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Spatial variation of physico chemical characteristics of ground water in the shallow phreatic aquifers of the Vembanad wetland system, Kerala, India

Parvathy K Nair[1*], Sibin Antony[2], DS Suresh Babu[3]
[1] Research Fellow, Marine Geosciences Group, National Centre for Earth Science Studies, Akkulam, Thiruvananthapuram, Kerala, India
[2] Research Fellow, Biogeochemistry Group, National Centre for Earth Science Studies Akkulam, Thiruvananthapuram, Kerala, India
[3] Scientist F, Marine Geosciences Group, National Centre for Earth Science Studies, Akkulam, Thiruvananthapuram, Kerala, India

Abstract
The present study reports the monitoring of physical characteristics of the shallow phreatic aquifer of the Vembanad Wetland System. The physical characteristics of the groundwater from the open dug well identified that the temperature, pH of the pre and post monsoon samples almost remain same throughout the seasons but the electric conductivity, total dissolved solids and salinity shows a significant difference between the seasons. Most of the groundwater is slightly acidic to slightly alkaline, fresh to brackish in nature.

Keywords: groundwater, Vembanad Lake, water quality

Introduction

Groundwater is an important resource for agricultural purposes, industrial sectors and for portable use. In general, the groundwater quality and quantity are extremely deteriorated due to various natural and anthropogenic factors across the continents. The groundwater chemistry is controlled by various physical and hydrogeological factors such as nature of recharge conditions, evaporation rate, rock water interaction, residence time of groundwater, depth to water table and aquifer characteristics. In recent years, deterioration of groundwater quality due to human activities drew great importance and hence a thorough understanding of groundwater chemistry is essential to decipher the solute characteristics and controlling processes.

The Vembanad Wetland System (VWS) consists of Vembanad Lake and its surrounding drainage basins. In the past decades many studies have been reported on the water quality, physical conditions and contamination levels in the groundwater systems (Manjusree *et al*., 2009; Nair *et al*., 2010; Sajeev *et al*., 2020) [4, 7]. In the present study, investigate the spatial temporal variation in physical parameters controlling the groundwater quality from the shallow phreatic aquifers in the Vembanad Wetland System.

The VWS consists of Vembanad estuary and its drainage basins. The Vembanad Lake is an oxbow shaped lake extending for a distance of 96.5 km, from Azheekode in the North to Alappuzha in the South with a NW-SE orientation. The estuary is approximately 14 kilometres wide at its widest point. The lake is connected to the Arabian Sea in the west through two inlets, with one channel at Kochi (400 m) and another channel further north at Azheekode (250 m). The lake consists of two major arms, the salt water dominant northern arm and the freshwater dominant southern arm. The northern arm is between Kochi bar mouth to Azheekode (Kochi lake/ kayal) and has a length of 32 km and width of 0.05-0.5 km.

The southern arm is between Kochi bar mouth to Alappuzha (Vembanad lake/ kayal) and has a length of 64 km and width of 0.8-6.9 km. The study area is the part of the VWS, covering Alappuzha, Kottayam and Ernakulam districts and falling in the Survey of India Toposheets Nos. 58 C/1, C/6, C/7, C/10, C/11, B/ 4 and B/8. The study area map with major places is shown in Fig. 2.1.

The research area includes the Vembanad Lake and the lower reaches of the five rivers draining in it and covers an area of 1215 km². In order to study how the lake water influences the spatial variability of physicochemical parameters of the aquifer system, almost about 2km buffer area were selected in the fresh water dominant part of the lake. The study area map for this aspect is shown in Fig.2.2.

Study area

The study area is the part of the VWS, covering Alappuzha and Kottayam districts and falling in the Survey of India Toposheets Nos. 58 C/1, C/6, C/7, C/10 and C/11. The study area map with major places and sampling locations is shown in Fig.1. In order to study how the lake water influences the spatial variability of physicochemical parameters of the aquifer system, almost about 2km buffer area were selected in the fresh water dominant part of the lake.

Materials and methods of study

The groundwater samples were collected from the 108 shallow open dug wells during pre (May) and post (November) monsoon season. The sampling locations is shown in Fig 1. Samples were analysed for various physical parameters such as temperature, pH, electric conductivity (EC), total dissolved solids (TDS) and salinity. These parameters were measured with the help of multi parameter water quality meter at the time of sampling (Aquaread AP 2000).

