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RESEARCH ARTICLE

Influence of Sulfate, Phosphate, Ammonia and Dissolved Oxygen on Biochemical Oxygen Demand of Marlimund Lake, Ooty, The Nilgiris

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ABSTRACT

The present study was done to ascertain the level biochemical oxygen demand (BOD) of Marlimund Lake situated in Ooty how it is related with the other parameters such as water temperature, dissolved oxygen, phosphate, sulfate, iron, and free ammonia. Four sampling sites were selected and studied over the period of 13 months from February 2016 to February 2017. The results were computed by best model fits applied for calculation using Curve Expert Version 4.2. The water temperature ranged from 8.1°C to 18.7°C, dissolved oxygen 3.468–6.976 mg/l, phosphate 0.1–1.92 mg/l, sulfate 1–18 mg/l, free ammonia 0.12–6.01 mg/l, and BOD 2.178–5.040 mg/l. BOD was found to be significantly related to dissolved oxygen (r = 0.5690291) by 4th degree polynomial fit, phosphate (r = 0.7095253) by rational function fit and free ammonia (r = 0.7395016) by MMF model fit, respectively. Sulfate was found to be nonsignificant (r = 0.2565396) by geometric fit model, and water temperature (r =0.4595060) shows a sinusoidal fit.

Keywords: Ammonia, biochemical oxygen demand, curve fit model, DO, iron, Marlimund lake, phosphate, sulfate

INTRODUCTION

Water, the liquid of life, is an important and vital resource for all life on this planet. The availability of clean water is going to be the greatest constraint in future for the survival and existence of all life forms. A large number of parameters signifies the water quality and determines the use of water for various uses. A regular monitoring of the water quality will help to maintain its standards and check the water resource from becoming polluted. Lake is a water body surrounded by land on all sides. The lake depends on the rain for water, and the surface water is contaminated by various sources that are dependent on it. Due to the various activities of humans and animals the water are polluted and becomes unfit for human consumption. The objective of this paper is to determine the relativity of a few physical and chemical properties with biochemical oxygen demand (BOD) of Marlimund Lake, Ooty.

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MATERIALS AND METHODS

The location for the present study, The Marlimund Lake, is situated in Ooty, The Nilgiris District, Tamil Nadu, India, where the Western Ghats and the Eastern Ghats meet. Marlimund is located at about 2240 m above mean sea level (Venugopal, 1993)[1]. Marlimund lake is a major source of drinking water to certain areas in Ooty. The study area is located at Latitude: 11°25’49.44” and Longitude: 76°41’49.92”. Marlimund is a natural Lake that depends on the South West and North East Monsoon rainfall for water [Figure 1].

Physicochemical characteristics of water of Marlimund lake were studied at monthly intervals from February 2016 to February 2017 by choosing four different sampling representing different regions of the lake. Water samples were collected in pre-washed polyethylene bottles (Ramizankhani *et al.*, 2008; Soylak *et al.*, 2002)[2,3]. At each sampling location, water samples were collected in two polyethylene bottles with the capacity of 1 L each. Standard methods APHA[4] were followed in the collection, storage, and analysis of the water samples. The following water quality parameters were determined which were chosen as the major indicators, namely water temperature, DO, BOD, phosphates, sulfates, iron, and free ammonia. All assays were carried out at least 3 times, and the means of all the values were calculated. The air and water temperature were recorded in the field. For the determination of dissolved oxygen, water was fixed in the field and brought to the laboratory described in APHA[4] and Trivedi and Goel.[5] The other parameters such as phosphate, sulfate, iron, free ammonia, and calcium were done as per the as standard methods [Table 1] recommended by CPHEEO standard test through TWAD board, Udhagamandalam during the study. The mathematical relationship of BOD of water with other physicochemical characteristics was assessed using the Curve Expert Software Version 4.2 for each parameter per month was computed, considering the values from four different stations.

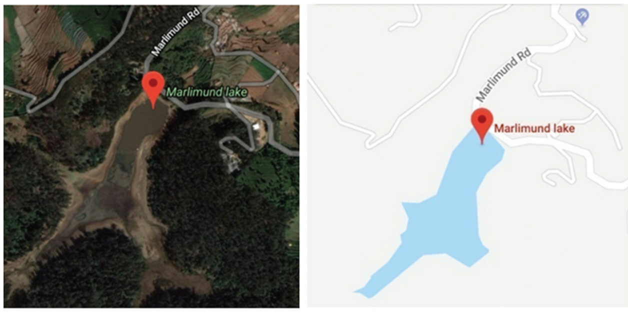

Figure 1: Location of Marlimund Lake in Ooty, The Nilgiris, Tamil Nadu

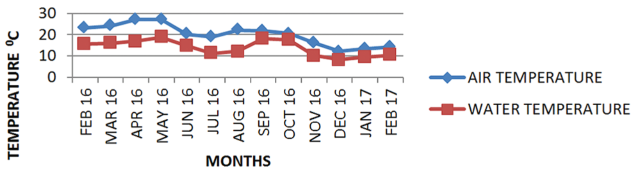

Figure 2: Seasonal variation of air temperature and water temperature in °C during the study period

