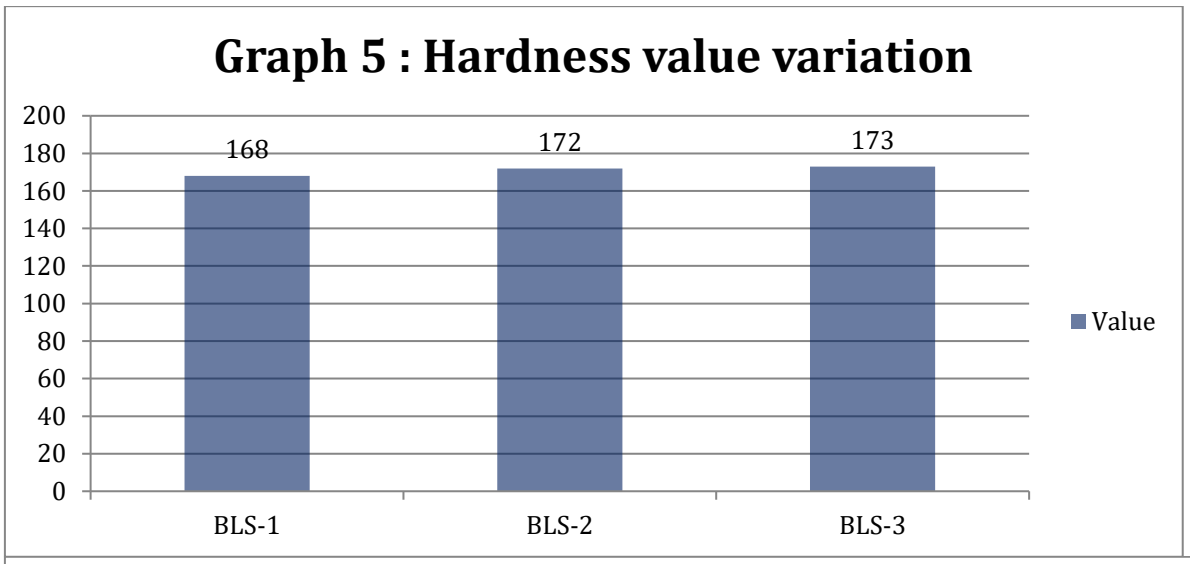
Sl. No	Parameters	Vn	Sn	q_n	Wn	q_nWn	WQI
1	pH	7.85	7.5	104.67	0.315	32.97	**90.36**
2	TDS	162	500	32.4	0.0047	0.152	
3	DO	4.98	5.0	99.6	0.4725	47.06	
4	Conductivity	336	400	84	0.0059	0.496	
5	Hardness	173	300	57.67	0.0079	0.454	
6	Alkalinity	212	200	106	0.0118	1.251	
7	Magnesium	24.29	30	80.97	0.0787	6.372	
8	Calcium	32.34	75	43.12	0.0315	1.358	
9	Nitrate	0.53	45	1.18	0.0525	0.062	
10	Sulphate	6.1	200	3.05	0.0118	0.036	
11	Chloride	41.80	250	16.72	0.0094	0.158	