The spatio temporal analysis of various physical parameters was carried out using the ArcGIS 10 software. In order to identify the spatial distribution of various parameters in the study area, an inverse distance weighted (IDW) interpolation algorithm was used.

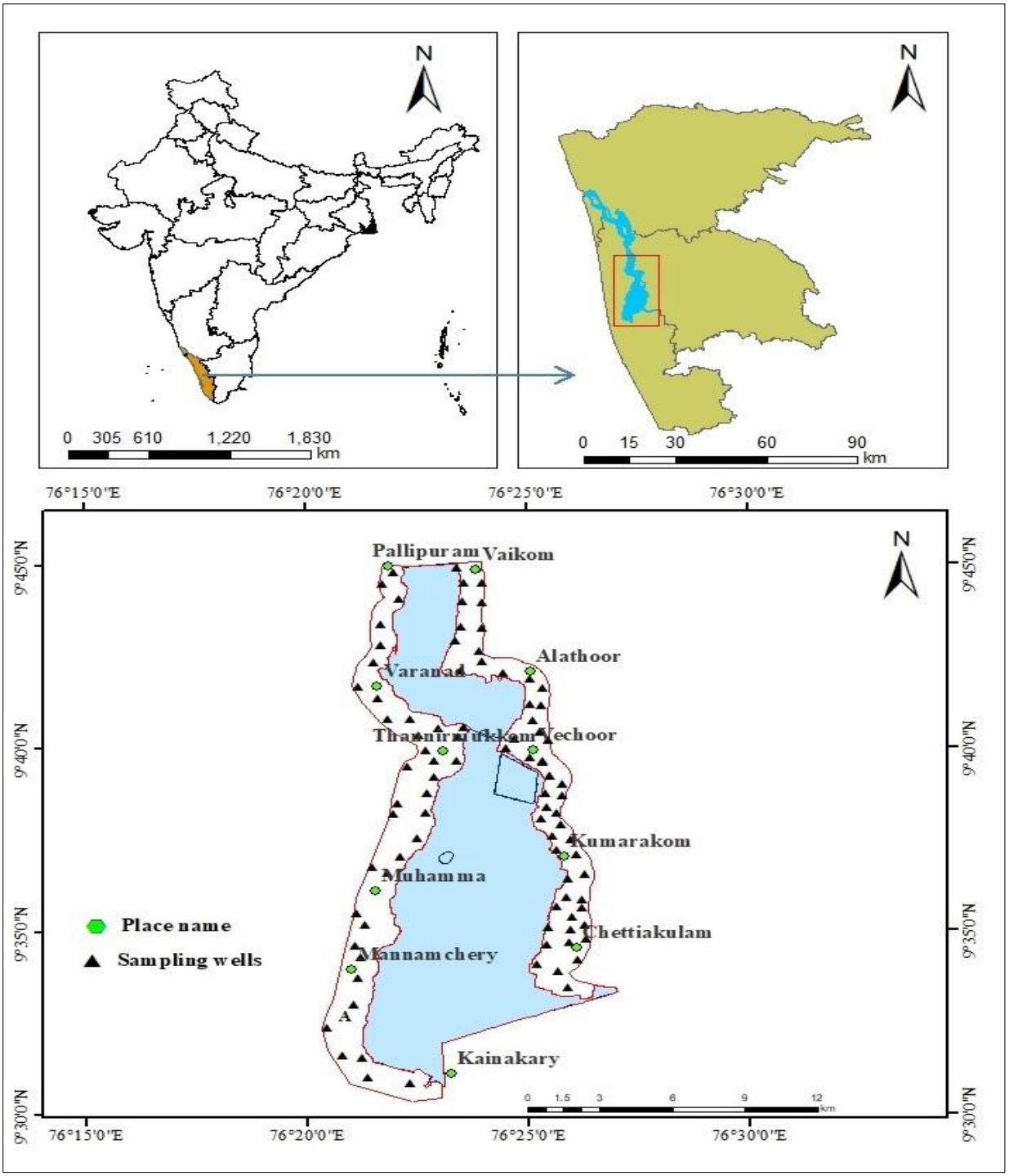

Fig 1: Study area map with sampling locations

Results and discussion

Physico-chemical properties of groundwater

The physical parameters such as Temperature, pH, Electric Conductivity, Total Dissolved Solids and Salinity were measured in the field at the time of sampling. These parameters were measured for two seasons namely premonsoon and postmonsoon of 2016, 2017 and 2018.

