GROUNDWATER QUALITY EVALUATION IN KARUR BLOCK AREA, TAMIL NADU (INDIA) , BASED ON CORRELATION MATRIX AND WATER QUALITY INDEX

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Abstract

The chemical properties of groundwater and the quality of drinking water have been investigated in the current study. In the Karur district, ten groundwater samples were taken in June 2023, during the southwest monsoon. The pH, electrical conductivity, total dissolved solids, bicarbonate, chloride, sulphate, calcium, magnesium, sodium, and potassium were measured in the water samples. The outcomes were assessed and compared with WHO water quality requirements. The correlation matrix indicates that Na^+, Ca^{2+}, and Mg^{2+} and Cl^- have an impact on the basic ionic chemistry and also suggests that the samples contain Na^+–Cl^-, Ca^{2+}–Cl^-, and mixed Ca^{2+}–Mg^{2+}–Cl^- kinds of water. Additionally, a thorough investigation was conducted in the research area to determine the Water Quality Index (WQI)-based drinking water quality during the southwest monsoon season. Only four blocks were found to be potable for drinking according to the WQI results.

Keywords: chemical characteristics, groundwater, correlation matrix, water quality index

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INTRODUCTION

The growing threat to ground water quality posed by human activity in recent years has given rise to serious concerns. Therefore, ongoing groundwater monitoring is necessary to reduce groundwater pollution and maintain control over the pollutants[1,2]. In many Indian towns and industrial clusters, groundwater pollution brought on by industrial effluents and municipal trash in water bodies is a major concern[3]. In hydrogeochemical research, correlation matrix analysis is a useful method that may specify the correlations between different parameters, illuminating the overall soundness of the data set and illuminating the connections between specific parameters and other regulating elements[4,5]. A correlation coefficient of less than 0.5 indicates poor correlation, more than 0.5 indicates good correlation, and greater than 0.5 indicates outstanding correlation[6]. The basic connections between the original variables are revealed by Pearson's correlation coefficient, which is reported in nonparametric form. A significant textile hub is Karur. Large factories even constructed tube wells to a depth of 275 metres and dumped effluents into them, causing the groundwater in the area to become contaminated. Around 250 open wells became contaminated, the production of the crops decreased, the farmlands gradually became sterile, and the soil became infertile. According to local residents of the afflicted areas, the prevalence of kidney ailments, cancer, and abortion is significant[7]. A total of 10 water samples were gathered in the Karur block area, and their physico-chemical characteristics were examined. A single parameter cannot be used to evaluate the quality of groundwater. Water Quality Index (WQI) often evaluates it[8]. According to a specified method of computation, a water quality index relates a series of water quality metrics to a common scale and combines them into a single number[9]. A highly helpful instrument for disseminating knowledge about the overall quality of water is the water quality index[10]. WQI was therefore employed in the current study to evaluate the quality of Karur's groundwater.

MATERIALS AND METHODS

Sampling: Ten groundwater samples were taken in the southwest monsoon season (June 2023) using hand pumps and bores. In addition to a variety of land-use patterns, bore wells and hand pumps for sampling were chosen on the basis of an industrial unit. The GIS map of the study region is shown in Fig.1 along with the locations of the sampling. High-density white polyethylene bottles were utilized to collect the samples. Laboratory testing was done on the labelled water samples to determine their physico-chemical characteristics. The American Public Health Association (APHA 2005) recommended practices were adhered to when collecting samples for handling and preservation in order to ensure the validity and dependability of the results.

