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EVALUATION OF HYDROCHEMISTRY AND DRINKING WATER QUALITY OF RAMAKKAL LAKE, DHARMAPURI DISTRICT, TAMIL NADU

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ABSTRACT

Securing public health and environmental sustainability depends on effective water quality evaluation. The present study is aimed to analyze the physical and chemical characteristics of lake water and evaluate its contamination level for drinking purposes. A total of ten surface water samples were collected from different stations in Ramakkal Lake, Dharmapuri, Tamil Nadu, India. In this study, 13 water quality parameters were analyzed to identify their concentration and were compared with the World Health Organization (WHO) standards for drinking purposes. The comparison results indicate that the lake water remains alkaline in nature at all sampling locations. Among the thirteen water quality parameters, Total Dissolved Solids, Ca^{2+}, K^{+}, HCO_3^{-}, and PO_4^{3-} exceed the permissible limits in most of the samples. Correlation analysis and principal component analysis reveal the degree of association among physicochemical parameters and the major factor governing water chemistry. The statistical results indicate that rock-water interaction, silicate weathering, mineral dissolution, and anthropogenic activities such as agricultural runoff and municipal waste dumping are significantly affect the water quality. Among the ten sampling stations, S10 exhibits high contamination with respect to various physical and chemical properties, and the overall water quality is severely deteriorated. Therefore, continuous monitoring and proper conservation measures are essential to mitigate the impact of growing anthropogenic activities in the present study area. The study also recommends that adequate

treatment measures should be implemented before the discharge of contaminants into water system of Ramakkal Lake, in Dharmapuri district.

KEYWORDS: Water quality, Physicochemical Properties, Contamination, Statistical analysis, Ramakkal Lake.

INTRODUCTION

The availability of clean drinking water is widely recognized as a fundamental human right.[1] In recent years, water pollution has emerged as a major global concern due to its severe environmental degradation and significant economic impacts, especially the growing reliance on freshwater extracted from surface water bodies such as lakes, rivers, and ponds.[2,3] Lakes are crucial for providing ecosystem services, including drinking water supply, fisheries, and transportation to local communities; however, the range of these services diminishes as lake health declines.[4] Surface water bodies are highly susceptible to contamination due to intense human-induced factors, such as climate change, urbanization, industrial and agricultural pollution, nutrient enrichment, sewage input, and the intrusion of invasive species.[5,6] Nearly 850 million people globally lack access to safe and clean drinking water, with contaminated water contributing to approximately 80% of diseases affecting this population. As a result, Concerns over water quality are significant due to its direct impact on human health and well-being.[7,8] It is monitored through the assessment of physical and chemical parameters, enabling diagnosis and future planning of conservation and prevention strategies.[9] If the physical and chemical parameters deviate significantly from recommended standards, either below or above the permissible limits, they may pose risks to human health.[10] Water resources in the Dharmapuri district are under pressure due to both geogenic and anthropogenic processes. According to the survey report, Dharmapuri district has 74 lakes maintained by the Public Works Department (PWD). Among these, Ramakkal Lake is located near Dharmapuri town and serves as an important water resource for domestic use and fishing activities. Previous study conducted in 2013 has reported that the water of Ramakkal Lake is polluted in several ways, including the discharge of sewage from settlements and the disposal of industrial effluents.[11] Therefore, the present study is focused on the investigation of physicochemical characteristics of surface water from Ramakkal Lake in Dharmapuri district, Tamil Nadu, India.

MATERIALS AND METHODS

Study area

Dharmapuri district is located in the northwestern part of Tamil Nadu and exhibits undulating terrain with hill ranges and valleys forming part of the Eastern Ghats. It covers an area of 4,497.77 sq. km and is bounded by Krishnagiri District in the north, Salem District in the south, Tiruvannamalai and Viluppuram Districts in the east, and the Cauvery River along its western boundary. In the Dhramapuri district, Ramakkal Lake is located near Dhamapuri town. It is an important water body spanning approximately 259 acres and plays a crucial role in supporting irrigation, livestock, and fisheries The lake primarily depends on rainfall as its main source of recharge.

