Water Quality Analysis of Lake – A Case Study

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Abstract: Due to rapidly increasing population, exponential industrialization and urbanization, etc. various water bodies, all over India are exposed to various forms of environmental degradations. This leads to aggregations of phytoplankton, macro algae and occasionally colourless heterotrophic protists can discolour the water giving rise to foam. Due to this, there is reduction in DO (Dissolved Oxygen) level which ultimately disturbs the ecological balance of the lake and finally leads to eutrophication in water bodies. In the present work, the Ramgarh Lake situated in Gorakhpur, Uttar Pradesh, India has been selected as case study and its physico-chemical water quality parameters have been analysed from sampling. The results show fluctuation of the values which have been analyzed with the help of significant water quality indices. This study reveals the current status of the Ramgarh Lake in terms of water quality as well as classifies the water at the sampling sites in terms of major water quality indices.

1. INTRODUCTION

The lakes and reservoirs, all over the country are exposed to various forms of environmental degradation. The degradation is due to rapidly increasing population, rising standards of living, exponential industrialization and urbanization. Water is most essential but scarce resource in India. Presently the quality and availability of the fresh water resources has many environmental challenges on the national horizon. The stress on water resources is from multiple sources and the impacts can take diverse forms. About 16% of the world population residing in India possesses only 4% of world water resources. Therefore the pressure on water resources in India is very high.

Lakes are dynamic ecosystem that reflects their specific lake basin characteristics, variations in climate and biological components. The size of the lake basin, its depth and volume, quantity and quality of water that enters the lake are important considerations. Lake management activities are implemented on the basis of this information, including surface use regulations, aeration, and native and exotic aquatic plant management. Important water quality issues include the biological productivity of a lake (trophic state), water chemistry profiles, regional water quality comparisons, nutrient concentrations, water transparency, specific pollutants and historical trends. Lake management issues related to the physical characteristics of the lake will require data on the surface area, shape, depth and volume of the lake. The inlet and outlet characteristics and bottom types are also important.

There are various problems related to lake such as excessive influx of sediments from the lake catchment, discharge of untreated or partially treated sewage and industrial waste waters/ solid waste, entry of diffused nutrients source from agricultural and forestry, improper management of storm water, over abstraction, over-exploitation of lake for activities like recreation, fishing, encroachments, land reclamation etc causing lake water shrinkage, shoreline erosion and impacting the lake hydrology, deteriorating water quality, impacting bio diversity, bringing climate changes etc[1]. Therefore, necessary conservation activities must be undertaken to regain/improve the health of water body.

The Gorakhpur city in India has a number of perennial lakes which are sources of fresh water for the local population however in last couple of years they have been blocked by accumulation of silt or by the stocking of pollutants of all kinds. The Ramgarh lake considered in the study is situated on the south-east of Gorakhpur city and the south side of the metalled road to the Kasia in Deoria district . The Ramgarh Lake is rich in fish and supports the livelihood of several villages on its bank. It is also a popular venue for recreational activities. The region of this lake is ecologically fragile and due to rapid urbanization in its catchment, the lake is experiencing an increase in nutrient loading and rapid loss of water quality.

Presently this lake is environmentally polluted due to inflow of untreated sewage and other activities like animal bathing, cloth washing and disposing religious offerings. Due to these activities the lake is in hyper eutrophic condition with abundance of algal bloom. An unplanned human settlement around the lake also poses a serious threat to the lake ecosystem. Considering the current condition of Ramgarh Lake, a comprehensive lake conservation plan needs to be prepared which should include use of environmental friendly fish species and aeration of the whole lake. This conservation should be implemented to reduce the pollution and slowly improve the lake ecosystem.

In the present study, an attempt has been made to present condition of Ramgarh lake and the factors responsible for the same. It is found that conservation program and monitoring

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should be implemented on the lake time to time. At the same time the evaluation of various conservation measures is necessary to check the quality of seriousness of the work done. The prime need is to conserve lake water to meet the future needs.

In this study, Carlson Trophic State Index (CTSI) and National Sanitation Foundation Water Quality Index (NSFWQI) are applied to assess the pollution status of Ramgarh Lake based on the analysis of water quality data.

