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A Study on Ground Water Chemistry and Water Quality Index from Tamil Nadu District of Karur

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KEYWORDS

Chemical characteristic, Groundwater, Piper trilinear, Dendrogram and Water Quality Index,

ABSTRACT:

In this study, we investigated the chemical properties of groundwater and drinking water and collected 10 groundwater samples in Karur district at the start of the 2019 monsoon. Water samples were then analyzed to determine pH, electrical conductivity, total dissolved solids, bicarbonate, chloride, sulfate, calcium, magnesium, sodium and potassium. Results were assessed and compared to WHO and BIS water quality standards. Research results reveal that groundwater is cool to brackish and moderately to moderately high in nature. Na and Cl are the dominant ions between cations and anions. Chlorides, calcium and magnesium ions are within acceptable limits, with the exception of a small number of samples. Based on WQI results from 10 samples, 20% of samples showed good water department, 80% of samples were from excellent water department. The majority of samples are classified from excellent to good categories and are suitable for drinking water purposes.

Introduction

Water chemistry is highly dynamic and is primarily controlled and modified by its contact medium. Monitoring and evaluation of water has gained great importance in the present century, since its chemistry directly suggests the quality of water for various purposes. Significant population growth has increased stress on both the surface and groundwater. It is believed at the beginning of human civilization itself that groundwater was the most reliable drinking water due to the filtering effect of aquifers. However, in today's world, drinking water directly from a water source without proper treatment is a difficult task [1].

Groundwater contributes approximately 80 percent of drinking water requirements in rural areas, 50 percent of water requirements in urban areas, and more than 50 percent of national irrigation requirements. Groundwater quality is a major concern for humanity because quality changes can also have a dangerous impact on human health and society. In India, groundwater has great value as it is a major source of drinking and irrigation [2]. In recent years, groundwater exploitation work has increased significantly, especially for agricultural purposes, as in many regions. Frequent failures of the monsoon have resulted in a decrease in groundwater recharge. This component serves as an essential contributor to the domestic, irrigation and industrial sectors. Groundwater quality is determined by physical, chemical, and biological parameters. The effect of this quality determines the usefulness of groundwater. Groundwater chemistry has an important function in evaluating water quality [3]. The aim of this study is to piper trilinear, dendrogram and water quality index in groundwater chemistry from Karur district.

Materials and Methods

Study Area :

Karur is the textile and dye industry-rich region of this state of Tamil Nadu. It has been classified into unions and blocks, the Karur block is one of them which has historical importance for temples, rivers and is blessed with fertile agicultural lands. The main sources of water are the Amaravathi River, today polluted by said industries. Karur includes exactly 53 panchayat villages, among which almost 10 villages are focused on our

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study of surface and groundwater and shown in Table 1. Figure 1 shows the location of sample collection.

Groundwater samples were collected from 10 representative wells during the pre-monsoon period (March 1 and May 31) in 2019. The samples were collected in previously cleaned 1 L polyethylene bottles. Each bottle was rinsed with distilled water to avoid possible contamination. The analysis was carried out systematically both volumetrically and using instrumental techniques. The procedures were followed using standard books and manuals [4-9] and the National Institute for Research in Environmental Engineering [10]. The analysis was performed immediately for pH, EC, OD and all other parameters.