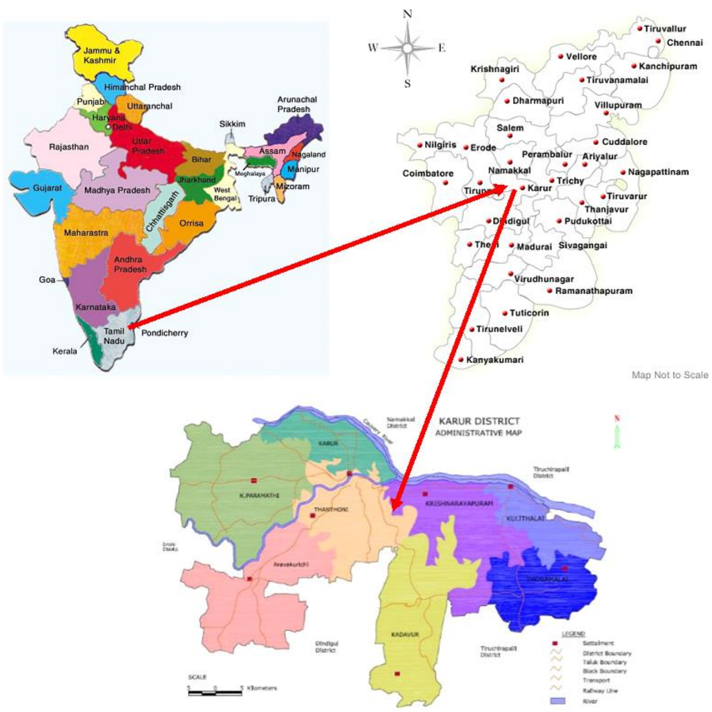

Fig.1: Sampling location

Table 1: Water collection stations in Karur

Station No.	Place	Location
S1	**Nanniyur**	11.0552 Latitude and 78.0095 Longitude
S2	**Thalappatti**	10.957348 Latitude and 78.080927 Longitude.
S3	**Emur**	10.9227966 Latitude and 78.1165269 Longitude
S4	**Thaanthoni malai**	10.9301249 Latitude and 78.0908511 Longitude
S5	**Puliyur**	10.936682 Latitude and 78.1521606 Longitude
S6	**Melappalayam**	10.9293 Latitude and 78.15385 Longitude
S7	**Vaangal**	11.129655 Latitude and 78.1478812 Longitude
S8	**Manavadi**	10.8882855 Latitude and 78.1029778 Longitude
S9	**Aathum**	10.9338334 Latitude and 78.0883645 Longitude
S10	**Somur**	10.9879951 Latitude and 78.1260397 Longitude

Karl Pearson correlation matrix analysis is a helpful tool in hydrogeochemical studies because it can show correlations between different parameters, revealing the overall consistency of the data set and illuminating the relationships between different parameters and various controlling factors[11,12]. The fundamental associations between the original variables, which are presented in non-parametric form, are provided by Pearson's correlation coefficient[6].

The Pearson Correlation Coefficient formula is as follows:

$$\mathbf{r} = \frac{\mathbf{n}(\sum \mathbf{xy}) - (\sum \mathbf{x})(\sum \mathbf{y})}{\sqrt{[\mathbf{n}\sum \mathbf{x}^2 - (\sum \mathbf{x})^2][\mathbf{n}\sum \mathbf{y}^2 - (\sum \mathbf{y})^2]}}$$

Where, The Pearson Coefficient is r.n is the number of stock pairs, and $\sum xy$ is the total of the products of the paired stocks, $\sum x$ is the total of the x scores, $\sum y$ is the total of the y scores $\sum x^2$ is the total of the squared x scores, and $\sum y^2$ is the total of the squared y scores.

RESULTS AND DISCUSSION

Due to the combined effects of the high concentration of dissolved ions, agricultural activities in the research area, and the pH value, the samples are somewhat slightly alkaline in nature (7.18–7.92). The concentrations of dissolved carbon dioxide, carbonate, and bicarbonate play a major role in determining the pH value of groundwater[13]. All ten samples' EC values fall within the permitted range (610-878 µS/cm; the WHO standard is 1500 µS/cm). Between 390 and 898 mg/L (WHO (2011) Std 500 mg/L), Nanniyur (410 mg/L), Thaanthoni malai (390 mg/L), and Manavadi (485 mg/L), the TDS value of groundwater samples in the study area fluctuated (Table 2). The remaining seven samples fall into the "not suitable for drinking" category.

A high TDS value may be brought on by saline water incursion and nutrient enrichment brought on by fertilizers. The term "hardness" refers to the influence of dissolved minerals, mostly calcium and magnesium, on the appropriateness of water for residential, industrial, and drinking purposes.