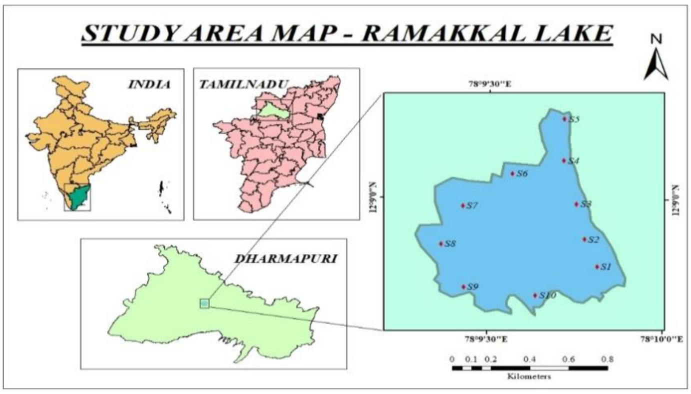

Fig. 1: Study area map of Ramakkal Lake, Dharmapuri district.

Sample collection

The present study initially involved the sample collection in the Ramakkal Lake. Ten surface water samples were collected from the ten different locations (referred to as St. 1-10) within this lake in the Dharmapuri district, Tamil Nadu. The study area was mapped using ArcGIS 10.8. which is shown in Fig 1. For sample collection, High-Density Polyethylene (HDPE) bottles were used, and after the sample collection, the bottles were sealed immediately to maintain originality.

Water Quality Analysis

The physical parameters, including pH, Total Dissolved Solids (TDS), Electrical Conductivity (EC), and Turbidity, were measured during the sample collection using a portable water quality analysis kit. The collected water samples were transported to the laboratory and stored at 4°C for further analysis.

Total hardness, total alkalinity, and the concentration of major ions (Ca^{2+}, Mg^{2+}, CO_3^{2-}, HCO_3^-, and Cl^-) were measured using standard titrimetric methods. The (Ethylenediaminetetraacetic acid) EDTA titration method was utilized to determine the concentrations of Na^+ & K^+ using a flame photometer, while a UV spectrophotometer was utilized to identify the concentration of F^-, NO_3^-, SO_4^{2-}, and PO_4^{3-}.

Multivariate Statistical Analysis

Multivariate statistical techniques were employed to examine the relationship among multiple variables.[12] In the present study, correlation analysis and principal component analysis were performed using SPSS statistical software (version 16.0).

Correlation describes the interrelationship between two variables. A positive correlation occurs when an increase or decrease in one parameter is accompanied by a corresponding increase or decrease in another parameter.[13] Principal component analysis (PCA) was used to represent the statistical relationships among water quality parameters in a simplified form.[14]

RESULT AND DISCUSSION

The concentration of physicochemical properties of the water samples was compared with the WHO drinking limits to assess the contamination status of all sampling locations. Table 1 shows the WHO (World Health Organization) and BIS (Bureau of Indian Standards) Permissible limits of all water quality parameters. The statistical range of water quality parameters for the collected water samples is displayed in Table 2.

Table 1: Drinking water quality standards set by WHO and BIS.

S.no	Parameters	Units	WHO Standards	BIS Standards
1	pH	-	7.0 – 8.5	6.5-8.5
2	EC	µS/cm	1500	1500
3	TDS	mg/l	1500	500
4	Calcium	mg/l	75	75
5	Magnesium	mg/l	50	30
6	Sodium	mg/l	200	100
7	Potassium	mg/l	12	10
8	Carbonate	mg/l	-	-
9	Bicarbonate	mg/l	200	300
10	Chloride	mg/l	200	250
11	Nitrate	mg/l	50	45
12	Sulphate	mg/l	200	250
13	Fluoride	mg/l	1.5	1.0

Table 2: Statistical range of the concentration of physicochemical parameters.

S.No	Parameters	Minimum	Maximum	Average	St. Deviation
1	pH	7.47	8.25	7.79	0.25
2	EC	925	1725	1079	235.5
3	TDS	648	1208	755	164.9
4	Total Alkalinity	176	384	223	70
5	Total Hardness	252	508	327	70.04
6	Calcium	62	115	75	14.8
7	Magnesium	21	53	33	8.41
8	Sodium	84	186	100	41.2
9	Potassium	8	20	11.8	3.35
10	Bicarbonate	176	384	223	70.04
11	Chloride	148	304	156	43
12	Nitrate	8	17	10	2.51
13	Sulphate	55	115	72	16.6
14	Fluoride	0	0.2	0.16	0.08
15	Phosphate	0.56	2.49	1.43	0.64