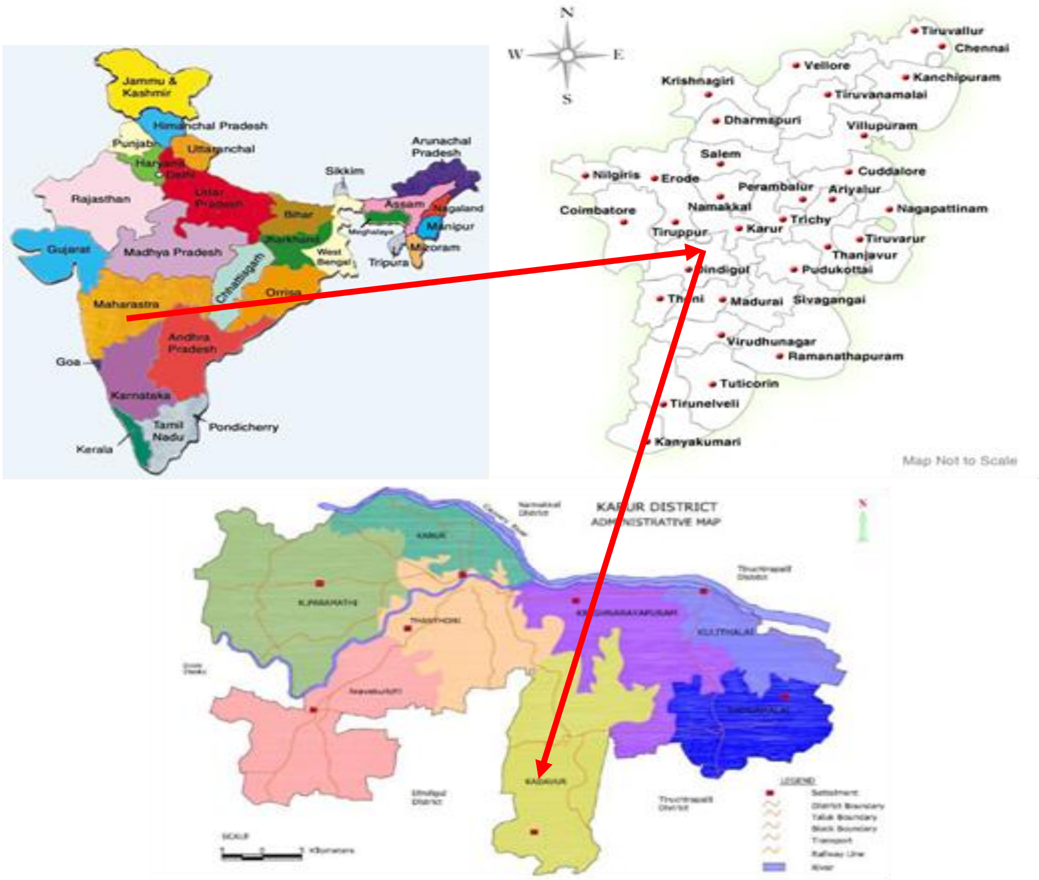

Figure 1 Location of sample collection

Table 1 Selected villages in Karur block area, Karur district

S. No	Place
1	Nanniyur
2	Thalappatti
3	Emur
4	Thaanthoni malai
5	Puliyur
6	Melappalayam
7	Vaangal
8	Manavadi
9	Aathunar
10	Somur

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Water quality index calculation (WQI)

The water quality index (WQI) was calculated for evaluating influence of natural and anthropogenic activities based on several key parameters of groundwater chemistry. To calculate the WQI, the weight has been assigned for the physico-chemical parameters according to the parameters relative importance in the overall quality of water for drinking water purposes. The assigned weight ranges from 1 to 5. The maximum weight of 5 has been assigned for nitrate and TDS, 4 for pH, EC, SO_4, 3 for HCO_3, Cl, 2 for Ca, Na, K and weight 1 assigned for Mg [11]. The relative weight is computed from the following equation.

$$Wi = wi / \sum_{i=1}^{n} wi,$$

Wi is the relative weight

wi is the weight of each parameter

n is the number of parameters.

The quality rating scale for each parameter is calculated by dividing its concentration in each water sample by its respective standards (World Health Organization, 2011) and multiplied the results by 100.

$$qi = (Ci/Si) \times 100$$

qi is the quality rating

Ci is the concentration of each chemical parameter in each sample in milligrams per liter, **Si** is the World Health Organization standard for each chemical parameter in milligrams per liter according to the guidelines of the [12].

For computing the final stage of WQI, the SI is first determined for each parameter. The sum of SI values gives the water quality index for each sample

$$SIi = Wi \times qi$$

$$WQI = \sum SIi$$

SIi is the sub-index of i^{th} parameter

qi is the rating based on concentration of i^{th} parameter

n is the number of parameters

Statistic analysis

Data ware analysis on correlation coefficient (r) statistic and Hierarchical cluster analysis using SPSS ver. 20. Geochemical evolution groundwater analysis (Piper trilinear diagram triangle) using Grapher software [13].

Results and Discussion

Karur district has Trichy district and Erode district as its neighbors. Karur block has an area of 145 hectare, of which 90 hectare are under cultivation. Though few of the village use river water as their major source of drinking, they also use groundwater as another source. Lot of work has been done and published already on the groundwater quality of many villages in other different blocks of the Karur district. But in Karur block, there is need to undertake the study to assess the drinking water quality. Hence, ten villages of Karur block were selected, where the people use groundwater for drinking. The statistical parameters like minimum, maximum, median and mean concentration of physico-chemical parameters, major ion concentrations are Table 2.