This effect is caused by the presence of bicarbonates, sulphates, chloride, and nitrates of calcium and magnesium. High levels of hardness are likely the result of nearby residential areas regularly adding significant amounts of detergent to lakes that drain into estuaries. Groundwater samples' Cl^- concentrations were found to be higher than permitted levels. Approximately 87% of the samples are unfit for drinking. Increased Cl^- concentrations in water are typically regarded as a sign of pollution and as the primary cause of groundwater contamination. Appetite, sodalite, connate fluids, and hot springs are all significant geological sources of chloride. Higher chloride concentrations were found, primarily as a result of surface runoff from agricultural land, sewage and municipal waste, and effluents from the dyeing and bleaching industries. Cl^- has a salty flavour, and larger consumption can sometimes increase the risk of developing essential hypertension, left ventricular hypertension, stroke, osteoporosis, renal stones, and asthma in people[14].

Table 2: Physico-chemical characteristics of the groundwater samples (June 2023)

	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	690	410	2.21	44.30	201.90	10.12	18.20	2.80	124.40	1.82	3.02
2	**Thalappatti**	7.90	718	890	1.86	268.28	387.50	48.89	60.07	3.56	270.78	2.32	20.74
3	**Emur**	7.60	817	674	2.18	160.20	250.32	32.67	38.75	3.19	195.64	2.54	8.46
4	**Thaanthoni malai**	7.18	610	390	3.20	250.14	200.15	18.30	18.02	2.54	190.03	1.90	4.12
5	**Puliyur**	7.82	790	680	1.21	123.93	218.25	18.79	30.15	3.56	172.04	2.46	8.90
6	**Melappalayam**	7.89	784	892	2.90	325.02	372.23	40.05	50.72	3.86	262.50	1.20	20.32
7	**Vaangal**	7.65	810	624	2.34	92.12	275.60	20.22	30.33	3.90	170.20	1.92	8.34
8	**Manavadi**	7.32	792	485	3.01	70.12	210.01	18.70	20.05	3.10	165.80	1.98	6.04
9	**Aathum**	7.90	878	790	1.82	265.60	248.90	19.56	36.92	3.45	160.98	2.52	10.24
10	**Somur**	7.92	875	898	3.98	298.80	390.80	40.24	57.12	3.80	280.84	2.04	19.16
	Descriptive statistic												
	Mean	7.65	776.4	673.3	2.47	189.85	275.56	26.75	36.03	3.37	199.32	2.07	10.93
	Median	7.77	791	677	2.27	205.17	249.61	19.89	33.62	3.51	181.03	2.01	8.68
	Maximum	7.92	878	898	3.98	325.02	390.80	48.89	60.07	3.90	280.84	2.54	20.74
	Minimum	7.18	610	390	1.21	70.12	200.15	18.30	18.02	2.54	124.40	1.20	3.02
***WHO (2011) Std.**		6.5-8.5	1500	500	-	500	250	250	75	50	200	45	12

Correlation coefficient : Pearson correlation analysis is commonly used to evaluate and establish the strength of a linear relationship between variables. The correlation coefficients among various water quality parameters were calculated and the values of the correlation coefficient are given in Table 3.

Table.3: Correlation coefficient (r) values between the Physico-chemical parameters

Parameters	pH	EC	TDS	CO_3	HCO_3	Cl	SO_4	Ca	Mg	Na	NO_3	K
pH	1											
EC	0.6679	1										
TDS	0.9479	0.6041	1									
CO_3	0.1624	-0.0035	-0.0119	1								
HCO_3	0.6742	0.1321	0.7022	0.3301	1							
Cl	0.9646	0.3241	0.8742	0.3044	0.6998	1						
SO_4	0.893	0.2148	0.8224	0.2195	0.7044	0.9159	1					
Ca	0.9737	0.4278	0.9507	0.1156	0.7224	0.9508	0.9385.	1				
Mg	0.7629	0.6976	0.8194	-0.0503	0.3283	0.7158	0.5431	0.7045	1			
Na	0.8707	0.1618	0.7752	0.4274	0.7909	0.9195	0.946	0.8879	0.5252	1		
NO_3	0.0789	0.2917	0.0703	-0.5308	-0.1447	-0.2372	-0.0575	0.031	-0.0811	-0.2102	1	
K	0.9819	0.3538	0.9311	0.1853	0.7514	0.9692	0.9215	0.9631	0.7269	0.9188	-0.1725	1