Temperature (^{0}C)

In the groundwater system, temperature plays an important role in the biological activity. The higher temperature was observed during the premonsoon **(**Table 1). This is due to the onset of summer season, which can rise the land temperature from 30 to 35^{0}C. Moreover, the time of sampling will also affect the water temperature.

While compared to the inland wells, study area well shows lower temperature than the inland wells. This is because of the presence of intrinsic water bodies around the study area. The spatial distribution of temperature in the study area is presented in Fig. 2.

It is noted that temperature distribution in the study area is more or less same.

Hydrogen ion concentration (pH)

The pH of the groundwater depends in concentrations of dissolved carbon dioxide and hydrogen ion, alkalinity and temperature. The statistical summary of the pH in the groundwater during the study period is provided in Table 2. The spatial distribution of pH on each season is presented in Fig. 2 and Fig. 3, which revealed that the study area aquifer shows slightly acidic to slightly alkaline in nature during pre and post monsoon seasons.

The slightly alkaline condition exists in the eastern part of the study area and slightly acidic to normal condition exists in the western part in all the seasons. The seasonal variability of pH in the groundwater shows that there is no significant change observed during the two seasons. The mean pH of the two seasons doesn't vary much, except that pre monsoon of 2016 shows slightly alkaline nature. This could be due to the dissolution of alkaline earth materials from the organic matter in the soil and also from subsurface aquifer material. The alkaline nature of water is due to the presence of bicarbonate ion. According to BIS standards, the pH of the groundwater should be in the range of 6.5 to 8.5. Most of the wells are under the permissible limit except few. Percentage of compliance of the well with pH is shown in the Table 3.

Electric conductivity (EC)

Electric conductivity of a solution is a measurement of an ability to carry an electric current through it. Table 4 shows the statistics of EC values in the shallow aquifer system at different seasons. Electric conductivity can be classified as type I, if the enrichment of salt is low (EC<1500 µS/cm), type II, if the enrichment of salts are medium (EC: 1500- 3000 µS/cm) and type III if the enrichment of salts area high (EC>3000 µS/cm*)* (Prasanth *et al*., 2012) [6]. Type I water is fresh water, type II is of Brackish in nature and type III is saline in nature (Saxena *et al*. 2009; Chandrasekar *et al*., 2013) [8, 2] The classification of the percentage of well tapping in the shallow aquifers in different season is given Table 5.

According to the above classification of EC during the premonsoon time is 71.81%, 69.09% and 60.90% of the total groundwater samples are come under the Type I category that means they are fresh water with low enrichment of salts. 20.9%, 18.18% and 20.90% of the premonsoon samples of the groundwater are fall under the Type II Category water of brackish nature with medium enrichment of salt. 7.27%, 13.63% and 18.18% of the groundwater samples are under the Type III category with high enrichment of salt and saline in nature. During the post monsoon seasons in the study period 65.45%, 53.63% and 51.81% of groundwater samples showed low enrichment of salt with fresh water nature and fall under the Type I category. 12.72%, 17.27% and 11.81% of total groundwater samples were in the Type II category with medium enrichment of salt and brackish in nature. 21.81%, 29.09% and 36.36% of groundwater samples fell in the Type III category with high enrichment of salt showing saline nature.

According to BIS (2012) the maximum permissible limit of EC for drinking water is 1500 µ S/cm, indicating that the EC values of both the season exceeds the permissible limit during the study period. The study area shows a decrease in the water quality during the post monsoon season due to the infiltration after the rainfall. The spatial distribution of EC for different seasons is shown in the Fig. 3. The high values are associated in the south eastern part, south western part (Mannamchery- Muhama) and low values are along the north eastern part of the study area in all the seasons.