Table.2: Ground water analysis of Karur block area during pre-monsoon period at 2019

S. No	Place	pH	EC (µS/cm)	TDS (mg/L)	CO_3 (mg/L)	HCO_3 (mg/L)	Cl (mg/L)	SO_4 (mg/L)	Ca (mg/L)	Mg (mg/L)	(r
1	Nanniyur	7.30	619	390.92	2.17	15.15	182.86	9.16	17.44	2.72	[illegible]
2	Thalappatti	8.00	704	845.13	1.65	274.08	386.41	41.37	53.47	3.49	[illegible]
3	Emur	7.50	817	642.85	2.18	147.19	242.39	21.44	32.14	3.19	[illegible]
4	Thaanthoni malai	7.20	587	374.73	3.15	248.04	174.18	7.32	16.92	1.50	[illegible]
5	Puliyur	7.50	796	618.07	1.76	119.73	219.74	19.73	27.45	3.20	[illegible]
6	Melappalayam	7.90	737	812.74	2.86	325.52	365.5	38.96	49.76	3.11	[illegible]
7	Vaangal	7.50	805	596.04	2.18	85.01	237.05	19.04	29.63	3.38	[illegible]
8	Manavadi	7.40	783	418.95	2.94	65.43	195.07	9.75	18.75	3.16	[illegible]
9	Aathunar	7.60	835	714.32	1.55	272.35	241.01	18.46	35.42	3.21	[illegible]
10	Somur	8.00	845	889.05	4.74	335.04	379.42	43.18	51.62	3.12	[illegible]
	Descriptive statistic										
	Mean	7.59	752.80	630.28	2.51	188.75	262.36	22.84	33.26	3.00	[illegible]
	Median	7.50	796.00	642.85	2.18	248.04	241.01	19.73	32.14	3.19	[illegible]
	Maximum	8.00	845.00	889.05	4.74	335.04	386.41	43.18	53.47	3.49	[illegible]
	Minimum	7.20	587.00	374.73	1.55	15.15	174.18	7.32	16.92	1.50	[illegible]
*WHO (2011) Std.		6.5-8.5	1500	500	-	500	250	250	75	50	

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Table.3: Correlation matrix (N=10)

	pH	EC (µS/cm)	TDS (mg/L)	HCO_3 (mg/L)	Cl (mg/L)	SO_4 (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	NO_3 (mg/L)	K (mg/L)	CO_3 (mg/L)
pH	1											
EC (µS/cm)	0.421	1										
TDS (mg/L)	0.957**	0.547	1									
HCO_3 (mg/L)	0.702*	0.134	0.733*	1								
Cl (mg/L)	0.984**	0.300	0.928**	0.734*	1							
SO_4 (mg/L)	0.981**	0.358	0.949**	0.716*	0.990**	1						
Ca (mg/L)	0.983**	0.392	0.976**	0.763*	0.982**	0.982**	1					
Mg (mg/L)	0.588	0.729*	0.599	-0.049	0.482	0.506	0.530	1				
Na (mg/L)	0.983**	0.481	0.931**	0.606	0.968**	0.971**	0.955**	0.655**	1			
NO_3 (mg/L)	0.986**	0.314	0.937**	0.750*	0.997**	0.992**	0.984**	0.471	0.963**	1		
K (mg/L)	0.969**	0.234	0.901**	0.737*	0.980**	0.966**	0.963**	0.468	0.942**	0.975**	1	
CO_3 (mg/L)	0.226	0.057	0.134	0.365	0.279	0.276	0.179	-0.297	0.254	0.293	0.178	1

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

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

Correlation matrix and Hierarchical Cluster Analysis (HCA)

Statistical matrix correlation analysis was performed on physicochemical parameters and major ion concentration to detect the relationship and differences between groundwater samples. In order to discuss the data, the values are grouped against the geochemical parameters. The average value of all variables (temperature, pH, , CO_3–, TDS, HCO_3^-, EC, Cl^-, Ca^{2+}, NO_3, SO_4^{2-}, Mg^{2+}, K^+, Na^+) determined and tabulated in matrix form in Table 3. This matrix was analyzed with Yesterdayarchical Cluster Analysis (HCA), rescaled distance cluster combinat analysis) using SPSS 20 software. Hierarchical cluster analyzes (HCAs) are the most widely applied clustering techniques in the earth sciences [14-15]. An HCA joins the most similar observations and then links the following most similar observations. The process repeats until the number of similar observations is reduced to one. Additionally, the similarity levels at which observations are merged are used to construct a dendrogram in which it is easy to find which observations belong to which clusters [16].

Hierarchical cluster analysis was used to group water samples into significant clusters. Hierarchical cluster analysis (CA) was applied to detect spatial similarity between parameters and location under the monitoring network using the Ward method and the results of parameters and location (location) are presented by groups in Figures 3 and 4. A dendrogram is constructed, where cohesion and correlations between variables can be clearly observed [17]. It presents a visual summary of the intra-relationship between variations in water parameters, which may lead to a better understanding of the determining factors of water quality [18]. HCA detected similar groups among the water samples, then produced a dendrogram performed as parameters (Figure 3) grouping 10 water samples into three groups. Likewise, a dendrogram produced in the form of places (Figure 4) grouping 10 water samples into five clusters.

