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Research Article

Seasonal Distribution of *Escherichia coli* and Relationship Among Physicochemical Parameters in Lake Water in the Gudiyattam Area, Tamil Nadu, India

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ABSTRACT

The freshwater ecosystem is deteriorating and becoming more polluted due to industrialization, urbanization, and increasing industries. This study is about the bacteriological and physicochemical properties of the lake water in Gudiyattam town and its surroundings. For this research, samples of lake water from different locations were collected monthly during the period from May 2019 to April 2020 and analyzed based on standard procedures. The physicochemical parameters and bacteriological analyses were studied for all four lakes (S1, S2, S3 and S4). The bacterial analysis results showed the presence of coliform bacteria in all lakes. The most dominant value of the MPN index for total coliform number was determined as 80,000 MPN/100mL, at S4 (Valathur) location during monsoon season. It is understood from the fecal coliform count that location S4 was again found to be dominant when compared to the other lakes, with a result of 8,500MPN/100mL in the monsoon season. The possible reason for the high bacteriological values is thought to be the mixing of drainage waters into the lakes. The MPN value was higher in the monsoon season compared to the pre-monsoon season, which indicates that agricultural runoff occurs in the monsoon season. All the lakes were contaminated with bacterial populations, especially at location S4, which needs the most attention among all the lakes. The above-selected lakes are major surveilling factors for humans for various activities.

Keywords: Lake water, bacterial study, *Escherichia coli*, Gudiyattam

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INTRODUCTION

Water is the most important natural resource for every lifeform on earth since it is an essential requirement for all living beings. Around 71% of the Earth's surface is covered by water, containing 1,386 million cubic kilometers of water, and only about 2% of the earth's water supply is being used by humans and other activities (Prakash, 2005). Increases in population, pollution, the expansion of industrializing economies, the demand for higher agricultural productivity, water-related disasters, and climate change are all the major contributors to Asia's clean water scarcity. More than 60% of agricultural pollution has been reported to cause high nutrient levels, eutrophication, and algal blooms that greatly disrupt freshwater ecosystems and prevent these ecosystems from providing essential environmental services to humans (Economic and Social Commission for Asia and the Pacific, 2018). Lakes, which give us a variety of commodities and services, play a significant role in the Earth's landscape of valuable ecosystems. They provide priceless habitats for plants and animals, reduce hydrological extreme events (e.g., droughts and floods), alter the microclimate, enlarge the aesthetic value of the environment, and provide enormous recreational opportunities (Ministry of Environment and Forests, Government of India, 2010).