2. MATERIALS AND METHODS

2.1 Study Area

Ramgarh Taal lake is located in Gorakhpur district which is situated in the north-east "Tarai" region of U.P., India. Ramgarh Lake is one of the important water bodies of this region. It is a natural, shallow, perennial eutrophic lake situated at $26^0$44'9" N and $83^0$24'16"E to the south-eastern side of the Gorakhpur town.

The lake lies within the floodplain of River Rapti. The maximum water depth of the lake was reported to be 4.5 m in 1990s .The lake has a catchment area of more than 11500 ha most of which is urbanized and densely populated. The lake and its catchment are under the control of the Gorakhpur Development Authority (GDA) [2]. The lake is mainly fed by a seasonal Godhariya nallah which joins the lake from the north-east side. It receives storm water runoff and wastewater through several other drains such as the Kuda Ghat Nalla, Mohaddipur Power House Nalla, Golf Ground Nalla and Padley Ganj Nalla. The outflow of the lake, after travercing a distance of about 8 kms, joins the Gurah nallah which merges with river Rapti, about 20 kms away.

The lake is rich in fish and offers living to the people in nearby villages. The water of the lake is also used for recreation and irrigation purposes. During later 1980s, a large tourist complex which included a Buddha museum, a Planetarium, a park and the facilities for water sports, was developed close to the lake. However, in recent years the lake is in limelight as it is engulfed with problems such as pollution and sedimentation. The condition of the lake is reported to be precarious and needs urgent remedial measures for conservation. The lake has been identified for restoration under the National Lake Conservation Plan [2, 3]. At present there are 2 STPs (Sewage Treatment Plant) in Gorakhpur city, one of 30 MLD (Million Litre per Day) and other 15 MLD. Table 1 gives the salient details of this lake.

Table 1. Salient Features of Ramgarh Lake.

City	**Gorakhpur, Uttar Pradesh**
Catchment Area (Ha)	11500
Area (Ha)	678
Maximum depth (M)	3.30
Total Storage Capacity (M^3)	7.36×10^6
Perimeter (Km)	14
Outlet Sill level (M)	71.30
Type of Outflow	Natural deep
Av annual rainfall in the lake catchment area (mm)	1245
Lake water usage	Fishing, Irrigation and Recreation
Area under Irrigation (Ha)	400 Ha

2.2 Sampling Locations

The physical and chemical monitoring of the lake has been done for the period November 2013 - September 2014.The physicochemical analysis includes data of seven parameters such as pH(units), total solids (ppm), turbidity (ntu), D.O (% sat), B.O.D (ppm), Temperature Change (°C), Faecal Coliform (colonies/100 ml), nitrate (ppm), and total phosphate (ppm) . For this study, the water samples available from ten location of the lake i.e. RL1, RL2, RL3, RL4, RL5, RL6, RL7, RL8, RL9 and RL10 were used for analysis. A map of the lake shown in figure 1 indicates the ten sampling locations at different points.

The samples were taken in BOD bottles and brought to the laboratory with necessary precautions for testimonial analysis. Some parameters like temperature, pH and dissolved oxygen were measured on site [4].