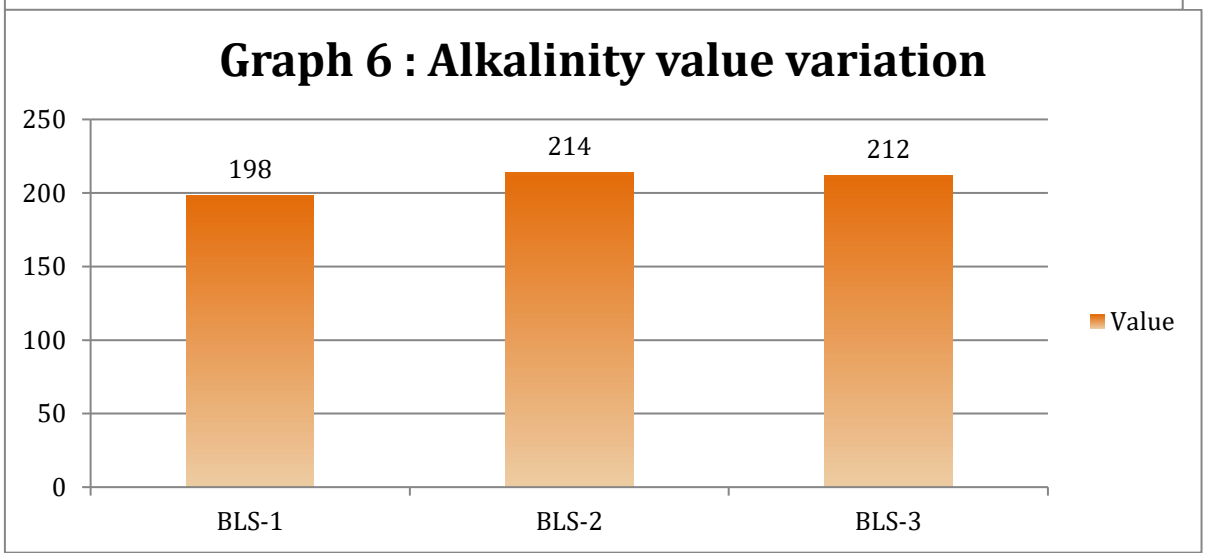

Grapha -1 : PH value variations
9
8
7
6
5
4
3
2
1
0
7.62
7.67
7.85
BLS-1
BLS-2
BLS-3
Value

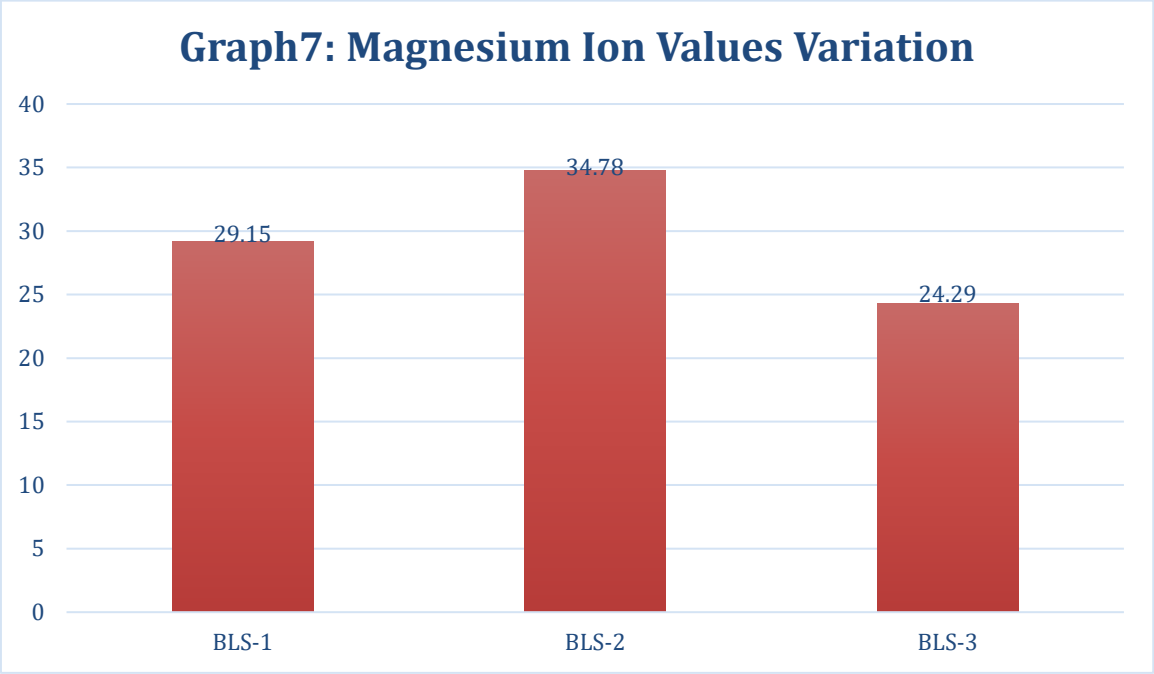

Graph 2 : TDS value varient
180
160
140
120
100
80
60
40
20
0
162
163
162
BLS-1
BLS-2
BLS-3
Value