RESULTS AND DISCUSSION

Air and water temperature

Temperature is one of the most important factors in the aquatic environment.[6] Temperature is basically an important parameter, and it has an effect on the chemical and biological parameters of water.[5] The air temperature recorded higher than the water temperature in all four stations throughout the study for 13 months [Figure 2]. Water temperatures always lag far behind the larger changes of air temperatures (Welch, 1952).[7] Similar findings were also recorded by Mamta and Jakher[8] in Gulab Sagar lake, Rajasthan. The air temperature record of a minimum of 12.1°C during winter in the month of December at Station I and a maximum temperature of 27.2°C during the month of May at Station II. The maximum temperature was recorded in the month of May and the lowest in the month of December.[9] The variations observed in the water temperature are closely related to the air temperature. The minimum of 8.1°C was recorded during the month of December at Station I and maximum temperature of 18.7°C during the month of May at Station II.

The maximum air and water temperature were observed in summer and minimum were observed in winter. Nongmaithem[10] reported that water temperature was found to be higher in the summer season and low in winter season during his study on different water bodies in Manipur. This is due to the weather condition in Ooty as it always records high temperature during the month of May and the lowest during the month of December. Similar trend was also observed by Ghule and Halwe.[11]

Dissolved oxygen

Dissolved oxygen is an important parameter to maintain a healthy water body, all the metabolic and physiological process in the water depends on it, maximum 6.976 (mg/l) during the month of February 2016 at Station I and minimum of 3.468 (mg/l) during the month of February 2017 at Station IV. Most of the stations showed high DO except the few recorded during the post-monsoon months during the year 2017. The maximum DO was observed during winter. It may be due to the high photosynthetic rate of phytoplankton communities in clear water that results in higher values of dissolved oxygen.[12,13] The high DO in winter may be due to a decrease in temperature and less duration of bright sunlight has less influence on the percent of soluble gases oxygen and carbon dioxide.[14]

The lake depends on the rainfall for water and since the South West and North East Monsoon failed the water level reduced drastically. Due to this February 2017 recorded the least dissolved oxygen as the water level decreased drastically.

Babu and Mohan (2018)[15] also reported that lowest values of DO were recorded in Errarajan Lake of Bangalore Rural during February 2017. The lower concentration of dissolved oxygen is a sign of organic population in the lake.[16] Lower DO values indicate that the water is polluted.

Phosphate

Phosphates are present in many natural waters, such as lakes. Phosphorus, necessary for the fertility and is generally recognized as a key nutrient in the productivity of the water.[17] Phosphates are present in natural lake waters. They are necessary for aquatic plants, and excess phosphate leads to algal blooms that decrease the DO and increases the BOD. The minimum of 0.06 (mg/l) was recorded during the summer month of March 2016 at Station 2 and maximum of 1.92 (mg/l) at Station 3 during the winter month of January 2017. Babu and Mohan (2018) showed that highest values were recorded during the winter month of December 2017.

Sulfate

Sulfate recorded the minimum of 1 mg/l during the months of March and November at Station I, August and November at Station II, July, November, and December at Station III and September, November, and December at Station IV and a maximum of 18 during the month of October in Station 1. Contaminated water will have high sulfate. The level of sulfate is an indication of pollution from organic matter Bhandarkar.[18] The sulfate values at all locations are found to be below the allowable limits being prescribed in the WHO (2012)[19] for drinking water. Hence, the lake is free from organic pollution. Sulfate concentration in natural water ranges from a few to a several 100 mg/l, but no major negative impact of sulfate on human health is reported. The WHO has established 250 mg/l as the highest desirable limit of sulfate in drinking water.

Table 1: Physical and chemical methods adopted for analysis of water samples

Parameter	Instrument
Temperature	Celsius thermometer
Dissolved oxygen	Winkler's iodometric method
BOD	Winkler's iodometric method
Phosphates	Colorimetric (molybosilicate method)
Sulfates	Turbidimetric at 420 nm
Free ammonia	Colorimetric (nesslerization)

Free ammonia

Free ammonia is influenced by temperature and pH. During the winter months, water has less free ammonia, and low pH water has less free ammonia. Free ammonia recorded both maximum and minimum at Station II, with the minimum of 0.12 (mg/l) during the month of May and maximum of 6.01 (mg/l) during the month of April. Shriram *et al*., 2014[20], and Thilaga[21] reported similar recording that ammonia concentration was found to be
highest in the summer season. The high ammonia content may be due to the animal discharge. Similar results were reported by Shrivastava *et al*.[22] Unusually, high ammonium concentration was reported at the sampling site (5.41 mg/L). The high concentration of ammonia causes a problem with taste and odor of water apart from toxicity to aquatic lives. The ammonia concentration in surface water is generally low but can reach high levels from agricultural runoff or contamination by human or animal waste discharge (WHO, 1998).

