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Water Quality Assessment of a Tropical Wetland Ecosystem with Special Reference to Backwater Tourism, Kerala, South India

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Abstract

Wetland ecosystems are estimated to cover more than 1,280 million hectares and deliver a wide range of ecosystem services that contribute to human well-beings. Degradation and loss have reduced the capacity of wetlands to provide sufficient amounts and quality of water. The continued degradation of wetlands, and more specifically the continued decline in water quantity and quality, will result in further impoverishment of human health especially for vulnerable people in developing countries. The waterborne pollutants (chemical and microbiological) have a major effect on human health and chemical pollutants accumulate in the food chain to the point where they harm people. Vembanad Kol Wetland ecosystem is one of the most attractive backwater systems in the world. Tourism is now flourishing on Vembanad Lake, especially in the Kumarakom area the southern part of the lake. As a result, many new tourism facilities (like resorts and hotels) are being built without concern for either the natural wetland system or the areas culture and heritage. Variables analysed for included air and water temperature, TDS, pH, EC, DO, BOD, total alkalinity, salinity, nitrate phosphate, hardness, sodium, potassium, calcium, and silicate. The microbial analysis of different samples consist of microbial colony count, MPN (most probable number), and the presence of enteric pathogenic organisms. The acceptable level of water quality is a minimum requisite for tourism activities in all tourism destinations. The continued degradation of wetlands specifically the continued decline in water quality will result in impoverishment of human health, especially for vulnerable people in developing countries.

Keywords: Vembanad kol wetland ecosystem, kumarakom, tourism, physico-chemical and bacteriological analysis

Introduction

"Wetlands" have been defined as swamps and other damp areas of land but in common parlance the word is used interchangeably with "Lakes" which denotes a large body of water surrounded by land. However, internationally accepted term of wetlands describes them as "Area of Marsh, Fen, Peat land or water whether natural or artificial, permanent or temporary with water, that is static or flowing, fresh, brackish or salt including areas of marine water, the depth of which does not exceed 6 meters"[1]. Wetlands are unique ecosystem having rich nutrient status and carrying capacity with immense production potential hence considered as food and fodder resources for human and its related allies. Ecologically wetlands are of great significant for an area as they support different food chain, food webs, regulate hydrological cycle, recharge ground water, trapping of energy and shelter to large numbers of flora and fauna having great ecological and economical value[2,3].

The value of the world's wetlands are increasingly receiving due attention as they contribute to a healthy environment in many ways. They retain water during dry periods, thus keeping the water table high and relatively stable. During periods of flooding, they mitigate flood and to trap suspended solids and attached nutrients. Thus, streams flowing into lakes by way of wetland areas will transport fewer suspended solids and nutrients to the lakes than if they flow directly into the lakes. The removal of such wetland systems because of urbanization or other factors typically causes lake water quality to worsen. In addition, wetlands are important feeding and breeding areas for wildlife and provide a stopping place and refuge for waterfowl. As with any natural habitat, wetlands are important in supporting species diversity and have a complex of wetland values[4].

The study has been conducted in the Kumarakom region (9° 37'57"- 9° 38'21"N Latitude, 76° 25'11"- 76° 25'06"E Longitude) of Vembanad-Kol wetland of Kerala, along the southwest coast of India. Vembanad Lake, which is connected to Arabian sea through Cochin estuary, is the largest brackish, tropical wetland ecosystem, which is of extraordinary importance for its hydrological function, biodiversity and rich fishery resources. Kumarakom is situated on the eastern banks of Vembanad Lake. Vembanad serves as a habitat for a variety of fin and shell fish, and a nursery of several species of aquatic life. Mangrove is found to grow in the Kumarakom region. The Vembanad Lake was declared as a Ramsar Site in November 2002. There are a number of tourist resorts nestling on its banks. Vembanad bird sanctuary is located at Kumarakom and

Pathiramanal, where a large number of tourists congregate during October-March every year - it being the peak season for visiting these bird sanctuaries. The Thanneermukkom Barrage is constructed across a narrow portion of Vembanad Lake between Thanneermukkom in the west and Vechoor in the east. The 1252 m long barrage is planned with 93 vents each 12.15 m X 5.47 m.

