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A Study on Multivariate Statistical Techniques of Water Quality Index in the Groundwater from Tamilnadu District of Karur

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ABSTRACT

In this study, we gathered ten groundwater samples in Karur district at the beginning of the 2019 monsoon season in order to examine the chemical characteristics of drinking water and groundwater. After that, pH, electrical conductivity, bicarbonate, chloride, sulfate, calcium, magnesium, sodium, and potassium were measured in water samples. The outcomes were evaluated and contrasted with the water quality standards set by the BIS and WHO. The findings of the study indicate that the type of groundwater is moderately to fairly high and cold to brackish. The two most prevalent ions among cations and anions are Na and Cl. The levels of calcium, magnesium, and chlorides are within permissible bounds, except for a few samples. According to WQI results from ten samples, the water department was good in 20% of samples and exceptional in 80% of samples. Most samples are suitable for use as drinking water and fall into the excellent-to-good category.

Key words: *Groundwater, Piper trilinear, Chemical characteristic, Dendrogram and Water Quality Index,*

Introduction

Water's contact medium is the primary factor that controls and modifies its extremely dynamic chemistry. Water monitoring and assessment have become increasingly important in the twenty-first century because water quality is directly suggested by its chemistry for a variety of uses. Both surface and groundwater are under more stress as a result of significant population growth from aquifers filter water, groundwater is said to have been the most dependable source of drinking water from the dawn of human civilization. Drinking water straight from a source without the necessary treatment is challenging in today's environment (Sajil Kumar, 2013).

More than half of the country's irrigation needs are met by groundwater, while over 80% of drinking water needs in rural areas and 50% in urban areas are met by groundwater. The quality of groundwater is an important concern for humanity since changes in quality can have harmful effects on society and human health. Since groundwater is a significant supply of irrigation and drinking water in India, it is highly valued (Kumar *et al.*, 2006). Particularly for agricultural purposes, groundwater exploitation has grown dramatically in recent years, as is the case in many areas. Recharge of groundwater has decreased as a result of frequent monsoon failures. This component is crucial to the industrial, agricultural, and household sectors. There are physical, chemical, and biological factors that impact the quality of groundwater. The utility of groundwater is determined by the impact of this quality. Assessing the chemistry of groundwater is crucial for determining the quality of water (CGWB, 1992). Trilinear, dendrogram, and water quality index piper analysis of groundwater chemistry from Karur district is the goal of this work.

Materials and Methods

Study Area

The Karur region of Tamil Nadu is a hub for the textile and dye industries. It has been divided into blocks and unions; the Karur block is one of them. It is endowed with fertile agricultural grounds and has historical significance for temples and rivers. The primary water source, the Amaravathi River, is currently contaminated by the aforementioned enterprises. Approximately ten of the 53 panchayat villages in Karur are the subject of our surface and groundwater study, as indicated in Table 1, Figure 1 depicts the sample collection site.