On the other hand, human actions affecting lakes have risen to a great extent in recent decades. Deforestation, agriculture, urban development, and industry are examples of anthropogenic activities that have sped up the aging process by introducing more sediment, nutrients, and harmful compounds into lakes through runoff (CPCB, 2001). The majority of lakes are degrading in various ways, whether it's through eutrophication, chemical contamination, or habitat loss. Catchment-based activities have also been accomplished through lake shoreline encroachment through reclamation of shallow lake margins, sewage disposal, water abstraction, and expansion of in-lake recreational activities. All these particular actions have led to the quick deterioration of lakes. The reduction of water quality is due to organic contamination by the discard of domestic wastewater and other solid garbage into the lakes. This is the most common and major reason for lake deterioration. Nutrient Enrichment happens due to nutrients entering the catchment via water runoff. Apart from positive nutrients and particle matter, water through flood runoff from urban catchments brings several harmful compounds (Rajamanickam & Nagan, 2016). Physio-chemical characteristics and biological diversity help sustain a safe and healthy environment for aquatic living beings (Ekhaise & Omoigberale, 2011). Research involving bacteriological analysis shows that pollution is caused by the overgrowth of microbes, which increases the likelihood of animals and plants becoming infected in the water. Waterborne infections are basically caused by enteric microorganisms (Schlosser & Bitton,1995). The World Health Organization (WHO, 2018) has recorded 1.7 billion cases of diarrhea in children per year, resulting in 525,000 fatalities. It is crucial to monitor the quality of water to prevent water-borne diseases by implementing appropriate water treatment, managing practices, and monitoring (Ekhaise & Omoigberale, 2011). The total coliform count includes the entire members of the coliform group including microorganisms found in vegetation, soil, and water. The total coliform group members originate in the intestinal tract of endotherms and are known as fecal coliforms. Coliforms are essential water-quality indicators in rivers as they can tell us whether consuming this water is safe or not (Seo, Lee, & Kim, 2019). The spread and detection of coliforms as a water quality issue have been studied (Cho & Song,2008; Crabill, Donald, Snelling, Foust, & Southam, 1999; Frena et al., 2019; Kindiki, Kollenberg, Siamba, Sifuna, & Wekesa, 2018; Lee et al.,2016). During the 12 sampling months, 72 surface water samples were collected from six sites in North Florida and 96 surface water samples were collected from eight sites in South Florida. Salmonella, generic Escherichia coli, total coliform, and aerobic bacterial populations were found for each sample (Murphy et al., 2022). In order to maintain the quality of water resources, multivariate statistical approaches like Discriminate Analysis (DA), Factor Analysis (FA), Cluster Analysis (CA), and Principal Component Analysis (PCA) are currently employed to identify the likely source(s) of water pollution. These methods are also employed to group data on water quality and identify similarities between samples or factors (Reghunath, Murthy, & Raghavan, 2002; Simeonova, Simeonov, & Andreev, 2003; Kotti, Vlessidis, Thanasoulias, & Evmiridis, 2005; Singh, Malik, Mohan, & Sinha, 2004). Due to various human activities, agricultural activities, and industrial processes, lake water pollution is a possibility in the Gudiyattam region. The previous findings in the Gudiyattam region showed that the existence of significant industrial and agricultural activity in the major lakes had resulted in pollution of the lakes (Naveen & Nair, 2022). Until now, there have not been any bacteriological analysis studies performed in the Gudiyattam lake region. Therefore, the current study aims to determine the presence of coliform bacteria, assess physicochemical parameters to find the quality of the lakes and perform statistical analysis on the data collected in the Gudiyattam region.

MATERIALS AND METHODS

Area of study

In Tamil Nadu, Gudiyattam is a town situated in the Vellore district. The location is identified by the coordinates Latitude 12.93972ºN and Longitude 78.8644ºE. It has a total size of 30.08 km^2 and is at the basin formed by the Palar stream. In this study, four lakes are identified in the Gudiyattam region namely Thattaparai (S1), Yeripattrai (S2), Thattankuttai (S3), and Valathur (S4). These four lakes are the major utility source providing lake water in above specified location. The monsoonal season for this location starts in the month of October and ends in the middle of January. The location map of the study area is given in Figure 1.

Collection of samples and experimental procedure

In each lake, the water sample was collected monthly from May 2019 to April 2020 and grouped as Pre-Monsoon season and Monsoon season. In each season, a water sample was drawn from every lake at a depth of 0.5 meters and stored in sterilized plastic containers. To preserve the collected lake water sample, 10% of nitric acid was prepared from 69% of nitric acid and used to preserve the collected water samples and the sample was stored at 4^{0}C in a refrigerator for future use. The samples were analyzed for the following parameters: Fluoride(F$^-$), Sulfate(SO$_4$), Chloride(Cl-), Magnesium ions (Mg^{2+}), Calcium ions (Ca^{2+}), Total Hardness (TH), Electric conductivity (EC), Turbidity, pH, and elemental analysis: Copper (Cu) and Chromium (Cr). All the param-

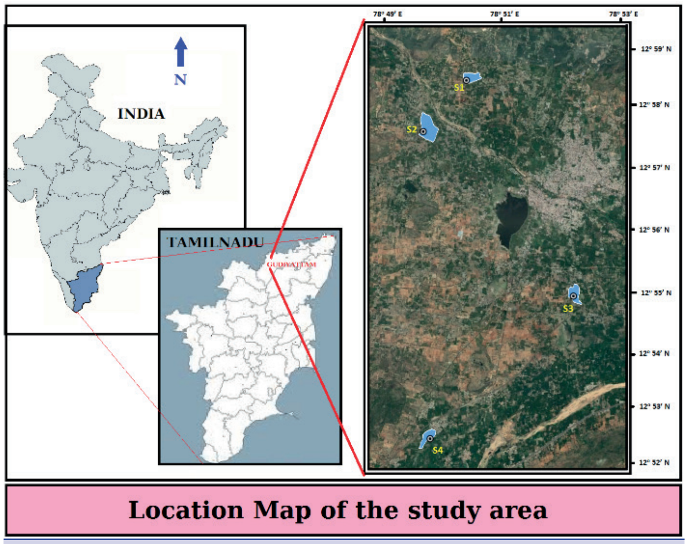

Figure 1. Location Map of the Study area.