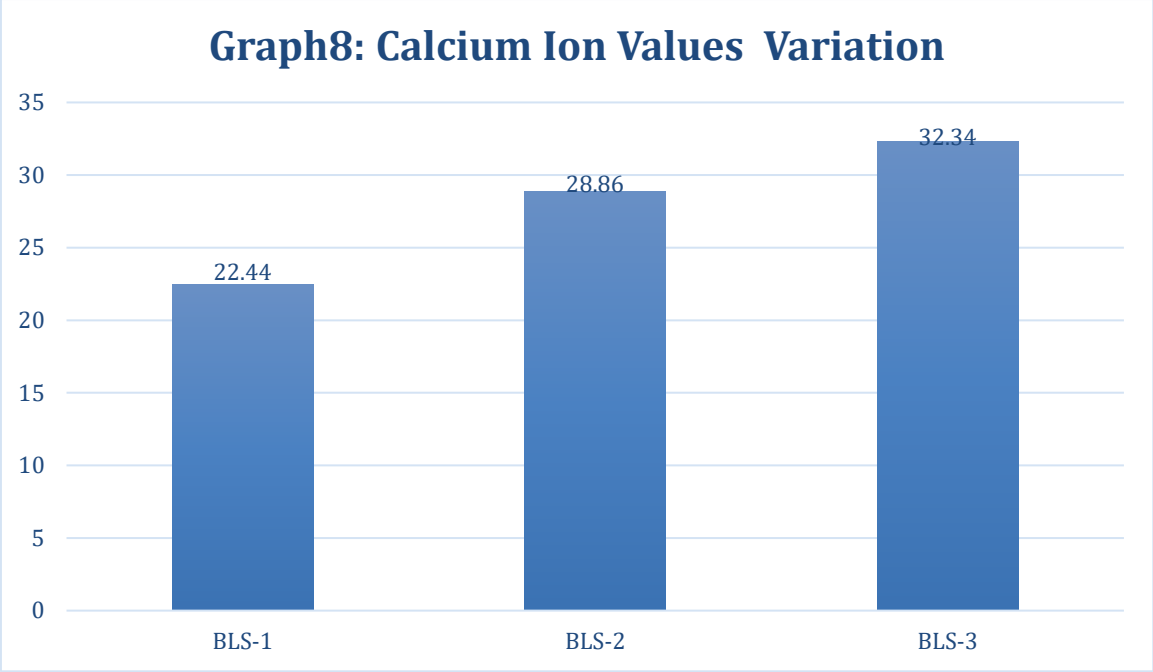

Graph 3 : DO value variation
6
5
4
3
2
1
0
5.2
5.5
4.98
BLS-1
BLS-2
BLS-3
Value

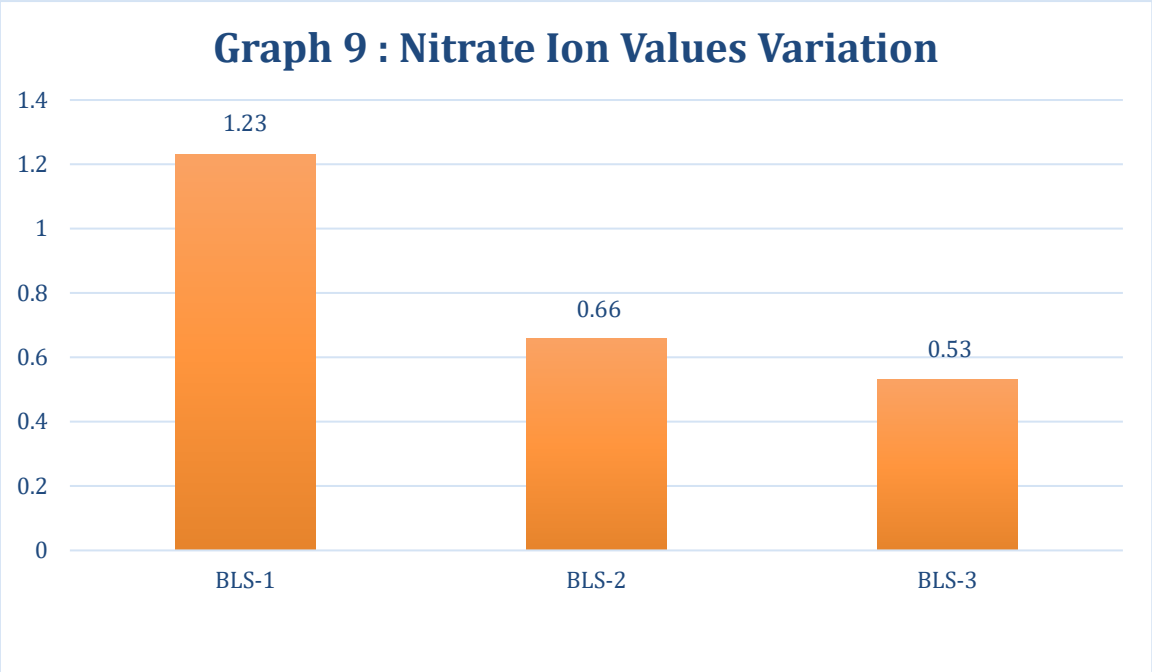

Graph 4 : Conductivity value variation
400
350
300
250
200
150
100
50
0
337.3
339
336
BLS-1
BLS-2
BLS-3
Value