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

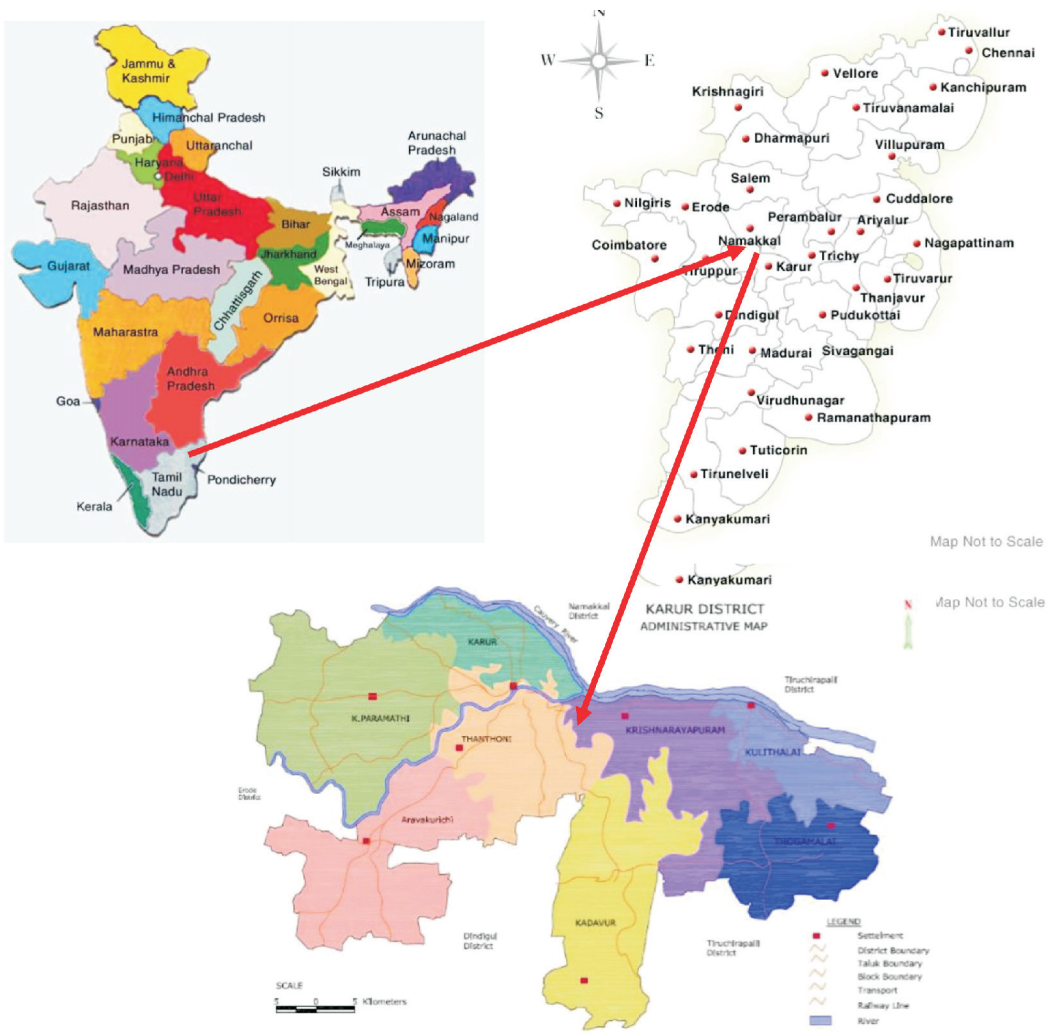

Fig. 1. Location of sample collection

During the pre-monsoon season (March 1–May 31) of 2019, ten typical wells provided groundwater samples. The samples were taken from 1 L plastic bottles that had been cleaned beforehand. Distilled water was used to rinse each bottle to prevent any potential contamination. Both volumetric and instrumental methods were employed in the systematic analysis. Standard publications and manuals (APHA, 2005; APHA, 1998; APHA, 1989; APHA, 1985; BIS, 2003 and Gloterman *et al.,* 1978) from the National Institute for Research in Environmental Engineering (NEERI, 1988) were used to follow the processes. The pH, EC, OD, and all other parameters were analyzed right away.

Water quality index calculation (WQI)

The WQI, or water quality index, was computed using a number of important groundwater chemistry characteristics to assess the impact of both natural and man-made activities. A weight has been allocated to the physico-chemical parameters based on their relative importance in the overall quality of water for drinking purposes in order to calculate the WQI. The weight awarded falls between 1 and 5. For nitrate and TDS, a maximum weight of 5 has been assigned; for pH, EC, and SO, it is 4; for HCO and Cl, it is 3; for Ca, Na, and K, it is 2; and for magnesium, it is 1 (Vasanthavigar *et al.,* 2010). The equation that follows is used to calculate the relative weight.

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

Wi stands for relative weight.

wi is each parameter's weight.

The number of parameters is denoted by **n**.

The concentration of each parameter in each water sample is divided by the corresponding standard to determine the quality rating scale (World Health Organization, 2011), and the results are then multiplied by 100.

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

qi is the quality rating

As to the rules of the World Health Organization, Si is the standard for each chemical parameter in milligrams per liter, while Ci is the concentration of each chemical parameter in each sample in milligrams per liter (World Health Organization, 2011).

The SI is first established for every parameter in order to compute the last step of WQI. Each sample's water quality index is determined by adding the SI values.

$$SIi = Wi \times qi$$

$$WQI = \Sigma_{SIi}$$

The i^{th} parameter's sub-index is **SIi.**

qi is the rating determined by the i^{th} parameter's concentration.

There are **n** parameters.

Statistic analysis

Data ware analysis utilizing SPSS version 20 on hierarchical cluster analysis and the correlation coefficient (r) statistic. Groundwater geochemical evolution analysis (Piper trilinear diagram triangle) with Grapher software (Piper, 1944).

Results and Discussion

Karur district is bordered by Trichy district and Erode district. The Karur block is 145 hectares in size, 90 of which are under cultivation. While some villages rely on river water as their primary source of drinking water, others use groundwater as a backup source. A lot of work has been done and published on the groundwater quality of many villages in other Karur district blocks, but a study was needed in Karur block to evaluate the drinking water quality, so ten villages that use groundwater for drinking were chosen. The statistical parameters, such as the minimum, maximum, median, and mean concentration of physico-chemical parameters and major ion concentrations, are listed in Table 2.