Material and Methods

Two different sampling stations of Vembanad Lake and Kumarakom wetland namely were selected. Water samples were collected from both stations at different sites. The physicochemical parameters are determined from sampling done during three seasons – pre-tourism (August-October), tourism (November - February) and post-tourism (April-May) for five years from 2008-2012. The water samples were collected in sterile glass bottles such that its neck is below the water surface so as to avoid the inclusion of atmospheric oxygen. Sampling and physicochemical and bacteriological investigation was carried out according to standard methods[5].

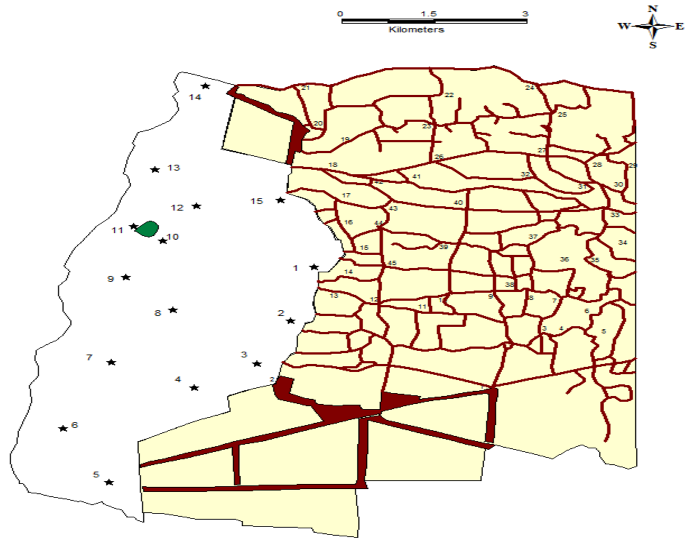

Figure-1
Study area map - Vembanad lake south to Thaneermukkam Barrage and locations of sampling sites

Table-1
Details regarding the physico-chemical analysis of water

Sl. No.	Parameters Analyzed	Unit	Methods/Instruments
A. Physico-Chemical Parameters			
1	Air temperature	^oC	Thermometer
2	Water temperature	^oC	Thermometer
3	TDS	ppm	TDS meter
4	Conductivity	mS	Conductivity meter
5	pH		pH meter
6	Chloride	mg/l	Argentometry
7	Salinity	ppt	Argentometric Method
8	Alkalinity	mg/l	Titrimetry
9	Hardness	mg/l	EDTA titrimetry
10	DO	mgO_2/l	Winkler method
11	BOD	mgO_2/l	5 day BOD test
12	Nitrate	mg/l	Brucine method
13	Silicate	mg/l	Silicomolybdate method
14	Phosphate	mg/l	Stannous chloride method
15	Sodium	mg/l	Flame photometry
16	Potassium	mg/l	Flame photometry
B. Bacteriological Parameters			
17	Faecal coliforms	MPN/100 ml	Multiple Tube Fermentation
18	Faecal streptococci	MPN/100 ml	Multiple Tube Fermentation

Table-2
Identification of the source of faecal pollution using FC/FS ratio

Sl. No.	Source	FC/FS ratio
1	Man	4.4
2	Duck	0.6
3	Sheep	0.4
4	Chicken	0.4
5	Pig	0.4
6	Cow	0.2
7	Turkey	0.1

(After USEPA, 1978; Geldreich, E. E., 1974)[6,7]

Calculation of FC/FS ratio: FC/FS ratios are required to identify the source of faecal contamination. This has been carried out as per the table given in table 2.