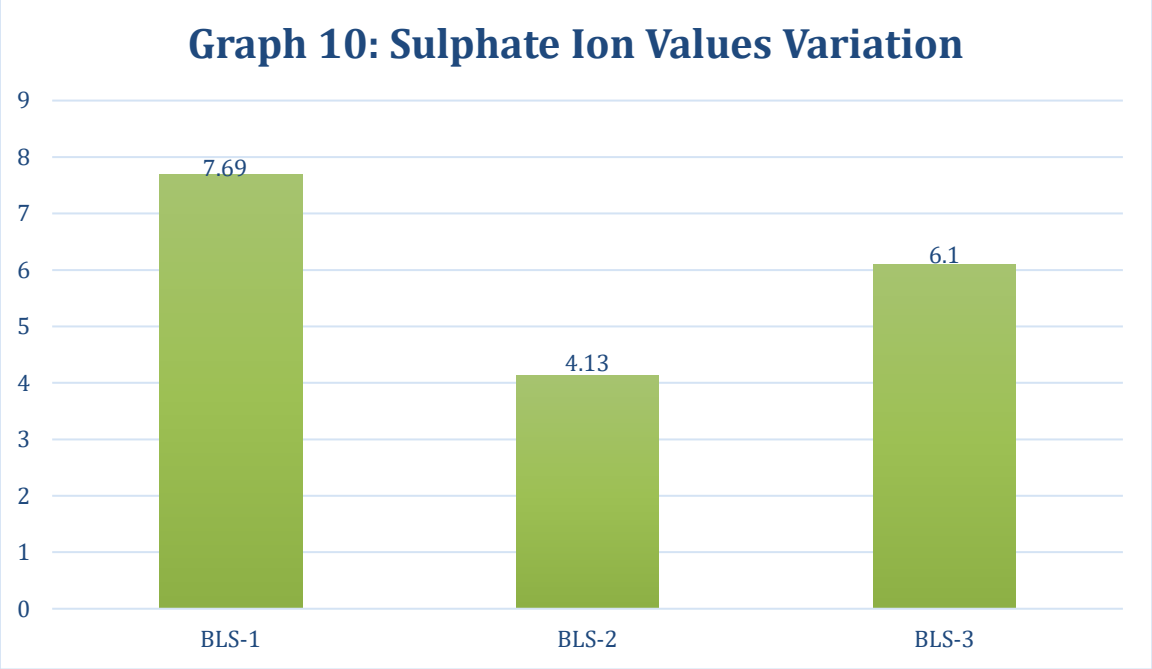

Graph 5 : Hardness value variation
200
180
160
140
120
100
80
60
40
20
0
168
172
173
BLS-1
BLS-2
BLS-3
Value