Table 1: Statistical summary of Temperature in the study area.

Year	Month	Temperature in ^{0}C			
		Min	Max	Mean	SD
2016	May	27.4	29.88	28.36	0.56
	November	27	29.1	28.02	0.47
2017	May	27.2	31.6	28.65	1.28
	November	27.3	30	28.35	0.56
2018	May	27	30.4	28.74	0.72
	November	27	29.4	28.37	0.72

Table 2: Statistical summary of pH in the study area.

Year	Month	pH values				Percentage of Compliance
		Min	Max	Mean	SD	
2016	May	6.02	7.61	6.93	0.34	92.47
	November	6.24	7.84	7.09	0.37	86.02
2017	May	6	8.1	7.02	0.77	83.87
	November	6.13	8.19	7.19	0.46	89.25
2018	May	6.1	8.1	7.02	0.38	89.25
	November	6.01	8.22	7.24	0.44	93.55

Table 3: Statistical summary of EC in the study area.

Year	Month	EC values in µS/cm			SD
		Min	Max	Mean	
2016	May	152	5527	1072.58	965.17
	November	140	7094	1130.11	1425.88
2017	May	142	6152	1132.92	1054.86
	November	205	7993	1850.1	1767.69
2018	May	212	7542	1314.92	1203.86
	November	434	8053	2052.24	1751.13

Table 4: EC classification in the study area.

	Month	EC classification		
		Type I	Type II	Type III
2016	May	71.81%	20.90%	7.27%
	November	65.45%	12.72%	21.81%
2017	May	69.09%	18.18%	13.63%
	November	53.63%	17.27%	29.09%
2018	May	60.90%	20.90%	18.18%
	November	51.81%	11.81%	36.36%

Total Dissolved Solids (TDS)

Total Dissolved Solids (TDS) comprises of inorganic salts and small amount of organic matter that are dissolved in water. TDS of groundwater is originated from natural sources, industrial and agricultural waste water, sewage etc. The statistical summary of the groundwater samples is shown in the Table 6. According to the BIS standards the desirable limit for drinking water is 500 mg/l. It is noted that most of the samples are above the BIS desirable limit. The maximum permissible limit of TDS according to BIS standards is 2000mg/l in the absence of alternative resources. Some of the monitoring wells show higher mineralisation and which are unfit for drinking. Higher concentration of TDS value in groundwater is due to leaching of minerals and also from anthropogenic activities.

Degree of groundwater quality can be classified as fresh, if the TDS is less than 1,000 mg/l; brackish, if the TDS is between 1,000 and 10,000 mg/l; saline, if the TDS is varied from 10,000 to 1,00,000 mg/l; and brine, if the TDS is more than 1,000,000 mg/l (Freeze and Cherry 1979 and Todd 1980**).** Accordingly, the groundwater from the study area is classified as fresh and brackish throughout the study period. Among the premonsoon samples of the study period 84.95%, 75.57% and 77.42% samples are of fresh water nature while 15.05%, 20.43% and 22.58% of monitoring well were brackish in nature. 75.27%, 69.89% and 62.36% samples from the post monsoon seasons are of fresh water in nature while 24.73%, 20.43% and 37.63% of wells are brackish in nature (Table 7). The spatial distribution of TDS in the study area is shown in the Fig. 4.

Table 5: Statistical summary of TDS in the study area.

Year	Month	TDS values in mg/l			
		Min	Max	Mean	SD
2016	May	64	2867	486.55	500.47
	November	140	2458	592.88	600.35
2017	May	68	2598	547.58	532.18
	November	205	2756	761.63	627.31
2018	May	62	2945	672.71	661.32
	November	174	2358	893.12	570.08

Table 6: TDS classification in the study area.

Year	Month	TDS classification (%)		
		Fresh	Brackish	Saline
2016	May	84.95	15.05	Nil
	November	75.27	24.73	Nil
2017	May	79.57	20.43	Nil
	November	69.89	30.12	Nil
2018	May	77.42	22.58	Nil
	November	62.36	37.63	Nil

Salinity

Salinity denotes concentration of dissolved ions and electric conductivity. The increase in salinity is also due to sewage and industrial effluences.