Correlation matrix and Hierarchical Cluster Analysis (HCA)

To find the relationships and variations between groundwater samples, physicochemical characteristics and main ion concentrations were subjected to statistical matrix correlation analysis. The numbers are classified according to the geochemical parameters so that the data can be discussed. All of the variables' average values (temperature, pH, CO, TDS, HCO^-, EC, Cl^-, Ca^2z, NO, SO^{2-}, Mg^2z, Kz, and Naz) were calculated and recorded in matrix form in Table 3. With the use of SPSS 20 software, this matrix was examined utilizing Yesterdayarchival Cluster Analysis (HCA) and rescaled distance cluster combin at analysis. In the earth sciences, hierarchical cluster analyses (HCAs) are the most commonly used clustering methods (Ouarda *et al.,* 2018

Table 2. Pre-monsoon ground water analysis of the Karur block region in 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)	Na (mg/l)	NO_3 (mg/l)	K (mg/l)
1	Nanniyur	7.30	619	390.92	2.17	15.15	182.86	9.16	17.44	2.72	98.35	1.82	2.95
2	Thalappatti	8.00	704	845.13	1.65	274.08	386.41	41.37	53.47	3.49	265.07	4.27	21.43
3	Emur	7.50	817	642.85	2.18	147.19	242.39	21.44	32.14	3.19	165.74	2.49	7.14
4	Thaanthoni malai	7.20	587	374.73	3.15	248.04	174.18	7.32	16.92	1.50	57.05	1.79	3.19
5	Puliyur	7.50	796	618.07	1.76	119.73	219.74	19.73	27.45	3.20	149.83	2.37	8.07
6	Melappalayam	7.90	737	812.74	2.86	325.52	365.5	38.96	49.76	3.11	250.46	3.95	19.21
7	Vaangal	7.50	805	596.04	2.18	85.01	237.05	19.04	29.63	3.38	157.18	2.52	6.21
8	Manavadi	7.40	783	418.95	2.94	65.43	195.07	9.75	18.75	3.16	140.72	1.93	5.18
9	Aathunar	7.60	835	714.32	1.55	272.35	241.01	18.46	35.42	3.21	152.18	2.61	8.43
10	Somur	8.00	845	889.05	4.74	335.04	379.42	43.18	51.62	3.12	274.74	4.31	17.15
	Descriptive statistic												
	Mean	7.59	752.80	630.28	2.51	188.75	262.36	22.84	33.26	3.00	171.13	2.80	9.89
	Median	7.50	796.00	642.85	2.18	248.04	241.01	19.73	32.14	3.19	157.18	2.52	8.07
	Maximum	8.00	845.00	889.05	4.74	335.04	386.41	43.18	53.47	3.49	274.74	4.31	21.43
	Minimum	7.20	587.00	374.73	1.55	15.15	174.18	7.32	16.92	1.50	57.05	1.79	2.95
*WHO (2011) Std.		6.5-8.5	1500	500	-	500	250	250	75	50	200	45	12

and Wu *et al.,* 2017). The most comparable observations are joined by an HCA, which then links the next most similar observations. The procedure is repeated until there is only one similar observation. A dendrogram that makes it simple to identify which observations belong to which clusters is also created using the similarity levels at which observations are merged (Davis and Sampson, 1986).

Water samples were grouped into meaningful clusters using hierarchical cluster analysis. Using the Ward technique, hierarchical cluster analysis (CA) was used to find geographic similarity between parameters and location under the monitoring network. The findings of this analysis are shown by group in Figures 2 and 3. When cohesiveness and correlations between variables are readily visible, a dendrogram is created (Yongming *et al.,* 2006). It offers a graphic representation of the intra-relationship between changes in water parameters, which could help people better comprehend what influences water quality (Pejman *et al.,* 2009). Ten water samples were divided into three groups by HCA after it identified comparable groupings among the samples and generated a dendrogram using the parameters (Figure 2). Ten water samples were grouped into five clusters in a dendrogram that took the shape of places (Figure 3).