Results and Discussion

Temperature: The maximum water temperature of the Vembanad Lake (33°C) was observed during tourism and post-tourism seasons and the minimum water temperature (27°C) was observed during pre-tourism. The water temperature of the river systems and canals indicate maximum values during pre-tourism and tourism seasons where as minimum values were recorded during the post-tourism. The variation in water temperature may be due to different timing of collection and the influence of season[8]. Temperature controls behavioral characteristics of organisms, solubility of gases and salts in water. Fecal contamination in the lake water may increase due to tourism activities and decomposition of fecal matter in turn increases the water temperature. Fecal coliforms were (>2400/100 ml) observed high in the lake ecosystems whereas the rivers and canals showed less fecal coliforms (150-1100/100 ml) which substantiate the above finding. Water temperature of the lake showed positive correlation with pH ($r = 0.55, p<0.05$), EC ($r = 0.51, p<0.05$), TDS and BOD ($r = 0.57, p<0.05$). It showed negative correlation with alkalinity ($r = -0.3, p<0.01$) and DO ($r = -0.58, p<0.05$). Water temperature of the freshwater systems showed positive correlation with DO ($r = 0.79, p<0.05$). It showed negative correlation with EC ($r = -0.86, p<0.05$), TDS ($r = -0.8, p<0.05$) and BOD ($r = -0.81, p<0.05$).

pH: In general the pH was within the limits of the standard values[5]. For drinking water, a pH range of 6.0 – 8.5 is recommended[7]. It has been mentioned that the increasing pH appear to be associated with increasing use of alkaline detergents in residential areas and alkaline material from wastewater in industrial areas[10]. pH values recorded in the river water is in agreement with the pH values for other freshwater systems of Thiruvananthapuram District[11] and elsewhere in Kerala[12]. pH of river water showed negative correlation with silicate ($r = -0.54, p<0.05$). pH of the lake showed positive correlation with EC ($r = 0.621, p<0.05$), TDS ($r = 0.69, p<0.05$), phosphate ($r = 0.32, p<0.01$), K ($r = 0.33, p<0.01$) and BOD ($r = 0.74, p<0.05$). It showed negative correlation with total alkalinity ($r = -0.41, p<0.05$) and DO ($r = -0.5, p<0.05$).

Conductivity: Conductivity is a good and rapid method to measure the total dissolved ions and is directly related to total solids. Higher the value of dissolved solids, greater the amount of ions in water[13]. Conductivity values were found to be the highest in the post-tourism period in both the sampling stations. Almost all the conductivity values fell within the “no effect” range of 0-70 µS/cm for drinking water use[14]. This indicates that no adverse health effects associated with the electrical conductivity of the water were expected. There was a positive correlation between conductivity and pH ($r = 0.62, p<0.05$), TDS ($r = 0.89, p<0.05$), total hardness and magnesium hardness ($r = 0.43, p<0.05$), calcium hardness ($r = 0.33, p<0.05$), potassium ($r = 0.57, p<0.05$) and BOD ($r = 0.67, p<0.05$) in the lake systems. It showed negative correlation with alkalinity ($r = -0.42, p<0.05$) and DO ($r = -0.6, p<0.05$). In the river water, conductivity showed positive correlation with TDS ($r = 0.94, p<0.05$), silicate ($r = 0.48, p<0.01$), K ($r = 0.49, p<0.01$) and BOD ($r = 0.5, p<0.01$). Negative correlation was set up with DO ($r = -0.55, p<0.05$). This was expected because the properties of conductivity are governed by the characteristics of the constituents inorganic salts dissolved in water.

Total alkalinity: The alkalinity of water is its capacity to neutralize acids. Alkalinity of water is a measure of weak acid present in it and of the cations balanced against them[15]. Total alkalinity of water is due to presence of mineral salt present in it. It is primarily caused by the carbonate and bicarbonate ions[16]. The alkalinity value of both the stations was found to be within the permissible limit of WHO and BIS standards. Alkalinity showed positive correlation with DO ($r = 0.58, p<0.05$) in the lake systems and BOD ($r = 0.62, p<0.05$) in the river systems. It was negatively correlated with pH ($r = -0.41, p<0.05$), EC ($r = -0.42, p<0.05$), TDS ($r = -0.59, p<0.05$), salinity ($r = -0.29, p<0.05$) and BOD ($r = -0.68, p<0.05$).