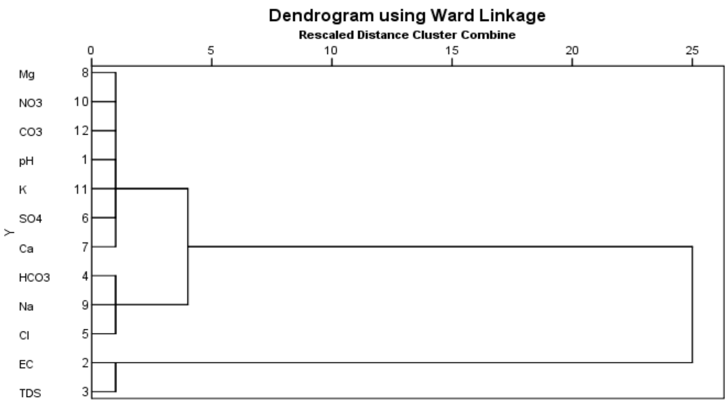

Fig.3: Dendrogram analysis was performed as parameters (Correlation matrix)

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Cluster I (Mg, NO_3, CO_3, pH, K, SO_4, Ca); Cluster II (HCO_3, Na, Cl); Cluster III (EC, TDS)

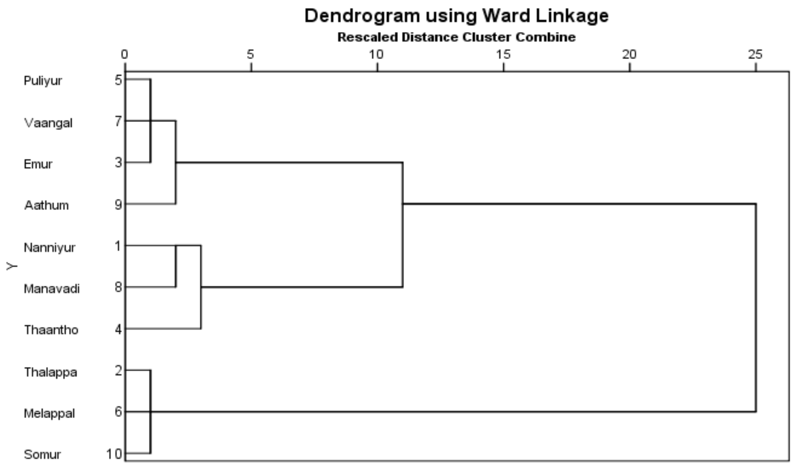

Fig.4: Dendrogram analysis was performed as Place

Cluster I (Puliyur, Vaangal, Emur); Cluster II (Aathunar); Cluster III (Nanniyur, manavadi); Cluster IV (Thaanthoni malai); Cluster V (Thalappatti, Melappalayam, Somur)

Piper trilinear diagram

The Piper [13] and Chadda [19] plots were used to identify the different types of hydrogeochemical facies from the main cations and anions. A Piper diagram is widely used to understand problems regarding the geochemical evolution of groundwater [15]. The Piper diagram was made in such a way that the milliequivalent percentages of the main cations and anions were plotted in a separate triangle. These points traced in the triangular fields are projected further into the central diamond field, which gives the overall character of the water [13]. Each point is then projected into the upper field along a line parallel to the upper margin of the field and the point where the extension intersects indicates the character of the water as represented by the relationship between among Na^+, K^+, Ca^{2+}, Mg^{2+}, $CO3^-$ + $HCO3^-$, Cl^- and $SO4^{2-}$. The diamond shows the general hydrochemical characteristics of the water sample, while the triangle shows the relative content of each ion [13].

In this study, a Piper diagram was obtained by using the Grapher software. As shown in Figure 6, a Piper triangle consists of a diamond and two triangles, in which the diamond is divided into nine regions. Most of water samples belong to Zones Sodium chloride type in the diamond portion. The cations and anions were plotted on the lower left and right ternary plots respectively while the central diamond plot was used in identifying the hydrochemical facies based on the information given in Figure 5. In the present study, most of water samples of cations are belong to Zones Sodium and potassium type (left lower triangle portion) while anions are chloride type. This indicates that the references to figure 5.