Physical Properties

The analytical results indicate that the pH of the water is alkaline in nature and falls within the permissible limits of 6.5 to 8.5 at all sampling stations. The term electrical conductivity (EC) refers to the ability of water to conduct electricity, which is primarily governed by ion concentration, ionic mobility, and water temperature.[15] The electrical conductivity of this present study ranges from a minimum of 925 to a maximum of 1725, with an average value of 1079. Only Station 10 recorded an elevated value of 1725. Total dissolved solids modify the ionic balance of water by influencing the salinity, which can induce toxicity in aquatic organisms and lead to changes in biodiversity.[16] The concentration of total dissolved solids (TDS) ranges between 648 mg/L and 1208 mg/L, with an average of 755 mg/L, indicating moderate levels of 500 mg/L to 1500 mg/L across all sampling stations.

Chemical properties

Calcium and magnesium concentrations range from 62 to 115 mg/L and 21 to 53 mg/L, respectively, with average values of 75 mg/L and 33 mg/L. These two elements are essential; however, elevated concentrations can increase water hardness.[17] Water with higher Ca^{2+} levels is attributed to anthropogenic inputs, including industrial effluent discharge and the intrusion of domestic waste.[18] The concentrations of calcium (Ca^{2+}) ions were found to be

above the permissible limit of 75 mg/L at Stations S3, S5, and S10, and the magnesium exceeds the permissible limit of 50 mg/L at Station S10. Sodium values are fall within the

Permissible limit < 200 mg/L set by WHO across all stations. According to the WHO, no guideline values have been established for potassium, as it generally occurs at lower concentrations in drinking water compared to sodium.[19] In this study, potassium concentrations lie between 8 and 20 mg/L with an average of 11.8 mg/L and exceed the permissible limit of 12 mg/L at sampling stations S5 & S10.

Bicarbonate concentration ranges between 176 mg/L and 384 mg/L, with an average of 223 mg/L, and out of the ten water samples, two water samples (Stations S3 and S10) exceed the permissible limit, which may be due to the weathering of silicate minerals. Chloride is a major anion, and elevated chloride levels are primarily influenced by natural factors such as precipitation and evaporation, as well as anthropogenic influences, including fertilizer leaching, urban runoff, wastewater discharge, and inadequate sewage systems.[20] In this study, the concentration of chloride fell within the permissible limit at all stations, except at sampling station S10, where a value of 304 mg/L was recorded.

Consumption of water containing excessive nitrate and nitrite ions poses health risks, leading to methemoglobinemia, generally referred to as "blue baby syndrome," in infants, while in adults, it may increase the risk of gastric cancer. Similarly, elevated fluoride concentration (>1.5) in drinking water can cause dental and skeletal fluorosis.[21] Nitrate, sulfate, and fluoride vary from 8 mg/L to 17 mg/L, 55 mg/L to 115 mg/L, and 0 to 0.2 mg/L, respectively, and remain within the permissible limits at all sampling stations. The phosphate ion at all stations falls under the not-permissible limit, with a minimum of 0.56 mg/L to 2.49 mg/L, with an average of 1.43 mg/L. The presence of phosphate in water bodies is attributed to both geogenic and anthropogenic sources, including phosphate-bearing rocks, fertilizers, and the seepage of sewage and industrial effluents.[22] Fig.2 illustrates the fluctuation in the concentration of physical and chemical properties.

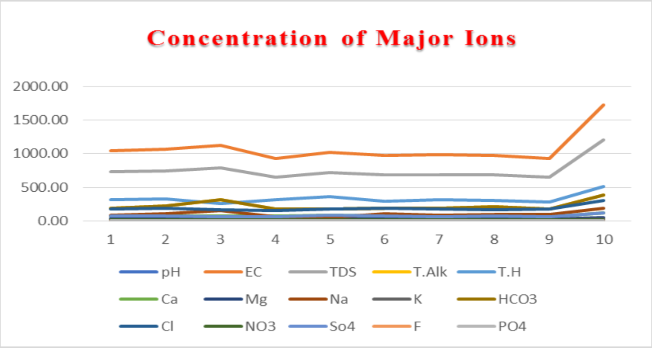

Fig. 2: Concentration of physical and chemical parameters of surface water samples.