Total hardness: Total hardness is the parameter of water quality used to describe the effect of dissolved minerals (mostly Ca and Mg), determining suitability of water for domestic, industrial and drinking purpose attributed to presence of bicarbonates, sulphates, chloride and nitrates of calcium and magnesium[17]. The total hardness level was found exceeding the WHO and BIS permissible limits in both the stations. The total hardness is mainly due to Ca; Mg and eutrophication. The water containing excess hardness is not desirable for potable water. It consumes more soap during washing of clothes. Total hardness levels were high in the lake systems when compared to river systems and canals. The above verdict has been supported with correlation studies showing strong positive correlation with CaH ($r = 0.998, p<0.05$), MgH ($r = 0.98, p<0.05$), nitrate ($r = 0.87, p<0.05$), sodium ($r = 0.89, p<0.05$) and silicate ($r = 0.63, p<0.05$) in the lotic systems and with EC ($r = 0.43, p<0.05$), CaH ($r = 0.93, p<0.05$), MgH ($r = 0.85, p<0.05$) and K ($r = 0.62, p<0.05$) in the lentic system.

Calcium Hardness: Calcium is an important micronutrient in an aquatic environment Hardness of the river water is of considerable significance in connection with the discharge of the sewage and industrial effluent containing pollution, as indicated by variations in the concentration of the hardness of the water[18]. The concentration of Ca Hardness exceeded the permissible limits in all the stations and seasons. CaH showed positive correlation with EC ($r = 0.35, p<0.01$), TH ($r = 0.93, p<0.05$), MgH ($r = 0.82, p<0.05$) and K ($r = 0.64, p<0.05$) in the lake systems. It showed positive correlation with TH ($r = 0.99, p<0.05$), MgH ($r = 0.95, p<0.05$), nitrate ($r = 0.87, p<0.05$), sodium ($r = 0.88, p<0.05$) and silicate ($r = 0.63, p<0.05$) in the river systems.

Magnesium Hardness: Magnesium as co factor for various enzymatic transformations within the cell especially in the trans-phosphorylation in algal, fungal and bacterial cell[19]. The concentration of Ca Hardness exceeded the permissible limits in all the stations and seasons. MgH showed positive correlation with EC (r = 0.43, p<0.01), TH (r = 0.853, p<0.05), CaH (r = 0.82, p<0.05) and K (r = 0.64, p<0.05) in the lake systems. It showed positive correlation with TH (r = 0.98, p<0.05), CaH (r = 0.95, p<0.05), nitrate (r = 0.85, p<0.05), sodium (r = 0.89, p<0.05) and silicate (r = 0.62, p<0.05) in the river systems.

DO: The value of Dissolved Oxygen is remarkable in determining the water quality criteria of an aquatic system. In the system where the rates of respiration and organic decomposition are high, the DO values usually remain lower than those of the system, where the rate of photosynthesis is high[20]. The DO was within the limits of the standard values (WHO and BIS). The results were in concurrence of studies performed by Varunprasath and Daniel[14]. Mishra and Tripathi[21] observed mean value of dissolved oxygen ranging from 1.8 to 5.9 mgl^{-1} of river Ganga at Varansi. It showed negative correlation with BOD (r = -0.88, p<0.05), EC (r = -0.55, p<0.05), TDS (r = -0.58, p<0.05) and phosphate (r = -0.75, p<0.05) in the freshwater systems. It showed negative correlation with BOD (r = -0.83, p<0.05), EC (r = -0.57, p<0.05), TDS (r = -0.74, p<0.05) and pH (r = -0.5, p<0.05) in the lake systems.

BOD: Biochemical Oxygen Demand is usually defined as the amount of oxygen required by bacteria in stabilizing the decomposable organic matter. The biodegradation of organic materials exerts oxygen tension in the water and increases the biochemical oxygen demand[22]. BOD gives an idea about the extent of pollution. BOD has been a fair measure of cleanliness of any water on the basis that values less than 1-2 mg/l are considered clean, 3 mg/l fairly clean, 5 mg/l doubtful and 10 mg/l definitely. BOD was found to be exceeding the permissible limits in all the stations. Increase in BOD levels was observed mainly in the post-tourism periods. BOD was negatively correlated with DO (r = -0.83, p<0.05) in the lake systems and (r = -0.88, p<0.05) in the river systems. It showed positive correlation with water temperature (r = 0.57, p<0.05), pH(r = 0.74, p<0.05), EC (r = 0.67, p<0.05) and TDS (r = 0.82, p<0.05) in the Vembanad lake.