eters were determined by the standard procedure recommended by the American Public Health Association (APHA, 2012) and an Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) instrument was used for elemental analysis. The mean value, which was found in each season, was taken into consideration for the physicochemical parameters and bacteriological analysis. All the lakes were dried during the Post-Monsoon season.Thus, only Pre-monsoon and Monsoon seasons were taken into consideration for evaluation.

Bacteriological Analysis (Most Probable Number (MPN)) Test
Determination of total coliform

Multiple tube fermentation technique was performed in a laboratory as outlined by Shariq et al., 2016. Figure 2. depicts the flowchart of the experimental procedure for Presumptive test, confirmed test and completed test.

Principle component analysis (PCA)

Using the water quality dataset from this investigation, all mathematical and statistical calculations were carried out using SPSS Software V.22., in which a large set of highly linked variables were reduced to a more manageable number of independent variables using PCA techniques to infer the variation within them (Regunath et al., 2002).

RESULTS AND DISCUSSION

Physicochemical analysis

Table 1 depicts the interactions between the lake water samples evaluated throughout the study period and the physicochemical features of the distinct seasons. The mean pH value ranged from 5.86 to 8.09. The highest pH value attained at S1 was found to be 8.09 in the Pre-monsoon season and the lowest value attained at S4 was 5.86 in the monsoon season. Especially, at S1 and S4 in the monsoon season, the pH values attained were 6.35 and 5.36, respectively, which is considered to be slightly acidic. The reasons for the acidic nature of the water samples were the waste from households and the municipality. Based on previous studies reported by Bhouyan (1979) and Mahmood et al.,, (1992), pH fluctuation in site due to the industrial and municipal waste dumping. In other sites, the lowest pH value in the monsoon season was due to the dilution of lake water from surface runoff. All the pH values of the all lakes in both seasons lie within the ac-

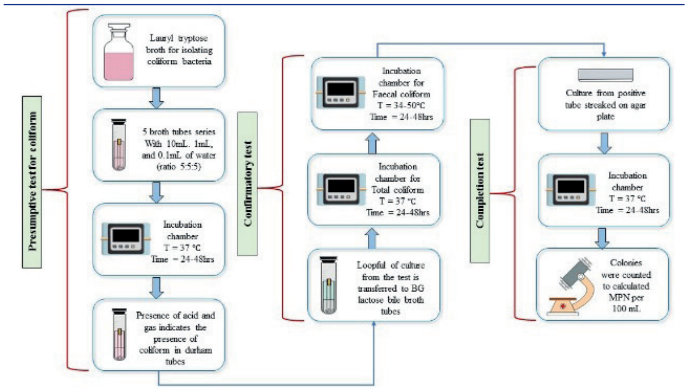

Figure 2. Flowchart for presumptive test, confirmed test, and completed test.

Table 1. Mean and Standard error of Physico-chemical and bacteriological analysis for various seasons.