The spatial distribution of the salinity values in the study area is shown in the Fig. 4 and Fig. 5. Low salinity values are observed near the northern part of the study area, while the high salinity is observed along the south eastern and south western part of the study area.

The high ionic concentration from the clam deposit and clam mining, infiltration from the lake and canals is the one of the Reason for high salinity. Based on the salinity values groundwater in the study area are fresh to brackish in nature. During the pre and post monsoons of 2016, 78.49% and 73.11% of wells are fresh water and 21.51% and 26.88% wells are brackish in nature. In the case of premonsoon of 2017, 72.04% and 53.76% of wells are fresh in nature and 27.95% and 46.24% wells of the postmonsoon are brackish in nature.

63.44% and 52.69% of wells of the premonsoon of 2018 was fresh and 37.63% and 47.31% of wells are brackish in nature. The statistics of the salinity distribution in the study area is shown in the Table 8.

Table 7: Statistical summary of the salinity in the study area.

Year	Month	Salinity in PSU			
		Min	Max	Mean	SD
2016	May	0.2	5.34	0.7	0.93
	November	0.01	7.1	1.08	1.66
2017	May	0.04	4.6	0.79	0.95
	November	0.07	9.25	1.79	2.07
2018	May	0.02	6.8	1.07	1.16
	November	0.1	8.43	1.74	1.96