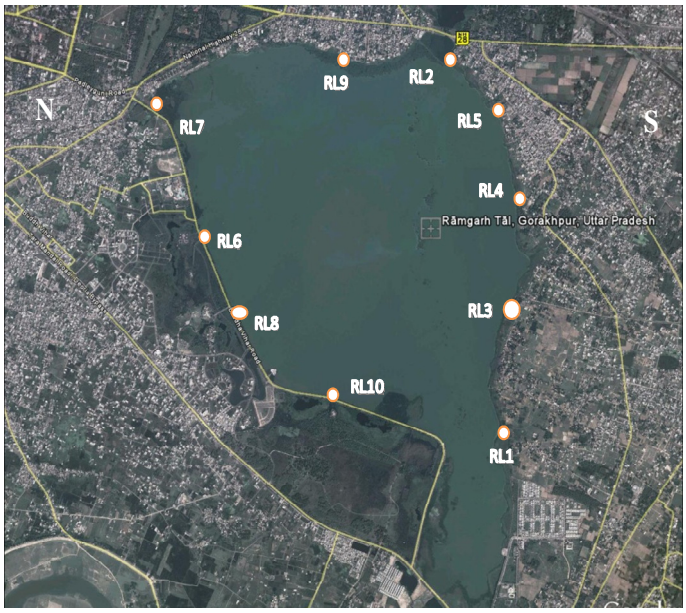

Fig. 1. Map Showing 10 Sampling Stations In Ramgarh Lake, Gorakhpur

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3. RESULTS AND DISCUSSION

Accurate and timely information on the quality of water is necessary to implement the water quality improvement programmes efficiently. The results obtained from analysis of water samples of Ramgarh Lake are shown in fig. 2, 3, 4, 5, 6 and 7. The reported values refer to the mean value of water samples collected in different seasons at different locations along the circumference of lake. The results show that the quality of water varies considerably from location to location. A summary of the findings is given below:

The water temperature of the Ramgarh Lake at Gorakhpur ranged between 29 °C to 34 °C. Moreover, the temperature between top and bottom layers at individual stations was observed to be in the range of 0.2 °C to 2.5 °C with formation of thermocline at many places in the lake body. The presence of thermocline indicates stratification in the lake body with no or minimal mixing patterns. The bottom layers were comparatively cooler as a result of penetration of light to a limited depth in upper region of the lake. This could be attributed to highly turbid nature of the water due to abundant algal growth and other suspended solids [5].

Testing of DO was done by using Digital DO Probe wherein DO readings of lake water at top layer were taken. The observations with respect to DO showed variations over a very wide range with lower value being 6.89 mg/L to 10.2 mg/L. These values correspond to locations RL9 and RL10 respectively. The RL9 is very near to ingress IG1. This feeder carries water in the lake which contains mostly sewage contributed from nearby areas. The station RL10 is located near the outlet in the west side. Overall observations with DO showed that at many stations it was at the saturation to super-saturation levels. The supersaturation values in the range of 9 to 12 mg/L could be mostly attributed to the abundant algal presence in the lake body.

From the biological Oxygen Demand (BOD) the values of minimum 24 mg/L and maximum 61 mg/L for top layers were observed. These observations were for stations RL4 and RL7 respectively. The interpretation of BOD levels could be attributed to sewage ingress and eutrophication status of the lake.

The COD values of water of the lake varied from minimum 104.11 mg/L to maximum 170.08 mg/L for stations RL4 and RL9 respectively. The station RL9 is near ingress IG1 on eastern region of the lake. The station RL4 is near the outlet of the lake.

Phosphate level in Ramgarh Lake was recorded as minimum 0.30 mg/L to maximum 0.44 mg/L. The minimum Phosphorus level at RL5 station was observed. Maximum Phosphorus level is observed at station RL3. Presence of phosphate is an indication of ingress of sewage as well as agricultural runoffs in the lake.

The nitrate- nitrogen shows significant variation. The values range from 0 mg/L to 1.46 mg/L. This also indicates the eutrophic status of the lake.

One of the most effective ways to communicate information on water quality trends is with indices. Water quality index (WQI) is commonly used for the detection and evaluation of water pollution and may be defined as *"a rating that reflects the composite influence of different quality parameters on the overall quality of water."*[6]. An attempt has been made to calculate the water quality index and Trophic State index of the Ramgarh Lake in Gorakhpur on the basis of physicochemical and biological data. The water quality index is calculated using National Sanitation Foundation WQI equations given below. The WQI based on NSF method is given in Table 2.The TSI was calculated by standard equations given below. The TSI based on Carlson method is given in Table 3.The average values of TSI were computed using Carlson's equation to get the TSI of Ramgarh Lake. The assessment is done in terms of seasonal variation in water quality index and Trophic State Index. Water quality Index of Ramgarh lake is established from important nine physiochemical parameters such as pH(units), total solids (ppm), turbidity (ntu), D.O (% sat), B.O.D (ppm), Temperature Change (°C), Faecal Coliform (colonies/100 ml), nitrate (ppm), and total phosphate (ppm). The values of Water Quality Index and Trophic State Index for various physicochemical parameters are presented in Fig 2 and 3 respectively. Water quality index (WQI) of surface water of Ramgarh Lake of 10 sampling stations of Gorakhpur ranged from 52 to 63 indicating medium quality of water. WQI was calculated to find the suitability of water for drinking purposes. An appropriate method for improving the surface water quality in the affected areas is considered for suitable treatment. WQI values ranges from 0 (very bad) to 100 (excellent). WQI scores were grouped into five categories that serve to summarize the overall state of the water quality.