Parameters	S1		S2		S3		S4	
	Pre-Monsoon	Monsoon	Pre-Monsoon	Monsoon	Pre-Monsoon	Monsoon	Pre-Monsoon	Monsoon
pH	8.09±0.01	6.35 ±0.01	7.83±0	7.21 ±0	7.05 ±0	7.19 ±0.02	7.65 ±0.33	5.86±0.04
Conductivity	264.5 ±1.25	265.2 ±0.33	321.68 ±1.56	619 ±2.56	312.9 ±0.43	315.2 ±0.57	351.1 ±0.33	301.8± 2.13
Turbidity (NTU)	393 ±1.52	73.6 ±0.98	21 ±0.88	2.2 ±0.01	123.5 ±0.03	69.3 ±0	290 ±0.04	2.6±0
Total Hardness (mg/L)	180 ±1.99	250 ±2.6	230 ±1.76	280±0.33	150 ±0.67	120 ±0.01	250 ±0.33	180±0.47
Ca^{2+}(mg/L)	48 ±0.88	20 ±0	50.66 ±0.7	48±0.01	40 ±0.33	16 ±0	52 ±0.01	20.8±0
Mg^{2+}(mg/L)	14.58 ±0.74	31.59 ±0.33	25.11 ±0.85	31.59±0.67	12.15 ±0.47	4.86 ±0	29.16 ±0.01	12.15±0.03
Chlorides (mg/L)	84.97±0.67	149.95 ±0.53	164.9 ±0.03	122.46±0.74	89.97 ±0.01	127.46 ±0.04	134.95 ±0.88	134.95±1.23
Sulfate (mg/L)	14.47±0	0.78 ±0	12.84±0.01	10.26±0.03	11 ±0	10.4 ±0.33	14 ±0.01	4±0
Fluoride (mg/L)	0.54 ±0	0.15 ±0	0.89±0	0.12±0	0.46 ±0.01	0.21 ±0	0.65 ±0	0.14±0
Chromium (mg/L)	-	-	0.0043±0	-	-	-	-	-
Copper (mg/L)	-	-	0.0136±0	-	-	-	-	-
Total Coliform	9600 ±10	15000 ±8.3	1600±0.58	2500±0.3	2240 ±0.88	3500±0.33	51200±12.88	80000±20
Fecal Coliform	3520 ±0.33	5500 ±0.57	960±0.83	1500±1.12	1600 ±2.83	2500 ±3.33	5440±0.33	8500±1.87

ceptable limit, which is mentioned in the standard BIS:(10500-2012). The mean conductivity value ranged from 264.5 (µs/cm) to 619 (µs/cm). The lowest conductivity value attained at S1 was 264.5 (µs/cm) in the pre-monsoon season and the highest value attained at S2 was found to be 619 (µs/cm) in the monsoon season. The variation in conductivity may be due to the agricultural activities happening around lakes. All the conductivity values in each lake were above the acceptable limit, which is outlined in BIS:(10500-2012).

The mean turbidity value for the different seasons ranged from 2.2 NTU to 393 NTU. The highest value of turbidity was obtained at location S1 (393 NTU) in the pre-monsoon season and the lowest value was 2.2 NTU in the monsoon season at S2. The lowest value in the monsoon season was due to the dilution of lake water by surface runoff and rainfall in the monsoonal season. In each lake, the turbidity value was found to be higher than the acceptable limit as per BIS:(10500-2012). The turbidity value was higher than 5 NTU, which has a link to the risk of microorganisms such as coliform bacteria (McCoy & Olson, 1986). The concentration of chloride ranged from 84.97 mg/L to 149.9 mg/L. The highest concentration of chloride was obtained (149.9 mg/L) at S1 in the monsoon season and S1's lowest concentration was in the pre-monsoon season. The chloride concentration of all the locations was below the acceptable limit, which is prescribed in BIS:(10500-2012). Ions of calcium and magnesium are responsible for total hardness. When water has a lot of hardness, scale starts to build inside utensils. The mean lowest concentration of total hardness was obtained at S3 in the monsoon season and the highest concentration was attained at S2 in the monsoon season. The location at S4 in the pre-monsoon season and the location at S1 in the monsoon season were at the border level of the acceptable limit as suggested in BIS:(10500-2012). Location S2 was above the BIS standard. It is thought that the proportions of the minerals calcium and magnesium in water are related (Worcester & Coe, 2010). The mean concentration of calcium ranged from 16 mg/L to 50 mg/L. The concentration was lower in the monsoon season compared to the pre-monsoon season due to surface runoff, and also the dilution of lake water due to the monsoonal effect. The concentration was below the acceptable limit in all the lakes, which is specified in BIS:(10500-2012). The mean lowest concentration of Mg^{2+} was obtained at S3 in the monsoon season (4.86 mg/L) and a higher concentration of Mg^{2+} at S1 and S2 in the monsoon season (31.59 mg/L and 29.16 mg/L). The concentration of Mg^{2+} in each lake was below the acceptable limit, which is prescribed in BIS:(10500-2012). A higher mean concentration of sulfate was attained at S1 (14.47 mg/L) in the pre-monsoon season and a lower mean concentration in the monsoon season at S1 was obtained (0.7 mg/L). The concentration of sulfate in the monsoon season was lower than in the pre-monsoon season due to the dilution of lake water, surface runoff, etc. The mean concentration of sulfate in each lake was below the acceptable limit, which is prescribed in BIS:(10500-2012). Fluoride was high at S4 in the pre-monsoon season (0.65 mg/L) and the lowest concentration obtained in the monsoon season was 0.14 mg/L at S4. The concentration of fluoride in each lake was below the acceptable limit, which is prescribed in BIS:(10500-2012). Only at S2, the heavy metal chromium was found compared with all other lakes. S4 obtained a mean concentration of 0.004 mg/L, which was below the acceptable limit as prescribed in BIS:(10500-2012). S2 attained a mean concentration of 0.01365 mg/L of copper. It was less than the acceptable limit, which is prescribed in BIS:(10500-2012).