Fig.5: Piper trilinear diagram reference standard (Sources: [20])

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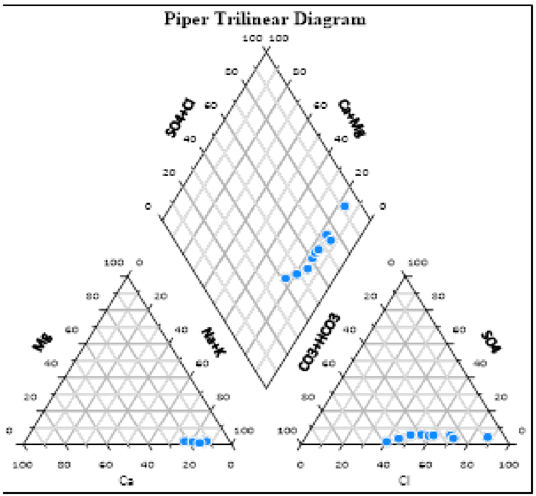

Fig.5: Piper trilinear diagram observation of 10 samples

Water quality index calculation (WQI)

Groundwater chemistry is often used as a tool for discriminating drinking water quality and irrigation [21, 11]. The Water Quality Index (WQI) is an important parameter for identifying water quality and its sustainability for consumption purposes [22-23]. IQO is defined as an assessment technique that provides the composite influence of individual water quality parameters on overall water quality [24]. World Health Organization and BIS standards [12, 25] for drinking water quality were used to calculate the EQI. Relative weight (wi) was assigned to water quality parameters based on their relative importance on drinking water quality (Table 4). The water quality classification based on WQI values is presented in Table 4. The calculation of the WQI for groundwater samples is presented in Table 6. A total of 10 samples were analyzed for WQI. Among the 10 samples, 20% of the samples fell into the excellent water category, 80% of the samples had a good water category respectively. The water quality classification reference ranges are shown in Table 5. Table 6 and Figure 5 show the water quality index (WQI) classification for individual samples.

Table.4: Relative weight of chemical of physico-chemical Parameters

Parameter	Weight (wi) [11]	Wi	WHO Standard [12]
pH	4	0.114	6.5 – 7.5
EC (µS/cm)	4	0.114	500
TDS (mg/L)	5	0.142	500
HCO_3 (mg/L)	3	0.085	500
Cl (mg/L)	3	0.085	250
SO_4 (mg/L)	4	0.114	250
Ca (mg/L)	2	0.057	75
Mg (mg/L)	1	0.028	50
Na (mg/L)	2	0.057	200
NO_3 (mg/L)	5	0.142	45
K (mg/L)	2	0.057	200
	n= 35	Sum = 1	

Table.5: Water quality classification ranges and types of water based on WQI values

Range	Type of water	Code
<50	Excellent water	EW
50–100	Good water	GW
100–200	Poor water	PW
200–300	Very poor water	VPW
>300	Water unsuitable for drinking purposes	WUDP

Table.6: Water quality index (WQI) in Karur block area

S. No	Place	WQI	Water quality type
1	**Nanniyur**	48.34	Excellent water
2	**Thalappatti**	86.08	Good water
3	**Emur**	68.64	Good water
4	**Thaanthoni malai**	49.31	Excellent water
5	**Puliyur**	65.30	Good water
6	**Melappalayam**	84.92	Good water
7	**Vaangal**	65.23	Good water
8	**Manavadi**	55.78	Good water
9	**Aathunar**	73.15	Good water
10	**Somur**	91.45	Good water

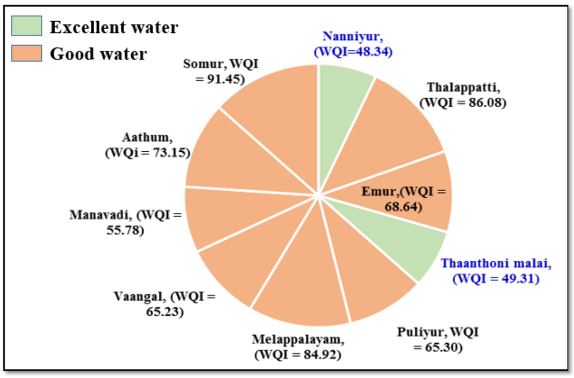

Fig.6: Water quality index (WQI) in Karur block area

Conclusions

The quality of drinking water and the chemical properties of groundwater were investigated. Of the 10

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samples, 20% were classified as having excellent water, and the remaining 80% as having good water. After identifying similar groups among the water samples, HCA created a dendrogram using parameters that divided the 10 samples into three groups, and a location-based dendrogram that divided the 10 samples into five groups. In the trilinear diagram of Piper. The majority of cation-containing water samples fall into the potassium and sodium type zones (lower left triangle portion), whereas anions are chloride type.

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