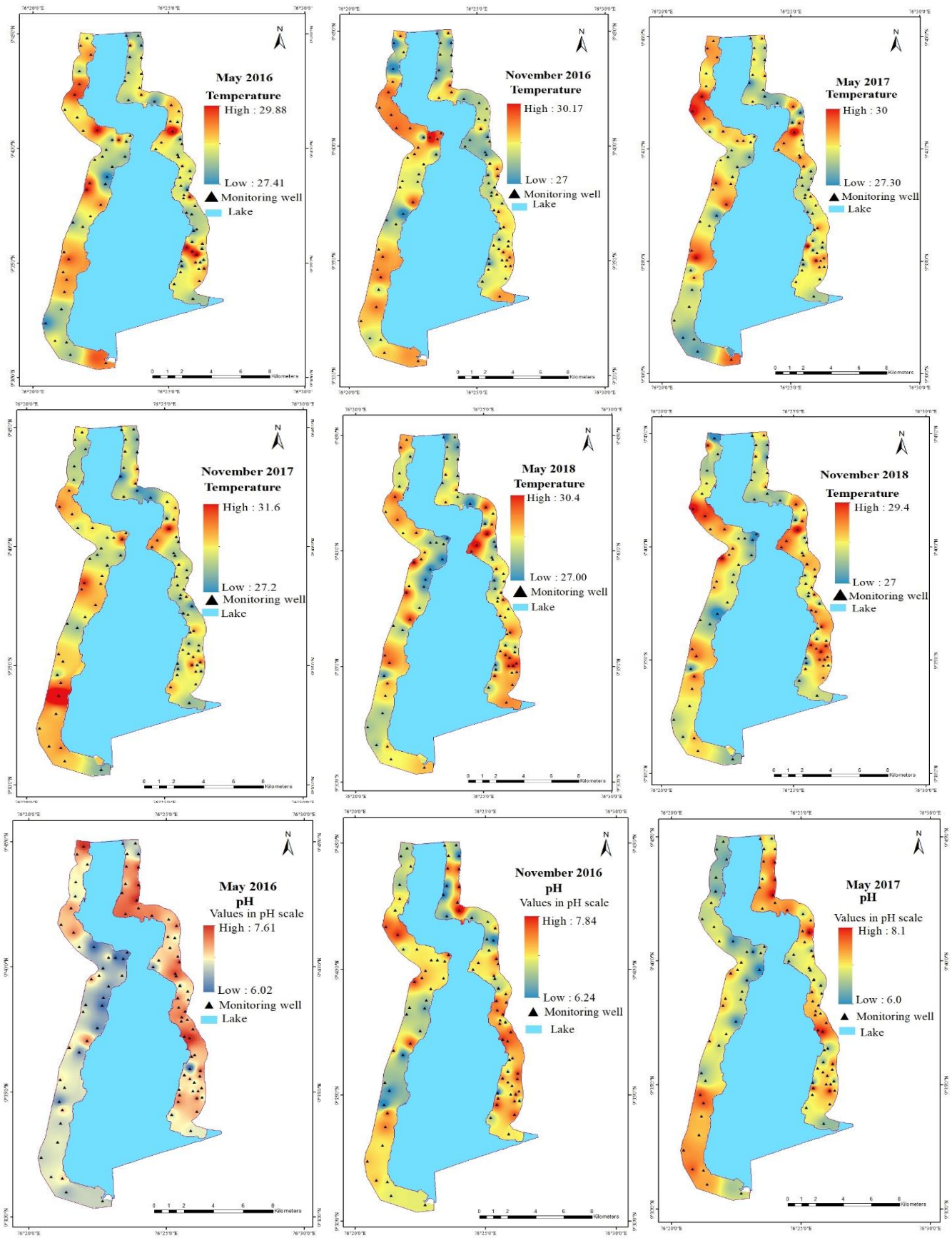

Fig 2: Spatial distribution of Temperature, pH in the groundwater of the study area