Bacteriological analysis

Total coliform is a type of bacterium that is prevalent in water. Fecal coliform is a kind of total coliform that is found in feces. *E. coli* is a subcategory of fecal coliform. Fecal coliform contamination in water serves as a warning sign that infectious microorganisms are present in that water. In this study, multiple tube fermentation was carried out and the results showed that MPN values ranged from 1,600 MPN/100mL to 80,000 MPN/100mL. All the lake water samples were above the limits which are specified in BIS:(10500-2012). At location S2, the pre-monsoon season obtained 1,600 MPN/100mL, which is the lowest range among all the lakes, and location S4 in the Monsoon season obtained 80,000 MPN/100mL, which is recorded as the highest value among all the lakes. It clearly shows that there is huge contamination of the lake at the S4 location both in the monsoon and pre-monsoon seasons. It might be due to the availability of waste from animals and the plantation processes, which pollute the lakes nearer to inhabited regions that take in surface runoff from pasture and agricultural land (Leong et al., 2018). The MPN value in the monsoon season is higher than the pre-monsoon in all the lakes. This is because of the agricultural runoff. During the monsoon season, when it rains a lot, sanitary waste from a vast area is transported into nearby low places or depressions, where dangerous microbes can reach a surrounding shallow aquifer (Escamilla et al.,2013). The minimum and maximum concentration of coliform in each location is tabulated in Table 2.

For the confirmation of fecal coliform, the required incubation temperature is 44.50°C and the results showed that the MPN value ranged from 960 MPN/100mL at S2 in the pre-monsoon sea-

Table 2. Minimum and Maximum value with standard error of Total coliform count and Fecal coliform (MPN/100mL) for all the lakes.

S.No	Place	Total Coliform (MPN/100mL)		Fecal coliform (MPN/100mL)	
		Minimum	Maximum	Minimum	Maximum
S1	Thattaparai	2400 ± 20	16800 ±23.3	2150 ±2.96	1,120±2.30
S2	Eripattrai	800 ± 8.81	3300 ± 5.77	448±0.66	2850±3.33
S3	Thattankuttai	1250 ±7.81	3230 ± 3.33	1,118±0.66	3250±1.99
S4	Valathur	30000 ± 10	72400 ±16	3680±3.33	11,150±8.81

son to 8,500 MPN/100mL at S4 in the monsoon season. In all the lakes, MPN values were greater than the value which is specified in BIS:(10500-2012). The monsoon season dominated the MPN values compared with the pre-monsoon season. It is because the greater load of *E. coli* and consequent high *E. coli* levels in lake water were caused by a wet season. Additionally, if *E. coli* grows at all, increased nutrient loads with runoff may aid in that growth.

Location S4 achieved a higher MPN value in Total coliform and also in fecal coliform, which indicates that there may be an influence of the household drainage and the results were supported by unpredictable changes in the coliform bacteria caused by seasonal fluctuations (Legenre, Baleux, & Troussellier, 1984; Barcina, 1986; Ramanibai, 1996). The fecal coliform value for each site and the minimum and maximum concentrations at each location are shown in Table 2.