Nitrate: The main sources of nitrate in water are human and animal waste, industrial effluent, use of fertilizers and chemicals, silage through drainage system[23]. The amount of nitrates in both the stations was found to be much below the accepted drinking water standards (20 ppm – ICMR 1975; 45 ppm – ISI 1991). It showed positive correlation with TH (r = 0.87, p<0.05), CaH (r = 0.87, p<0.05), MgH (r = 0.85, p<0.05), silicate (r = 0.84, p<0.05), sodium (r = 0.61, p<0.05), potassium (r = 0.51, p<0.05) and DO (r = 0.52, p<0.05) in the river systems. It was negatively correlated with phosphate (r = -0.77, p<0.05). Nitrate showed insignificant correlation with all the parameters in the lake systems.

Phosphate: The increased application of fertilizers, use of detergents and domestic sewage greatly contribute to the heavy loading of phosphorous in the water[24]. The BIS (Bureau of Indian Standard) suggested the limit of phosphate is 0.1mg/l. Phosphate levels were high in all the sampling sites in all the seasons.

Bacteriological Parameters: A total of 17 bacterial genera were identified in water samples. Thirty Gram positive bacterial species were identified in water samples, which were distributed in 5 genera, such as *Bacillus*, *Listeria*, *Kurthia*, *Carnobacterium* and *Staphylococc*i. While 40 species of Gram negative bacteria were identified in water of Kumarakom region of Vembanad lake. About 41% of bacterial isolates from water were identified as *Bacillus*. Twenty Bacillus species were identified from water. *Bacillus subtilis* and *Bacillus cereus* was found to be the most dominant

Nitrate reductase was detected in 40 % of *Bacillus* isolates from water. While 78% of *Bacillus* isolates from water have protease activity. All the *Bacillus* isolates from water samples revealed amylase activity. Tyrosinase was detected in 13% of Bacillus isolates from water. About 15% of *Bacillus* isolates from water samples of Kumarakom lake were also survived up to 55°C.

L. ivanovii, L. murrayii and *L. grayi* were identified from water samples. *K. zopfii, C. gallinarum, S. aureus* and *S. epidermidis* were identified from water. β-haemolytic activity was detected in 40% of Listeria isolates from water.

Coagulase activity was detected in 50% of *Staphylococci* isolates from water. Four species of Enterobacteriaceae were identified in water of Kumarakom lake. *Enterobacter cloacae* was the dominant one in water. 17 species of *Vibrio* were identified from water samples. *V. coralliilyticus* was identified from water samples collected from almost all the stations. More diverse *Vibrio* species were identified in water during the month of June. Various species of *Aeromonas* identified in this study were isolated from water samples collected during warmer times of the year. Five species of *Aeromonas* and Alcaligenes and two species of Pseudomonas were identified from water in the study area.

Conclusion

The variations in the water quality parameters are evident in all the physico – chemical parameters examined. The present study concluded that river water of study area was moderately polluted in respect to analyzed parameters. pH, total hardness, chloride and fluoride were found within permissible limit but the higher values of BOD in present study attributed river water was not fit for drinking purpose. It needs to aware local villagers to safeguard the precious river and its surrounding.