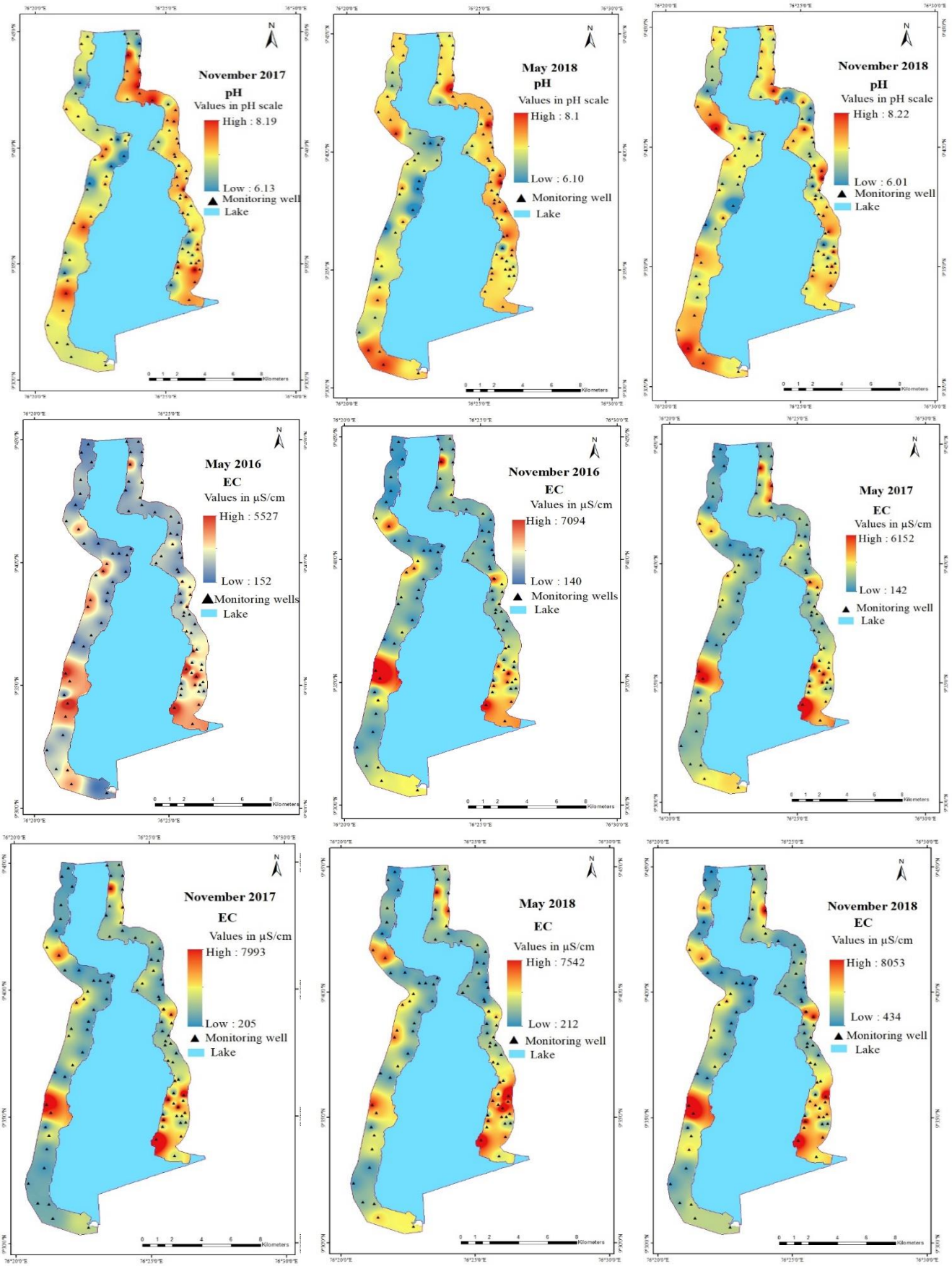

Fig 3: Spatial distribution of pH and EC in the groundwater of the study area

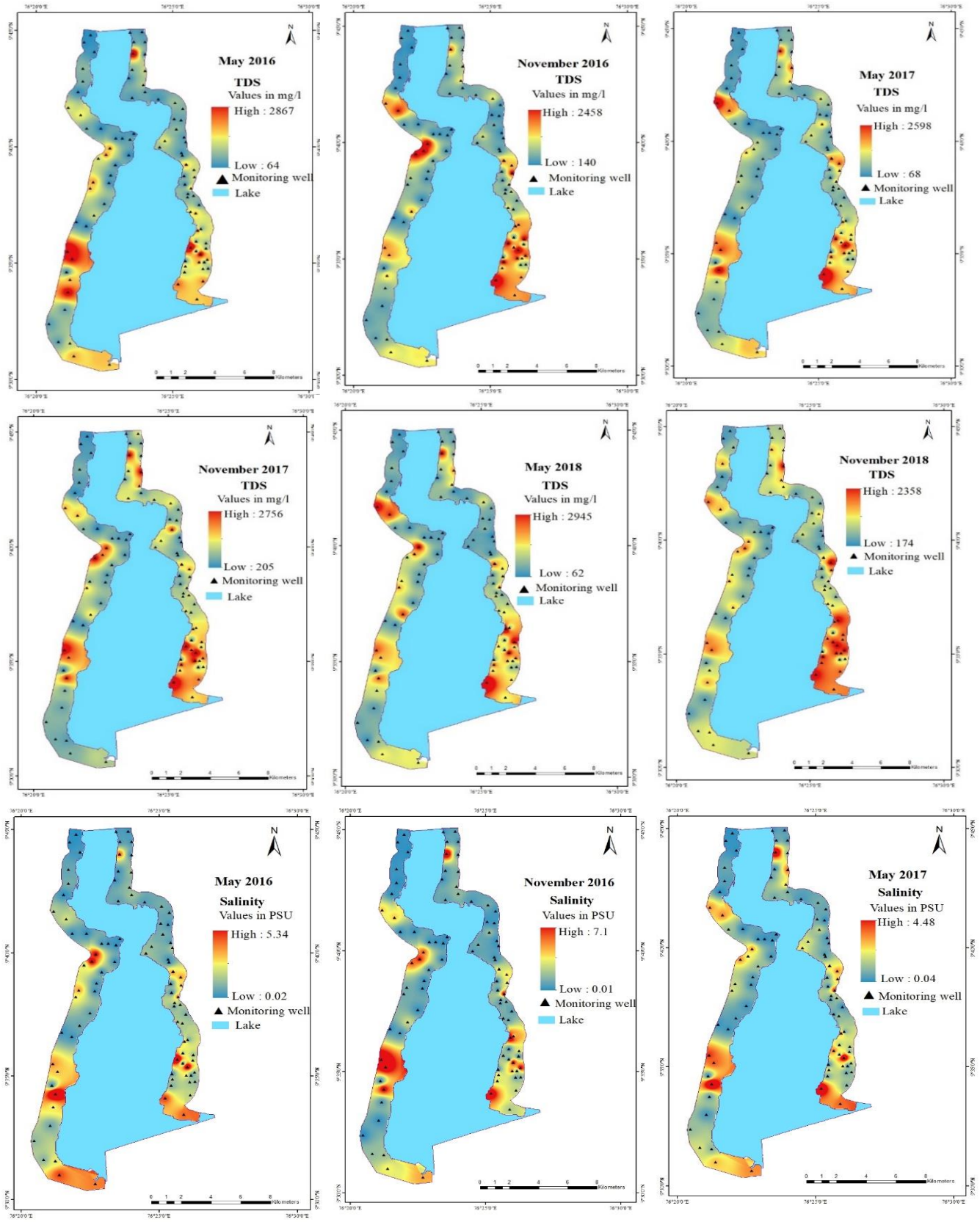

Fig 4: Spatial distribution of TDS and Salinity in the groundwater of the study area

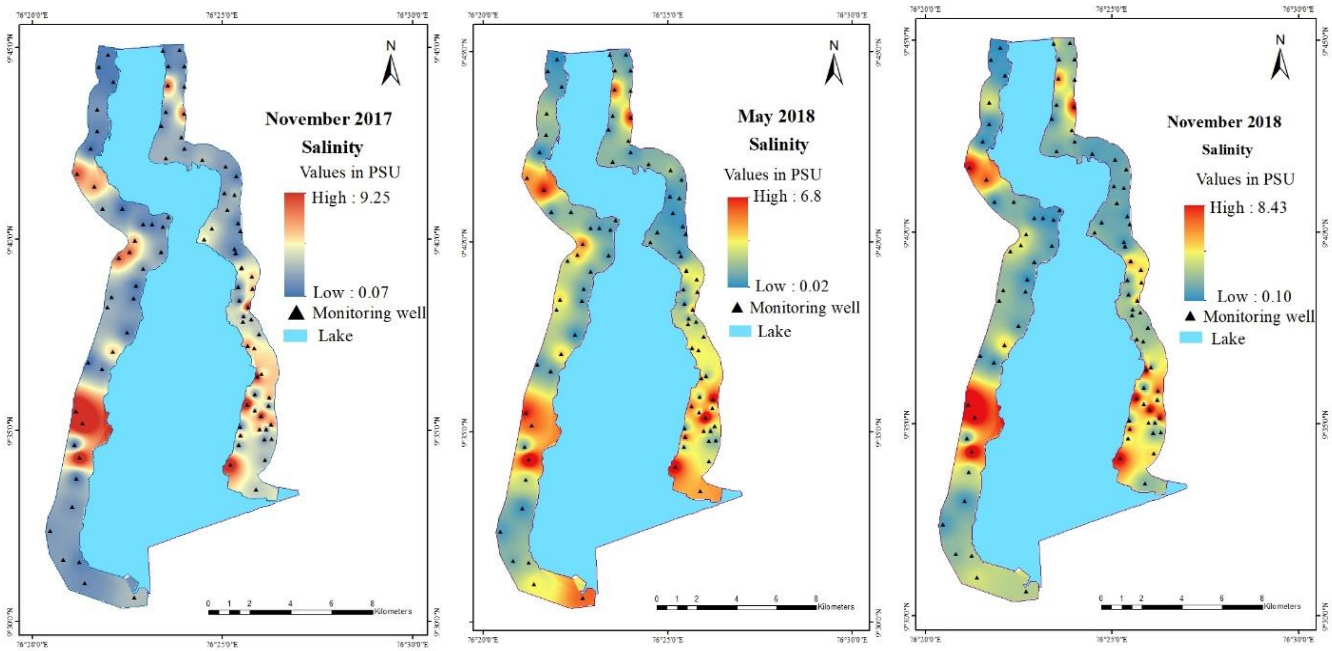

Fig 5: Spatial distribution of Salinity in the groundwater of the study area

Conclusion

The physical characteristic of groundwater for the shallow phreatic aquifers of Vembanad Wetland System has been identified by measurement of pH, electrical conductivity, total dissolved solids and salinity. The groundwater characteristic is varied depends on the locations and interaction to the brackish water from the lake. Mostly the groundwater of the study area remains slightly acidic to slightly alkaline, fresh to brackish in nature during the study period. The studied physical parameters concentration in a majority of wells exceeded the guideline limit of BIS standards making the water unfit for drinking purposes.

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