Table 2. NSF Water Quality Index Legend.

Range	Quality
90-100	Excellent
70-90	Good
50-70	Medium
25-50	Bad
0-25	Very bad

3.1National Sanitation Foundation Water Quality Index

Water quality Index (WQI) provides a single number which expresses the overall water quality at a certain location and time based on several water quality parameters. The objective

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of the index is to convert the complex physicochemical parameters into information that is usable and understandable. It is one of the most effective tools to communicate the water quality information between policy makers and other stakeholders. National Sanitation Foundation Water quality Index (NSFWQI) of USA was proposed by Horton in 1965 which is considered to be one of the most acceptable and convenient WQI . The NSFWQI, which is used for the assessment of water quality of Ramgarh lake, is expressed as following equation: [7]

$$WQI = \sum W_i Q_i$$

Where Q_i: Sub index for i^{th} water quality parameter;
Wi: Weight associated with quality parameter;
n: Number of water quality parameters

3.2 Carlson Trophic State Index

The trophic status is a measure of the trophic status of a water body using several measures of water quality including: turbidity, chlorophyll-a and total phosphorus levels. TSI helps in rating individual lakes, ponds and reservoirs based on the amount of biological productivity occurring in the water. The extent of productivity of a lake can be determined using the index. The overall trophic state index (TSI) of a lake is the average of the TSI for phosphorus, the TSI for chlorophyll-a and the TSI for secchi depth; therefore, it can be thought of as the lake condition taking into account phosphorus, chlorophyll-a and secchi depth. An increasing trend in TSI over a period of several years may indicate the degradation of the health of a lake.

TSI and water quality index for lakes and rivers respectively was developed by Carlson [8]. The following equations can be used to compute the Carlson's TSI.

TSI-P = 14.42 * Ln [TP] + 4.15 (in ug/L)..... (a)

TSI-C = 30.6 + 9.81 Ln [Chlor-a] (ug/L)..... (b)

TSI-S = 60 – 14.41 * Ln [SD] (in meters)..... (c)

Average TSI = [TSI (P) + TSI (CHL 'a') + TSI (SD)]/3 (d)

Where TP is total phosphorus, chlor 'a' is chlorophyll 'a', SD the sechhi depth.

Table 3. TSI Based on Carlson's Method.

S. No.	Trophic State	Carlson's TSI Range
1	Oligotrophic	10-30
2.	Mesotrophic	31-50
3	Eutrophic	51-70
4	Hypertrophic	71-90, >90