Table-3
Physico-chemical parameters of Vembanad lake

Parameters	Units	Seasons	Mean±SD
Air temp.	^oC	PRE	35.5±1.87
		TOURISM	29±1.26
		POST	28.17±0.75
Water temp.	^oC	PRE	31.67±0.52
		TOURISM	30.42±0.49
		POST	26.5±0.55
pH		PRE	6.85±0.47
		TOURISM	6.64±0.94
		POST	6.63±0.1
EC	mS	PRE	1.67±0.35
		TOURISM	2.55±0.19
		POST	3.13±0.16
TDS	mg/l	PRE	1449.33±83.66
		TOURISM	1887.83±37.1
		POST	2051.17±60.26
Salinity	ppt	PRE	7.58±1.07
		TOURISM	7.75±1.08
		POST	8.08±1.32
Total Alkalinity	mg/l	PRE	48.33±4.08
		TOURISM	25±5.48
		POST	50±10.95
Total Hardness	mg/l	PRE	371.83±101.2
		TOURISM	403.67±96.55
		POST	417±101.49
Calcium Hardness	mg/l	PRE	249.83±62.38
		TOURISM	273.17±68.6
		POST	280±66.76
Magnesium Hardness	mg/l	PRE	124.83±35.06
		TOURISM	133.67±32.71
		POST	137.67±35.79
Phosphate	ppm	PRE	0.1±0.07
		TOURISM	0.13±0.08
		POST	0.17±0.08
Nitrate	ppm	PRE	5.52±1.34
		TOURISM	5.52±1.4
		POST	5.65±1.33
Silicate	ppm	PRE	2.67±0.5
		TOURISM	2.85±0.51
		POST	3.07±0.48
Sodium	mg/l	PRE	109±36.94
		TOURISM	115±16.38
		POST	136.83±18.14
Potassium	mg/l	PRE	73.33±27.33
		TOURISM	87.83±26.27
		POST	97.67±23.42
DO	mg/l	PRE	5±0.64
		TOURISM	4.67±0.62
		POST	3.33±0.52
BOD	mg/l	PRE	4.03±0.76
		TOURISM	3.45±0.31
		POST	5.93±0.33

Table-4
Physico-chemical parameters of Kumarakom

Parameters	Units	Seasons	Mean±SD
Air temp.	^oC	PRE	35.5±1.87
		TOURISM	29±1.26
		POST	28.17±0.75
Water temp.	^oC	PRE	31.67±0.52
		TOURISM	30.42±0.49
		POST	26.5±0.55
pH		PRE	6.85±0.47
		TOURISM	6.64±0.94
		POST	6.63±0.1
EC	mS	PRE	1.67±0.35
		TOURISM	2.55±0.19
		POST	3.13±0.16
TDS	mg/l	PRE	1449.33±83.66
		TOURISM	1887.83±37.1
		POST	2051.17±60.26
Salinity	ppt	PRE	7.58±1.07
		TOURISM	7.75±1.08
		POST	8.08±1.32
Total Alkalinity	mg/l	PRE	48.33±4.08
		TOURISM	25±5.48
		POST	50±10.95
Total Hardness	mg/l	PRE	371.83±101.2
		TOURISM	403.67±96.55
		POST	417±101.49
Calcium Hardness	mg/l	PRE	249.83±62.38
		TOURISM	273.17±68.6
		POST	280±66.76
Magnesium Hardness	mg/l	PRE	124.83±35.06
		TOURISM	133.67±32.71
		POST	137.67±35.79
Phosphate	ppm	PRE	0.1±0.07
		TOURISM	0.13±0.08
		POST	0.17±0.08
Nitrate	ppm	PRE	5.52±1.34
		TOURISM	5.52±1.4
		POST	5.65±1.33
Silicate	ppm	PRE	2.67±0.5
		TOURISM	2.85±0.51
		POST	3.07±0.48
Sodium	mg/l	PRE	109±36.94
		TOURISM	115±16.38
		POST	136.83±18.14
Potassium	mg/l	PRE	73.33±27.33
		TOURISM	87.83±26.27
		POST	97.67±23.42
DO	mg/l	PRE	5±0.64
		TOURISM	4.67±0.62
		POST	3.33±0.52
BOD	mg/l	PRE	4.03±0.76
		TOURISM	3.45±0.31
		POST	5.93±0.33