Multivariate Statistical Analysis

In this Present study, the Physical chemical behaviour of ten surface water samples has been interpreted through a few multivariate statistical methods by employing SPSS 16.0 software.

Correlation Analysis

Pearson correlation analysis was performed to evaluate the interrelationship between water quality parameters, which is illustrated in Fig.3. pH shows a moderate to good positive correlation coefficient (0.63 to 8.10) with EC, TDS, total alkalinity, sodium, potassium, and bicarbonate. Electrical conductivity exhibits a strong positive correlation with TDS (r=1.000). Both EC and TDS demonstrate good positive correlation with most of the major ions, with the correlation coefficient ranging from 0.737 to 0.940, suggesting the water chemistry is primarily governed by possible geogenic processes. Sodium shows a moderate to good correlation with potassium (K^+) (r= 0.639), bicarbonate (HCO_3^-) (r= 0.951), chloride (Cl^-) (r= 0.746), and nitrate (NO_3^-) (r= 0.741), while potassium exhibits a good positive correlation with HCO_3^- (r=0.779), Cl^- (r= 0.823), NO_3^- (r= 0.800) and $SO4^-$(r= 0.893). Bicarbonate forms a moderate positive correlation with Cl^- (r= 0.762) and nitrate NO_3^- (r= 0.767), suggesting a possible silicate weathering process. Nitrate also shows a moderate to strong correlation with a few ions, indicating significant anthropogenic activities such as runoff from agriculture. In contrast, fluoride and phosphate show a weak correlation with all major ions, indicating the additional anthropogenic and lithological inputs.

Correlations

	pH	Ec	TDS	Ca	Mg	Na	K	HCO3	Cl	NO3	SO4	F	PO4
pH	1												
Ec	.635*	1											
TDS	.634*	1.000**	1										
Ca	0.389	.930**	.930**	1									
Mg	0.195	.737*	.738*	.887**	1								
Na	.731*	.819**	.819**	0.591	0.239	1							
K	.705*	.916**	.916**	.896**	.794**	.639*	1						
HCO3	.810**	.900**	.900**	.702*	0.402	.951**	.779**	1					
Cl	0.423	.940**	.941**	.937**	.764*	.746*	.823**	.762*	1				
NO3	0.429	.891**	.891**	.859**	0.629	.741*	.800**	.767**	.862**	1			
SO4	0.372	.866**	.866**	.945**	.925**	0.511	.893**	0.601	.900**	.809**	1		
F	-0.175	0.147	0.148	0.174	0.17	0.183	0.027	-0.008	0.387	0.156	0.306	1	
PO4	-0.613	-0.124	-0.124	0.032	-0.012	-0.152	-0.243	-0.289	0.057	0.201	0.057	0.469	1

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

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

Fig. 3: Representation of the relationship between all water quality parameters.

Principal Component Analysis

Principal Component Analysis (PCA) with Kaiser - Varimax rotation was applied to 13 water quality parameters. Table 3 shows that three components with eigenvalues greater than 1 were retained. PC1 has the eigenvalue of 8.697, while PC2 and PC3 have eigenvalues of

2.161 and 1.137, respectively. PC1 accounted for 45.156% of total cumulative variance and showed strong positive loadings of Mg, Ca, Na, EC, TDS, Cl, SO4, and NO3, indicating water quality influenced by water-rock interaction and anthropogenic inputs such as agricultural return flow and domestic wastes. Similarly, PC2 holds a total cumulative variance of 32.925% and is characterized by high positive loadings with K, HCO3, pH, EC, and TDS reflecting carbonate minerals dissolution and associated buffering reactions, and fertilizer use. PC3 explained 14.195% of total cumulative variance and showed positive loadings with K and PO4, suggesting the influence of specific lithological sources and agricultural activities. Fig 4 and Table 4 show the relationship between the variables and the corresponding Principal Components, as represented by the rotated sum of squared loadings.