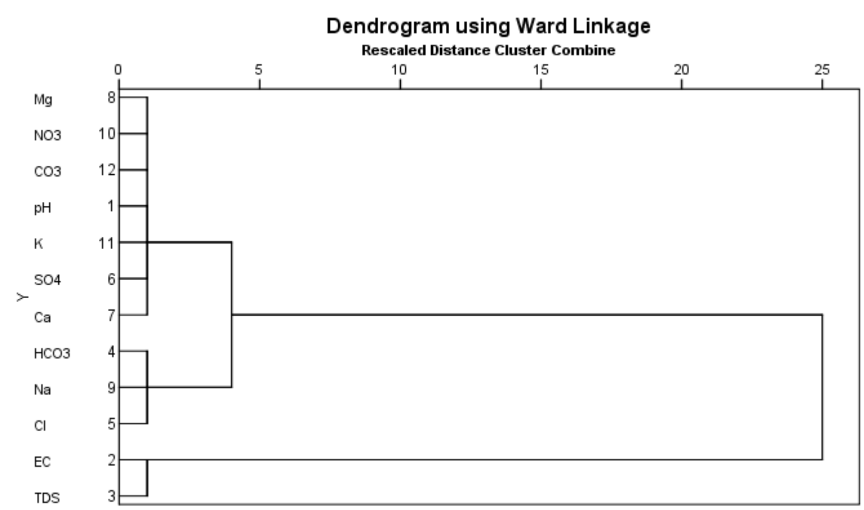

Fig. 2. Dendrogram analysis was performed as parameters (Correlation matrix)
Cluster I (Mg, NO_3, CO_3, pH, K, SO_4, Ca); Cluster II (HCO_3, Na, Cl); Cluster III (EC, TDS)

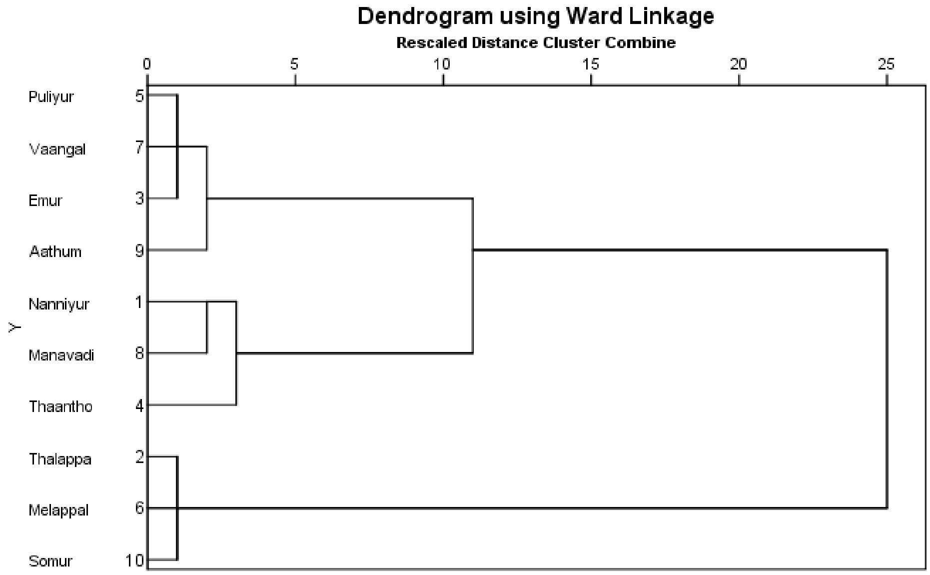

Fig. 3. Dendrogram analysis was performed as Place. Cluster I (Puliyur, Vaangal, Emur); Cluster II (Aathunar); Cluster III (Nanniyur, manavadi); Cluster IV (Thaanthoni malai); Cluster V (Thalappatti, Melappalayam, Somur)

Piper trilinear diagram

The distinct hydro geochemical facies types from the primary cations and anions were identified using the Piper (1944) and Chadda (1999) plots. To comprehend issues pertaining to the geochemical evolution of groundwater, a Piper diagram is frequently utilized (Wu *et al.,* 2017). In order to plot the milliequivalent percentages of the primary cations and anions in a distinct triangle, the Piper diagram was created. The general character of the water is given by the projection of these triangular field points farther into the central diamond field (Piper, 1944). After that, each point is projected into the upper field along a line that runs parallel to the field's upper edge. The intersection of the extension shows the water's characteristics, which are represented by the relationships between Naz , Kz, Ca^{2}z, Mg^{2}z, CO{ + HCO{, Cl{, and SO^{2}{. The water sample's general hydro chemical properties are displayed by the diamond, and each ion's relative content is displayed by the triangle (Piper, 1944).