Table-5
Physico-chemical parameters of Kumarakom

	AT	WT	pH	EC	TDS	SAL	ALK	TH	CaH	MgH	PHOS	NITR	SIL	SOD	POT	DO	BOD
AT	1	0.71(**)	0.13	-0.88(**)	-0.92(**)	-0.23	0.31	-0.2	-0.17	-0.2	-0.31	-0.03	-0.29	-0.21	-0.41	0.55 (*)	-0.36
WT	0.71(**)	1	0.2	-0.86(**)	-0.8(**)	-0.19	-0.31	-0.14	-0.13	-0.11	-0.39	-0.02	-0.3	-0.18	-0.34	0.79(**)	-0.81(**)
pH	0.13	0.21	1	-0.36	-0.4	-0.17	0.12	-0.2	-0.27	-0.11	0.19	-0.39	-0.54(*)	-0.03	-0.37	0.04	-0.02
EC	-0.88(**)	-0.86(**)	-0.36	1	0.94 (**)	0.29	-0.08	0.39	0.38	0.38	0.2	0.24	0.48 (*)	0.41	0.49(*)	-0.55(*)	0.5(*)
TDS	-0.92(**)	-0.8(**)	-0.4	0.94(**)	1	0.18	-0.22	0.3	0.3	0.25	0.21	0.14	0.38	0.28	0.47(*)	-0.58(*)	0.45
SAL	-0.23	-0.19	-0.17	0.29	0.18	1	0.344	0.1	0.07	0.14	0.13	0.16	0.15	0.17	0.79(**)	-0.18	0.22
ALK	0.31	-0.31	0.12	-0.08	-0.22	0.34	1	-0.11	-0.11	-0.12	0.12	-0.02	-0.01	-0.03	0.14	-0.33	0.62(**)
TH	-0.2	-0.14	-0.2	0.39	0.3	0.1	-0.11	1	0.99(**)	0.98(**)	-0.72(**)	0.87(**)	0.63(**)	0.89(**)	0.45	0.42	-0.21
CaH	-0.17	-0.13	-0.27	0.38	0.3	0.07	-0.11	0.99(**)	1	0.95(**)	-0.75(**)	0.87(**)	0.63(**)	0.88(**)	0.43	0.42	-0.22
MgH	-0.2	-0.11	-0.11	0.38	0.25	0.14	-0.12	0.98(**)	0.95(**)	1	-0.63(**)	0.85(**)	0.62(**)	0.89(**)	0.44	0.43	-0.22
PHOS	-0.31	-0.39	0.19	0.2	0.21	0.13	0.12	-0.72(**)	-0.75(**)	-0.63(**)	1	-0.77(**)	-0.43	-0.52(*)	-0.14	-0.75(**)	0.52(*)
NITR	-0.03	-0.02	-0.39	0.24	0.14	0.16	-0.02	0.87(**)	0.87(**)	0.85(**)	-0.77(**)	1	0.84(**)	0.61(**)	0.51(*)	0.52(*)	-0.26
SIL	-0.29	-0.3	-0.54(*)	0.48(*)	0.38	0.15	-0.01	0.63(**)	0.63(**)	0.62(**)	-0.43	0.84(**)	1	0.37	0.41	0.17	0.02
SOD	-0.21	-0.18	-0.03	0.41	0.28	0.172	-0.03	0.89(**)	0.88(**)	0.89(**)	-0.52(*)	0.61(**)	0.37	1	0.31	0.25	-0.09
POT	-0.41	-0.34	-0.37	0.49(*)	0.47(*)	0.79(**)	0.14	0.45	0.43	0.438	-0.14	0.51(*)	0.41	0.31	1	-0.1	0.16
DO	.55(*)	0.79(**)	0.04	-0.55(*)	-0.58(*)	-0.18	-0.33	0.42	0.42	0.43	-0.75(**)	0.52(*)	0.17	0.25	-0.1	1	-0.88(**)
BOD	-0.36	-0.81(**)	-0.02	0.5(*)	0.448	0.22	0.62(**)	-0.24	-0.22	-0.22	0.52(*)	-0.26	0.02	-0.09	0.16	-0.88(**)	1