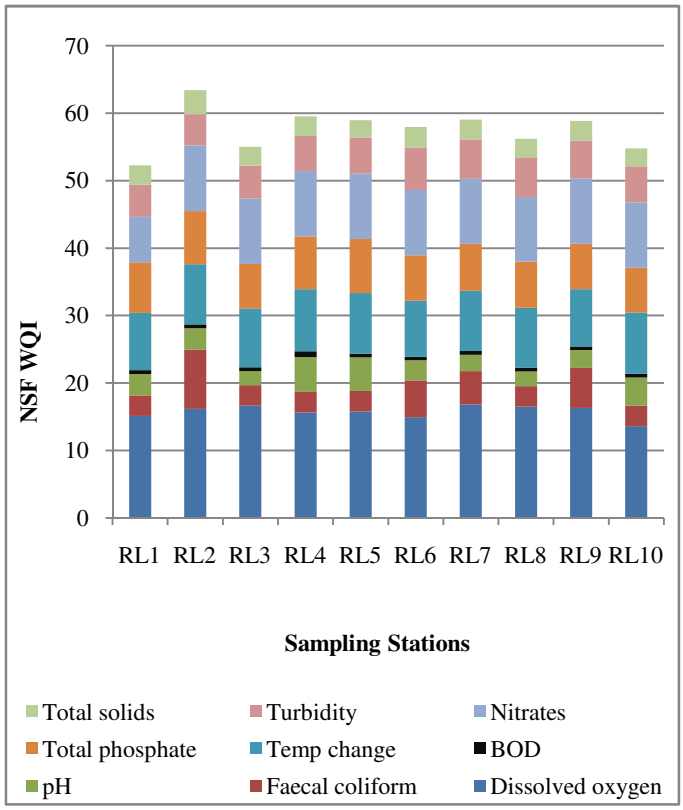

Fig. 2. National Sanitation Foundation Water Quality Index Values at 10 Sampling Stations in Ramgarh Lake

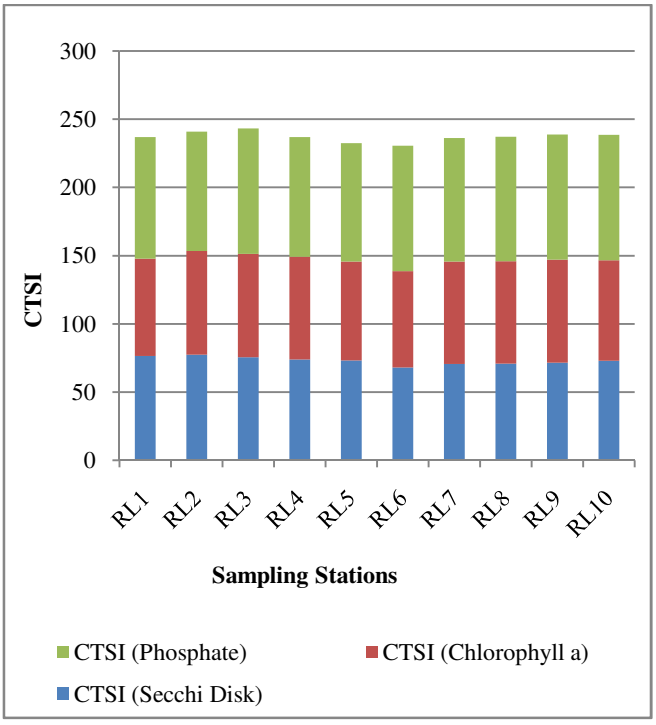

Fig. 3. Carlson Trophic State Index (CTSI) Values at 10 Sampling Stations in Ramgarh Lake

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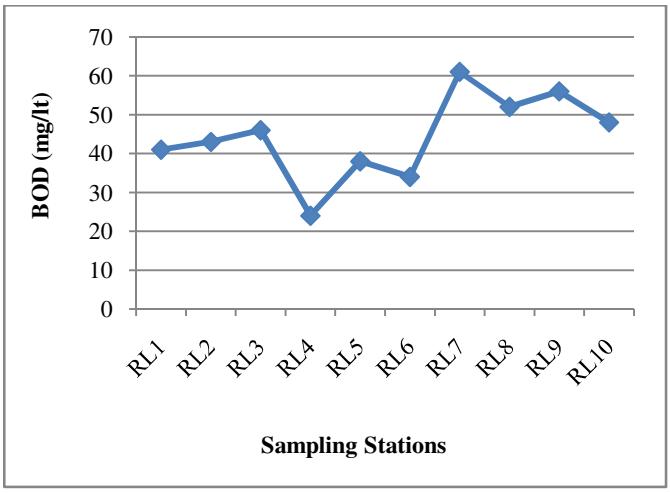

Fig. 4. Biological Oxygen Demand (BOD) Trend at 10 Sampling Stations in Ramgarh Lake