Data analysis

Mathematical modeling

In the present study, mathematical modeling was used to identify the highly related water quality parameters. The results for the correlations among all independent variables with BOD showed the following result.

Table 2: Evaluation of best fit models to compare other parameters (x) with BOD (y)

Parameters (x)	r	SE	Best fit model	Equation
Water temperature	0.4595060	0.858	Sinusoidal Fit	y = 3.77 + 8.24*cos (8.04x+−4.03011)…
Dissolved oxygen	0.5690291	0.803	4th degree polynomial fit	y=-3.22 + 2.706x-8.27 × 2 + 1.101 × 3…
Phosphate	0.7095253	0.681	Rational function fit	y=(2.018 + 2.48x)/(1 − 6.28x + 6.67 × 2)….
Sulfate	0.2565396	0.915	Geometric fit	y = 3.59 × 2(−9.379x)….
Free ammonia	0.7395016	0.6501	MMF model fit	y=(2.44129*7.81 + 4.07*x26.6)/(7.81 + x26).

The BOD is a direct measure of oxygen requirement and indirect measure of biodegradable organic matter. BOD indicates the rate of pollution and to what extent the water body is contaminated. The BOD ranged from 2.177 to 5.081. The minimum of 2.177 (mg/l) was recorded during the month of February 2016 at Station I and the maximum of 5.081 (mg/l) was recorded during the month of September 2016 at Station I. Since the water is one of the most important natural resources, its contamination can cause serious problems relating to the environment that could affect the health of people. For this reason, the mathematical modeling of water quality is of great importance. Several similar studies have been conducted,[23] and the water quality modeling has proved as a reliable and economic method of assessing pollutant distribution in surface waters and can be effectively used in management decisions.[24] Modeling is not an alternate to observations but under certain circumstances can be a powerful tool in understanding observations and in developing and testing theory.[25]

To study effect of rapid natural variations. The use of mathematical models leads to an increased capability for defining and evaluating possible alternatives and provides for a wider range of options at every level of decision that is made.

The relationships between the dependent variable (the response variable) with the independent variable(s) can be expressed as linear or non-linear functions. The most correlated independent variable was the free ammonia (r = 0.7395016), phosphate (r = 0.7095253), dissolved oxygen (r = 0.5690291), and iron (r = 0.5128611). Sheeja[14] showed that these three parameters were not significant with BOD. However, the present study has proved that dissolved oxygen, ammonia, and phosphate have a significant relationship with BOD [Table 2].

The discharge into the rivers will accelerate bacterial growth and consume the dissolved oxygen.[26] The BOD recorded the highest in the month of September at Station I as the values of iron and ammonia exceeded the permissible in the same month which could be the reason for the increase in the BOD value indicating that the water is contaminated.

The mathematical modeling shows an MMF model fit with free ammonia.

The phosphate is the second highly correlated parameter with BOD. The phosphates values recorded are within the permissible limit and do not influence the BOD level. BOD shows a rational function fit model with phosphate.

The DO is the third highly correlated parameter with BOD showing 4th degree polynomial fit. In the present investigation, dissolved oxygen was high in most of the stations. Most of the ponds in the study area showed high DO which may be due to the increased solubility of oxygen at a lower temperature.[27]

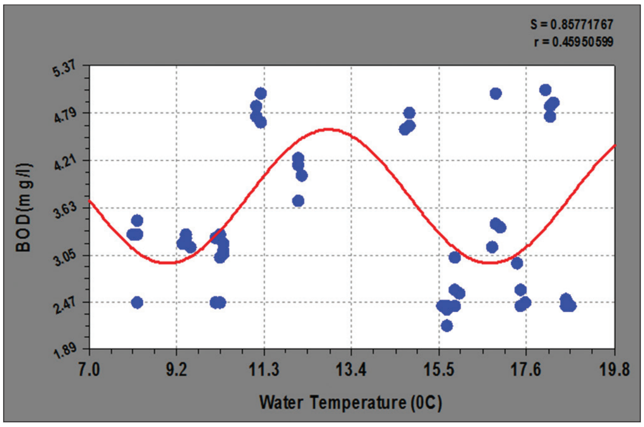

Figure 3: Sinusoidal fit showing the mathematical relationship between water temperature and biochemical oxygen demand