Table-6
Physico-chemical parameters of Vembanad lake

	AT	WT	pH	EC	TDS	SAL	ALK	TH	CaH	MgH	PHOS	NITR	SIL	SOD	POT	DO	BOD
AT	1	0.63(**)	0.58(**)	0.46(**)	0.56(**)	-0.18	-0.32(*)	0.1	0.03	0.1	0.32(*)	-0.08	0.08	0.16	0.11	-0.63(**)	0.62(**)
WT	0.63(**)	1	0.55(**)	0.51(**)	0.57(**)	-0.007	-0.3(*)	0.14	0.11	0.19	0.21	0.01	0.05	0.09	0.25	-0.582(**)	0.57(**)
pH	0.58(**)	0.55(**)	1	0.62(**)	0.69(**)	-0.22	-0.41(**)	0.2	0.19	0.24	0.32(*)	0.17	-0.1	0.26	0.33(*)	-0.501(**)	0.74(**)
EC	0.46(**)	0.51(**)	0.62 (**)	1	0.89(**)	-0.13	-0.42(**)	0.43(**)	0.35(*)	0.43(**)	0.22	0.25	-0.13	0.22	0.57(**)	-.0573(**)	0.67(**)
TDS	0.56(**)	0.57(**)	0.69 (**)	0.89(**)	1	-0.11	-0.59(**)	0.22	0.18	0.19	0.35(*)	0.18	0.11	0.15	0.38(**)	-0.741(**)	0.82(**)
SAL	-0.18	-0.01	-0.22	-0.13	-0.11	1	-0.29(*)	-0.07	-0.08	-0.09	-0.09	0.002	-0.13	0.05	-0.19	0.06	-0.06
ALK	-0.32(*)	-0.3(*)	-0.41(**)	-0.42(**)	-0.59(**)	-0.29(*)	1	0.06	0.08	0.13	-0.21	0.09	-0.14	-0.1	-0.12	058(**)	-0.68(**)
TH	0.1	0.14	0.2	0.43(**)	0.22	-0.07	0.06	1	0.93(**)	0.85(**)	-0.25	0.15	-0.34(*)	-0.17	0.62(**)	-0.03	0.16
CaH	0.03	0.11	0.19	0.35(*)	0.18	-0.08	0.08	0.93(**)	1	0.82(**)	-0.24	0.17	-0.22	-0.19	0.53(**)	0.03	0.11
MgH	0.1	0.19	0.24	0.43(**)	0.19	-0.09	0.13	.846(**)	0.82(**)	1	-0.16	0.11	-0.4(**)	-0.03	0.64(**)	-0.004	0.1
PHOS	0.32(*)	0.21	0.32 (*)	0.22	0.35(*)	-0.09	-0.21	-0.25	-0.24	-0.16	1	-0.05	0.13	0.34(*)	-0.22	-0.23	0.33(*)
NITR	-0.08	0.01	0.17	0.25	0.18	0.002	0.09	0.15	0.17	0.11	-0.05	1	0.07	-0.16	0.12	0.17\8	0.128
SIL	0.08	0.05	-0.1	-0.13	0.11	-0.13	-0.14	-.34(*)	-0.22	-0.4(**)	0.13	0.07	1	-0.24	-0.39(**)	-0.16	0.09
SOD	0.16	0.09	0.24	0.22	0.15	0.05	-0.1	-0.17	-0.19	-0.03	0.34(*)	-0.16	-0.24	1	-0.01	-0.03	0.09
POT	0.11	0.25	0.33(*)	0.57(**)	0.38(**)	-0.19	-0.12	0.62(**)	0.53(**)	0.64(**)	-0.22	0.12	-0.34(**)	-0.01	1	-0.13	0.26
DO	-0.63(**)	-0.58(**)	-0.5(**)	-0.57(**)	-0.74(**)	0.06	0.58(**)	-0.03	0.03	-0.004	-0.23	0.18	-0.16	-0.03	-0.13	1	-0.83(**)
BOD	0.62(**)	0.57(**)	0.74(**)	0.67(**)	0.82(**)	-0.06	-0.68(**)	0.156	0.11	0.1	0.33(*)	0.13	0.09	0.09	0.26	-0.83(**)	1

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).

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