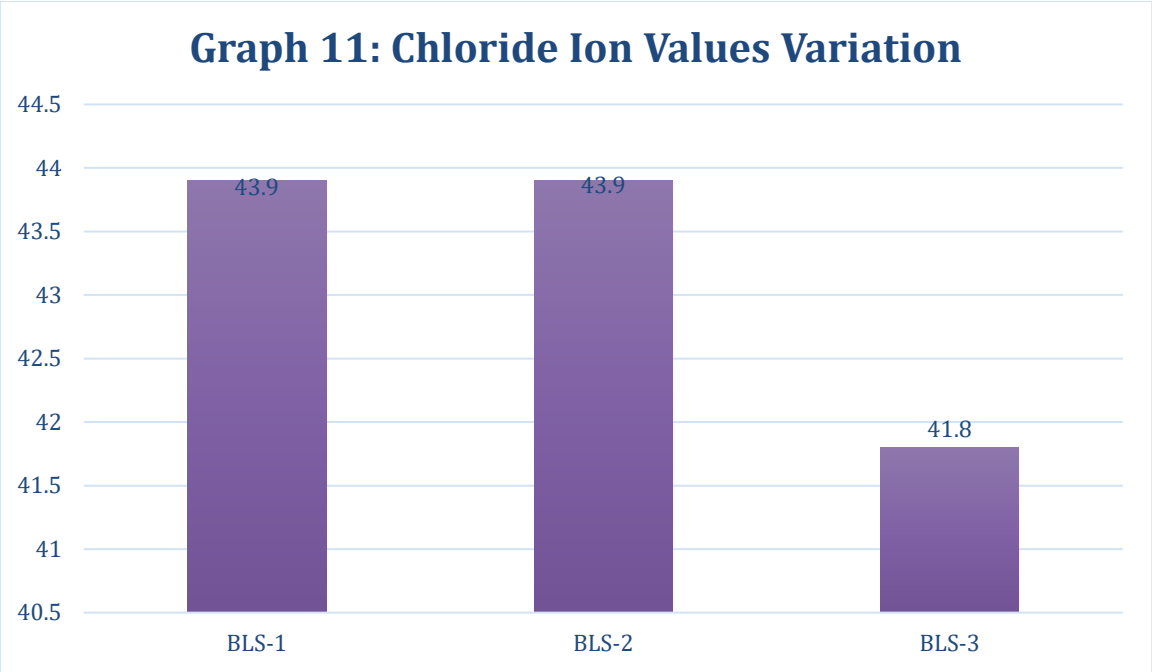

Graph 6 : Alkalinity value variation
250
200
150
100
50
0
198
214
212
BLS-1
BLS-2
BLS-3
Value


Graph7: Magnesium Ion Values Variation
40
35
30
25
20
15
10
5
0
29.15
34.78
24.29
BLS-1
BLS-2
BLS-3


Graph8: Calcium Ion Values Variation
35
30
25
20
15
10
5
0
22.44
28.86
32.34
BLS-1
BLS-2
BLS-3


Graph 9 : Nitrate Ion Values Variation
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1.23
0.66
0.53
BLS-1
BLS-2
BLS-3


Graph 10: Sulphate Ion Values Variation
9
8
7
6
5
4
3
2
1
0
7.69
4.13
6.1
BLS-1
BLS-2
BLS-3



Challenges and Recommendations

Baraila wetland plays an important role in maintaining hydrological regimes of the region. Actually, water forms the chief constituent of the ecosystem [13]. Many organisms depend on freshwater for survival and humans frequently depend on lakes for a great many "goods and services "such as drinking water, waste removal, fisheries, irrigation, industrial activities and reaction [14]. Villagers around the Baraila lake harvest fish and aquatic plants for use as food, fodder. Salim Ali Jubba Sahni Bird Sanctuary is there and this wetland is one of the important heavens for migratory birds in north Bihar. In Spite of such ecological socio-economic significance, management of Baraila lake has received little attention. Also, the perception of the locals is that this is a water-logged wasteland and interested in developing this wetland for permanent agriculture. However, in the constitution of India, Part IVA, Article 51A(g) has provision that it shall be the duty of every citizen of India to protect and improve the natural environment including forests, lakes, rivers and wildlife and to have compassion for living creatures [15]. So, conservation and wise use of all wetlands through local and national actions and international cooperation as a contribution towards achieving sustainable development throughout the world. Need of proper management and conservation of Baraila lake is urgent because of environmental, social, cultural and economic reasons.

Recommendations

- Steps should be taken to convert the lake from seasonal to perennial by connecting it through Baya River and Noon River.
- Plantation and conservation of plants should be done to revert the trend of reducing numbers of migratory birds. Plantation through 'Jeevika didi' should be done.
- Quality of water should be maintained by practicing green agriculture around the wetland area.
- It should be developed as a proper tourist place as it is very near to Patna, capital city of Bihar. The only need is a good approach road to the lake and development of basic facilities for a tourist place. It will generate employment and income of locals and interest to convert wetland into agricultural land will be diminished.
- Locals should be involved in conservation and management.

CONCLUSION

In this study, preliminary water quality assessment of Baraila Lake reveals that water quality status is very poor, as the water quality index ranges from 90.36 to 97.36. It is not suitable for drinking purposes but suitable for irrigation and fishing. Dissolved oxygen, electrical conductivity, magnesium are more than permissible limits and these parameters have significant contribution in compromising water quality of this wetland. This wetland is an important surface water resource in the local area for the purpose of irrigation, livestock maintenance, fishing and other daily uses. Also important for maintaining water level in this area, especially in summer. However, the quantity and quality of water is deteriorating. This study reflects the preliminary water quality status of Baraila lake and suggested recommendations can be a support in planning and implementations of conservation and management measures for Baraila lake.

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