In this study, the Grapher software was used to create a Piper diagram. A diamond and two tri-

Table 3. Matrix of correlation (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).

angles make up a Piper triangle, as seen in Figure 4, where the diamond is separated into nine parts. In the diamond section, the majority of water samples are of the sodium chloride kind. The hydro chemical facies were identified using the central diamond plot, which was based on the data in Figure 5, while the cations and anions were plotted on the lower left and right ternary plots, respectively. Anions in the current study are of the chloride type, but the majority of water samples with cations are of the sodium and potassium types (left lower triangular area). This suggests the citations to Figure 5.

Fig. 4. Piper trilinear diagram reference standard (Sources: (Ogbozige and Toko, 2020)

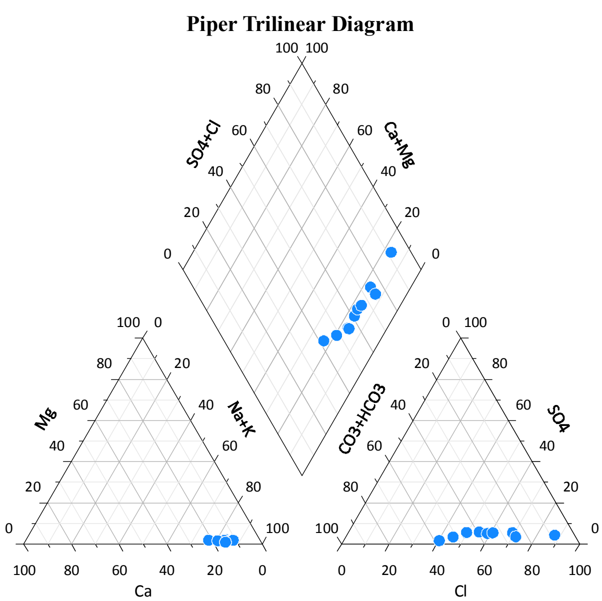

Fig. 5. Piper trilinear diagram observation of 10 samples

Water quality index calculation (WQI)

Groundwater chemistry is frequently employed as a method to distinguish between irrigation and drinking water quality (Subba Rao, 1997 and Vasanthavigar *et al.*, 2010). The Water Quality Index (WQI) is a crucial metric for determining the sustainability of water for human consumption (Subba Rao, 2006 and Magesh *et al.*, 2013). The term "IQO" refers to an evaluation method that shows the combined impact of distinct water quality criteria on the overall quality of the water (Mitra, 1998). For drinking water quality, the EQI was calculated using BIS and World Health Organization guidelines (BIS, 1991 and WHO, 2011). Water quality characteristics were assigned relative weights (wi) according to their respective significance for drinking water quality (Table 4). Table 4 displays the water quality classification according to WQI values. Table 6 displays the results of the WQI calculation for groundwater samples. Ten samples in all were examined for WQI. Twenty percent of the ten samples were in the excellent water category, and

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

Parameter	**Weight (wi)** (Vasanthavigar *et al.*, 2010)	**Wi**	**WHO Standard (2011)**
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

eighty percent were in the good water category. Table 5 displays the reference ranges for the water quality classification. The water quality index (WQI) classification for each sample is displayed in Table 6 and Figure 6.

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

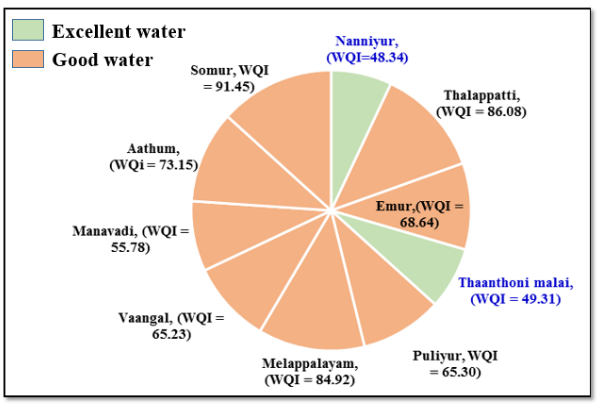

Fig. 6. Water quality index (WQI) in Karur block area

Conclusion

Investigations were conducted into groundwater's chemical characteristics and drinking water quality. Eighty percent of the ten samples had good water, while twenty percent had outstanding water. Following the identification of comparable groups among the water samples, HCA produced a location-based dendrogram that separated the ten samples into five groups and a dendrogram using parameters that separated the ten samples into three groups in Piper's trilinear diagram. While anions are of the chloride type, most cation-containing water samples are of the potassium and sodium type zones (bottom left triangle area).

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Conflicts of Interest: The authors declare no conflicts of interest.

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