The occurrence of *E. coli* was confirmed with EMB (Eosin-Methylene Blue) agar and is shown in Table 3.

PCA (Principal Component Analysis) analysis

Thirteen parameters were analyzed for the lake water samples and the results were subjected to Principal Component Analysis(PCA) and the relationship between the parameters was determined. The identified parameters were regarded as independent variables and for the dependent variable, the sampling site was taken into consideration. The output of PCA analysis is depicted in Table 4 and Table 5 for the pre-monsoon and monsoon seasons.

In the pre-monsoon season, the entire 13 parameters were classified into 3 components in the Principal Component Analysis(PCA). In PC (principal component) 1, chromium, copper, andfluoride had a total variance of 47.2%. This may be a result of human-made contaminants released from the disposal of household garbage and liquid wastes from industries. In PC2, Total coliform, magnesium, Total Hardness, and Conductivity had some similarities and the total variance was 37.1%. In PC3, the parameter pH and sulfate had similar patterns and showed a 17.9% total variance.

In the monsoon season, all the water quality parameters were divided into 3 components in the PCA analysis. In PC1, the parameter pH and sulfate had similar patterns with a total variance of 41.3%. In PC2, Total Hardness and magnesium had unique patterns with a total variance of 36.4%. In PC3, the heavy metal copper and Conductivity had unique trends with a variance of 22.2% and the presence of these pollutants is due to industrial activity and also dumping of waste near the lakes.

Table 3. Completed test for *E. coli* for all the lakes.

S.No	Place	Sample concentration (Pre-monsoon)			Sample concentration (Monsoon)		
		10ml	1ml	0.1ml	10ml	1ml	0.1ml
S1	Thattaparai	+++++	+++	+++	+++++	+++	+++
S2	Eripattrai	+++++	+++++	+++++	+++++	+++++	+++++
S3	Thattankuttai	+++++	++	++	+++++	++	++
S4	Valathur	+++++	+++++	+++++	+++++	+++++	+++++

Table 4. PCA for Pre-Monsoon season.

Parameters	Component		
	PC1	PC2	PC3
pH	.201	-.017	**.980**
Conductivity	.135	**.891**	-.433
Turbidity	-.788	-.050	.613
Total Hardness	.310	**.863**	.399
Calcium	.275	.645	.713
magnesium	.312	**.914**	.258
Chloride	**.759**	.647	.075
Sulfate	-.189	.258	**.948**
Fluoride	**.861**	.422	.285
Chromium	**.995**	.074	.071
Copper	**.995**	.074	.071
Total coliform	-.490	**.847**	.206
Fecal coliform	-.708	.568	.420
Eigen Value	6.143	4.569	2.287
Variability %	47.258	35.147	17.595
Cumulative %	47.258	82.405	100%

Table 5. PCA for Monsoon season.

Parameters	PC1	Component PC2	PC3
pH	**.987**	-.083	.135
Conductivity	.565	.532	**.630**
Turbidity	.269	-.380	-.885
Total Hardness	.103	**.994**	-.021
Calcium	.430	.716	.549
Magnesium	.151	**.962**	-.230
Chloride	-.531	.188	-.826
Sulfate	**.736**	-.301	.606
Fluoride	.255	-.926	-.278
Chromium	.552	-.834	-.010
Copper	-.068	-.062	**.996**
Total Coliform	-.943	-.109	.314
Fecal Coliform	-.994	-.061	-.093
Eigen Value	5.369	4.714	2.889
Variability %	41.301	36.473	22.226
Cumulative %	41.301	77.774	100

The scree plot displays the change in eigenvalue as the number of components is increased while keeping the cutoff eigenvalue at 1. The entire data set was grouped into 3 principal components in the pre-monsoon season and for the monsoon season, the entire data set was grouped into 3 components based on pollution load. The Scree plots for the pre-monsoon and monsoon seasons are depicted in Figure 3(a) and Figure 3(b).