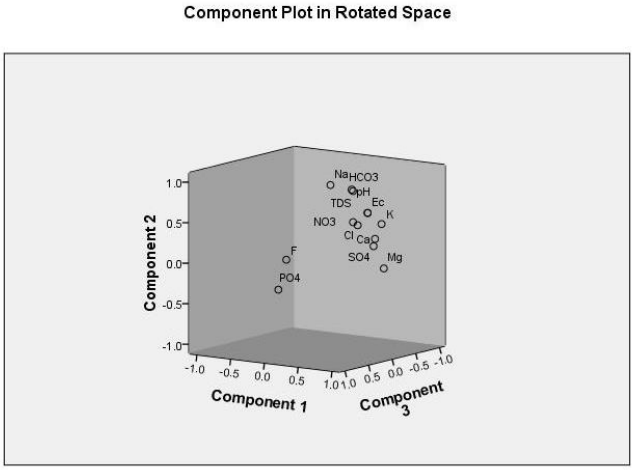

Fig. 4: Rotated Factor Component Plot of Physical and Chemical Properties.

Table 3: Total cumulative variance for the physicochemical characteristics of groundwater.

Component	Initial eigen values			Rotation squared loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	8.697	66.902	66.902	5.87	45.156	45.156
2	2.161	16.625	83.527	4.28	32.925	78.081
3	1.137	8.749	92.276	1.845	14.195	92.276

Extraction method: Principal component analysis

Rotation method: Varimax with Kaiser normalization component score

Table 4: Rotated component matrix for water quality parameters.

Variables	Principal Components		
	PC1	PC2	PC3
pH	0.193	**0.791**	-0.484

Ec	**0.753**	0.65	0.005
TDS	**0.754**	0.649	0.006
Ca	**0.917**	0.356	0.083
Mg	**0.986**	-0.014	-0.005
Na	0.258	**0.955**	0.084
K	**0.818**	0.49	-0.197
HCO3	0.42	**0.883**	-0.134
Cl	**0.778**	0.536	0.251
NO3	0.694	0.561	0.228
SO4	**0.932**	0.276	0.135
F	0.112	0.122	**0.809**
PO4	0.035	-0.246	**0.867**

In the Scree plot, 13 water quality parameters were summarized into three major principal components with eigenvalues greater than 1, and are displayed in Fig 5. The scree plot exhibits a sharp decline in eigenvalues from PC1 (8.69) to PC2 (2.16) and then to PC3 (1.13), with each successive contributing progressively less variance, followed by the nearly flat trend for the remaining components. This suggests that the chemistry of surface water samples is governed by three major processes, along with some subsidiary sources of variance. The marked elbow after PC3 confirms that three principal components were sufficient to explain the major variance in the dataset for further hydrogeochemical interpretation.

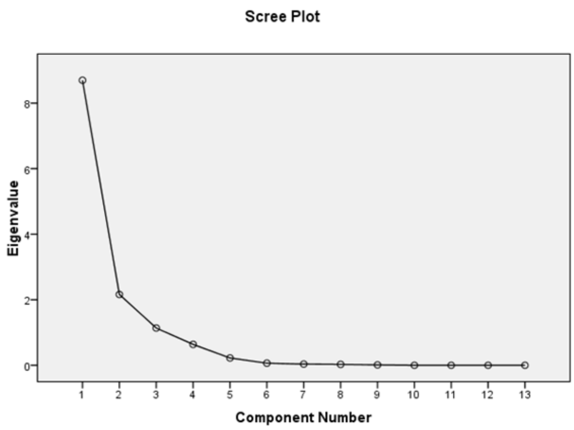

Fig. 5: Rotated Factor Component Plot of Physical and Chemical Parameters.

CONCLUSION

Ten surface water samples were collected from different stations in Ramakkal Lake, Dharmapuri district. The analytical results of these water samples were compared with WHO drinking water quality standards to evaluate the contamination status of the lake. The comparison suggests that the lake water quality of Ramakkal Lake has deteriorated due to fluctuations in ionic composition influenced by both geogenic and anthropogenic sources. The primary geogenic processes responsible for the variation in ion concentration are mineral dissolution and weathering of silicate minerals, whereas the human-induced factors include agricultural runoff, sewage from nearby settlements, and the discharge of industrial waste around the lake. Overall, the present study concludes that the lake water quality falls within a moderate to poor condition contamination range, with Sampling Station S10 being highly contaminated, possibly due to direct input of sewage and agricultural waste. Therefore, this study recommends regular monitoring and the implementation of appropriate measures to improve and protect the water quality of Ramakkal Lake.

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