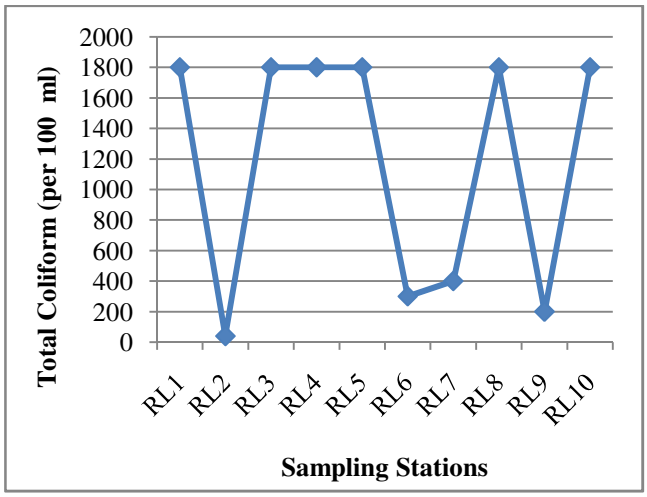

Fig. 5. Total Coliform Trend at 10 Sampling Stations in Ramgarh Lake

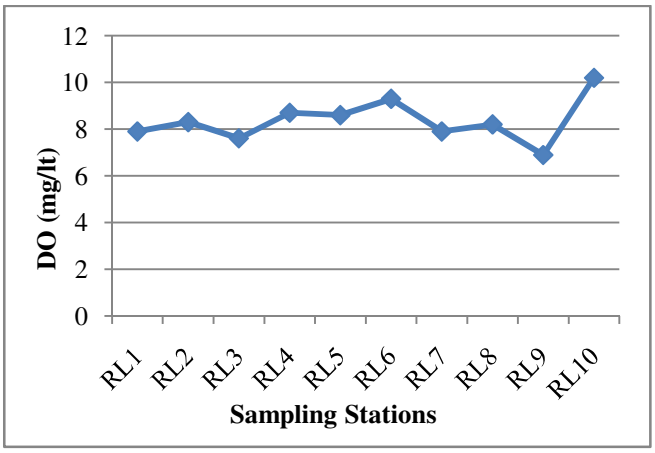

Fig. 6. Dissolved Oxygen Trend at 10 Sampling Stations in Ramgarh Lake

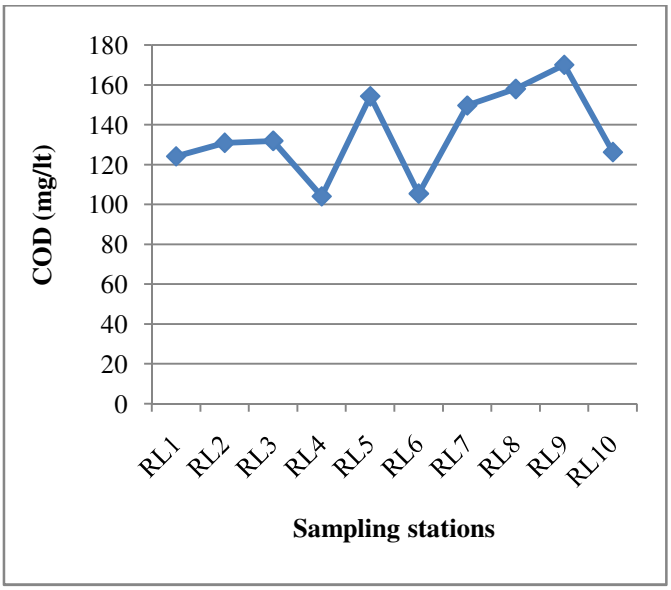

Fig. 7. Chemical Oxygen Demand (COD) Trend at 10 Sampling Stations in Ramgarh Lake.

4. CONCLUSIONS

Based on the study carried out, following conclusions are drawn.

1. National Sanitation Foundation Water quality index (WQI) of Surface water of Ramgarh Lake at 10 Sampling Stations has been found from 52 to 63 indicating the medium quality of water.

2. The lake is getting polluted overtime. The lake was initially oligotrophic which has gradually changed to mesotrophic due to increased anthropogenic activities in the catchment. The lake has become eutrophic due to increased addition of pollutants/contaminants.

3. The results of sampling at ten locations during November 2013- September 2014 indicated that the lake has reached to eutrophic state and conservation measures are being implemented to revive the lake.

5. ACKNOWLEDGEMENT

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