Relationship between physicochemical and bacteriological analysis

Physicochemical and bacterial interaction for the pre-monsoon and monsoon seasons at The Gudiyattam Lake region is shown in Table 6 and Table 7 respectively. During the pre-monsoon season, FC had a significant positive correlation with turbidity and also had a positive correlation with TC. For the monsoon season, FC had a negative correlation with pH and a positive correlation with TC. Pereira et al.,2011) reported that there was an inverse relationship between the mean concentrations of bacterial population and the mean value of pH in the water.

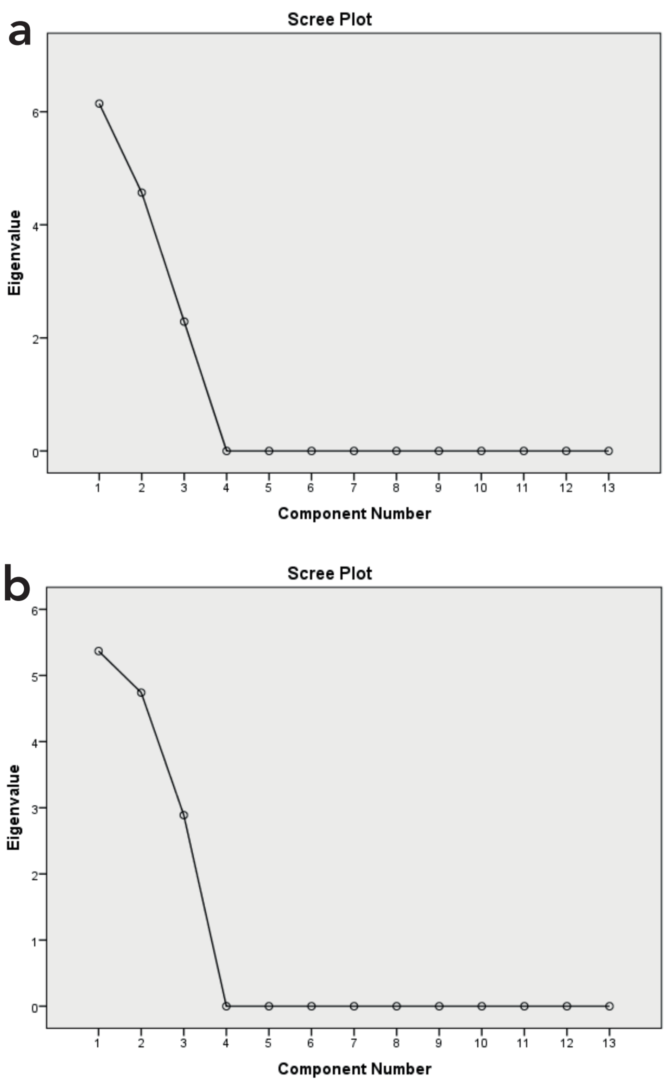

Figure 3. Scree plot for pre-monsoon and post monsoon seasons.

CONCLUSION

The major physio-chemical result lies within the standards except for the following parameters,hich are conductivity, turbidity, and magnesium ion which were specified in BIS:(10500-2012). All the lakes were contaminated with bacteria in the higher range. Especially, location S4 dominated when compared to all the other lakes for total coliform and fecal coliform as well as in the monsoon season. This happens due to the runoff caused by rainfall, which contributes significantly to the influx of fecal debris into the lake, and thus the results revealed there was a correlation between fecal coliform concentrations in the river or lake water and runoff. Also, S4 is exposed to a variety of daily human activities as well as receiving the direct waste from dwellings. The remaining sites also achieved higher bacterial contamination than the standard value, which was specified in BIS10500-2012). This might be due to various human, agricultural, and industrial activities having a serious impact on the microorganisms in the water. Surface runoff from agricultural and grazing land, animal waste, and effluent runoff discharges from industrial sites and plantations will contaminate lakes near populated areas, resulting in bacterial infection and flues via water. The fecal counts were typically high, notably at locations S1, S3, and S4, implying the presence of human or animal waste, as well as harmful bacteria. Nonpoint sources of fecal coliform bacteria in urban and rural regions include bird feces, rats, wild animals, and even domestic animals are also responsible for the microbial load. Organic waste produced from industries, like raw sewage, and other drainages may contain an enormous number of chemicals, disrupting the surface water ecological food chain and is forecasted to be the cause of high MPN indices. Considering the correlation analysis, FC was significantly positive with turbidity and negative correlation with pH, which clearly indicates the lakes had been polluted by various actions.