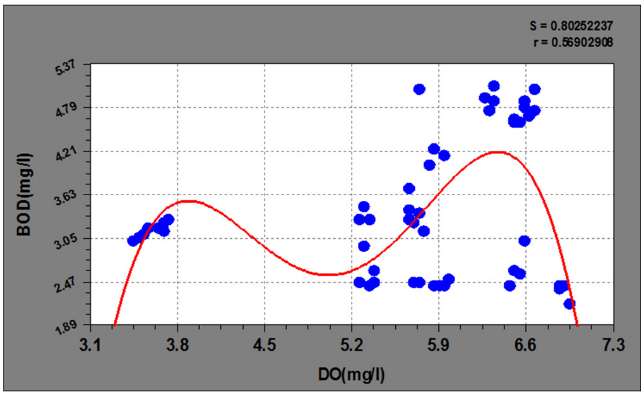

Figure 4: 4th degree polynomial fit showing the mathematical relationship between DO and biochemical oxygen demand

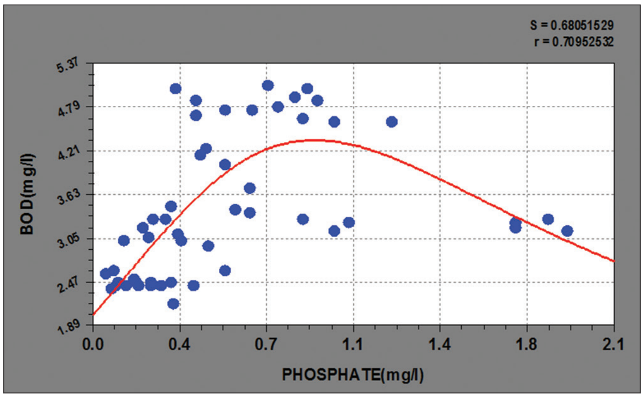

Figure 5: Rational function fit showing the mathematical relationship between phosphate and biochemical oxygen demand

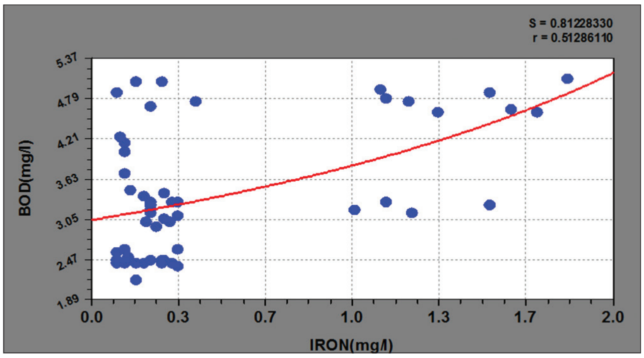

Figure 6: Geometric fit model showing the mathematical relationship between sulfate and biochemical oxygen demand

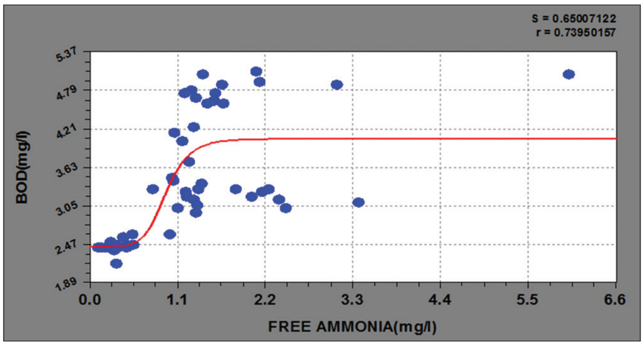

Figure 7: MMF model fit showing the mathematical relationship between free ammonia and biochemical oxygen demand

Iron is correlated with BOD showing a reciprocal model fit. The iron exceeded the permissible range during the month of June, September, and January. The high correlation between ammonia, phosphate, dissolved oxygen, and iron with BOD shows that they have an influence on the BOD in indicating the pollution.

Water temperature (r = 0.4595060) and sulfate (r = 0.2565396) showed no significance with BOD. Similar results were observed by Sheeja[14] for water and sulfate parameters [Figures 3-7].

CONCLUSION

The water is free from heavy metal and toxic pollutants. In certain months at few stations, the ammonia and iron exceed the permissible limits and have to be monitored frequently and regularly. The larger the degree of organic pollution, the larger is the BOD of the water; similarly, when there is stabilization of organic matter, the BOD decreases. The BOD value is high showing the water is contaminated due to organic waste, bacterial contamination, animal discharge and exceeding limits of iron and free ammonia. The water should go through general treatment processes such as sedimentation, filtration, and disinfection before it is released for drinking and domestic purpose. In this paper, the mathematical model was used to assess the concentration of the BOD in the lake water and its relativity with other parameters. In the future work, methods to optimize the biological process to stabilize the water quality of the lake will be developed.

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