Overall, this study gives an output that S4 (valathur) needs serious attention compared to all the other lakes concerning bacteriological pollution and the current study recommends continuous monitoring of this region and efficient management to prevent future contamination of this aquatic environment.

Ethics Committee approval: Ethics Committee approval was not required for this study.

Competing Interest: To the best of our knowledge, we haven't ever sent identical work for review or publication to another journal.

Conflict of Interest: There was no conflict of interest in this study.

Financial disclosure: We did not receive any financial assistance from others.

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Table 6. Correlation Matrix of Physico-chemical and bacterial parameters of the lake water in Gudiyattam region during Pre-monsoon season.

Parame-ters	pH	Con-duct ivity	Turbi dity	TH	Ca^{2+}	Mg^{2+}	Cl	SO_4	Fluor ide	Cr	Cu	TC	FC
pH	1												
Conducti Vity	0.606	1											
Turbidity	0.139	-0.057	1										
TH	0.207	-0.129	-0.256	1									
Ca+	-0.095	-0.441	0	0.54	1								
Mg+	0.3	0.102	-0.299	0.874	0.064	1							
Chloride	0.129	-0.13	-0.542	0.677	-0.105	0.861	1						
Sulfate	0.512	-0.201	-0.219	0.252	-0.03	0.311	0.572	1					
Fluoride	0.744	0.837	-0.2843	0.138	-0.517	0.461	0.378	0.287	1				
Cr	-0.33	-0.748	-0.419	0.472	0.21	0.435	0.737	0.553	-0.296	1			
Cu	0.498	0.357	-0.6	0.346	-0.417	0.647	0.804	0.642	0.795	0.329	1		
TC	-0.005	0.072	0.617	0.379	0.216	0.331	-0.111	-0.512	-0.123	-0.264	0.397	1	
FC	0.076	-0.025	0.939	-0.01	0.052	-0.037	-0.376	-0.35	-0.24	-0.361	-0.55	0.845	1

TH(mg/L):Total Hardness,Ca^{2+}(mg/L):calcium ion, Mg^{2+}(mg/L):magnesium ion, Cl(mg/L):Chloride, SO_4(mg/L):Sulfate, Cr(mg/L): Chromium, Cu(mg/L):Copper, TC:Total coliform, FC: Faecal Coliform

Table 7. Correlation Matrix of Physico-chemical and bacterial parameters of the lake water in Gudiyattam region during Monsoon season.

Parameters	pH	Conduct ivity	Turbi dity	TH	Ca^{2+}	Mg^{2+}	Cl	SO_4	Fluor ide	Cr	Cu	TC	FC
pH	1												
Conductivity	0.608	1											
Turbidity	0.071	-0.466	1										
TH	0.364	0.805	-0.327	1									
Ca+	0.519	0.918	-0.555	0.927	1								
Mg+	0.407	0.816	-0.214	0.988	0.896	1							
Chloride	-0.61	-0.554	0.67	-0.21	-0.55	-0.139	1						
Sulfate	0.583	0.942	-0.385	0.947	0.976	0.946	-0.437	1					
Fluoride	-0.32	-0.794	0.653	-0.91	-0.96	-0.851	0.493	-0.898	1				
Cr	0	0	0	0	0	0	0	0	0	1			
Cu	0	0	0	0	0	0	0	0	0	0	1		
TC	-0.83	-0.186	-0.311	-0.21	-0.26	-0.227	0.383	-0.307	0.16	0	0	1	
FC	-0.97	-0.472	-0.039	-0.3	-0.47	-0.315	0.661	-0.493	0.321	0	0	0.921	1

TH (mg/L): Total Hardness, Ca^{2+} (mg/L): calcium ion, Mg^{2+} (mg/L): magnesium ion, Cl (mg/L): Chloride, SO_4 (mg/L): Sulfate, Cr (mg/L): Chromium, Cu (mg/L): Copper, TC: Total coliform, FC: Fecal Coliform

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