Weathering and dissolving activities have an impact on the groundwater chemistry during the southwest monsoon season (June 2023). Through secondary evaporation, an intense weathering process improves the principal cations, such as Ca^{2+} and Mg^{2+} and Na^{2+}. The correlation between TDS and Ca^{2+} (r = 0.9507), SO_4^{2-} (r = 0.8224), Na^+ (r = 0.7752), Cl^- (r = 0.8742), and Mg^{2+} (r = 0. 7752) is good. These correlations are a result of silicate lithology weathering as well as geochemical behaviour during ionic mobilisation.

The strong positive correlation between TDS and Ca^{2+} (r = 0.9507), Mg^{2+} (r = 0.7752), and Cl^- (r = 0.8742) suggests that both $CaCl_2$ and $MgCl_2$ are responsible for the hardness in groundwater. The strong positive correlation between TDS and Ca^{2+} (r = 0.9507), Mg^{2+} (r = 0.7752), and HCO_3^{2-} (r = 0.7022) suggests that both $Ca(HCO_3)_2$ and $Mg(HCO_3)_2$ are responsible for the hardness in groundwater. In the research area, poor water quality is evident due to pollution from a variety of sources, including sewage, industrial effluents, the dumping of agricultural and chemical waste, and human wastes.

Results clearly reveal (Table 3) that EC and TDS show a positive association (r = 0.6041) during the southwest monsoon season (June 2023), which may be caused by the fact that conductivity rises as ionic concentration rises. Both geochemical processes and anthropogenic activities have an impact on the ionic chemistry of the groundwater throughout this season. TDS vs. SO_4^{2} (r = 0.8224), SO_4^{2} vs. Na^+ (r = 0.946), and Cl^- vs. SO_4^{2-} (r = 0.9159) show the possibility of ion exchange and gypsum and halite dissolution with good agreement. Na^+, Ca^{2+}, and Mg^{2+}, however, have an impact on the fundamental chemistry of ions, suggesting that the samples are Na^+–Cl^-, Ca^{2+}–Cl^-, or mixed Ca^{2+}–Mg^{2+}–Cl^- types of water.

Calculation of the Water Quality Index: Five crucial factors were utilised to determine the WQI: pH, total dissolved solids (TDS), electrical conductivity (EC), calcium (Ca), and magnesium (Mg). These factors have the biggest impact on river quality. The total Water Quality Index was computed by linearly combining the unit weight and quality rating.

$WQI=\sum q_n W_n/ \sum W_n$ Further, quality rating or sub index (q_n) was calculated using the following expression.

qn = 100[Vn -Vio]/[Sn -Vio] (A quality rating or sub index (qn) corresponding to the nth parameter is a number reflecting the relative value of this parameter in the polluted water with regard to its standard allowed value.) qn = The nth quality rating. parameter for water quality Vn is the nth parameter's estimated value at the specified sample site. The nth parameter's standard acceptable value is denoted by Sn. Vio = The n-th parameter's ideal value in pure water. (i.e., 0 for all parameters other than pH 7.0 and 1)[15]. WQI values for Stations 1 through 10 presented in Tables 4 and 5.

Table 4: WQI values for Station 1 to Station 5

Station 1: Nanniyur						
Sl. No.	Parameter	Observed value	Standard Value (S_n)	Unit Weight (W_n)	Quality Rating (q_n)	W_nq_n
1	pH	7.30	7.0 – 8.5 **	0.322	20	6.44
2	Total Dissolved Solids (TDS)	410	<300*	0.009	136.66	1.23
3	Electrical Conductivity (EC)	690	< 1500**	0.002	46	0.092
4	Calcium (Ca)	18.20	<75*	0.037	24.26	0.0898
5	Magnesium (Mg)	2.80	<50*	0.055	5.6	0.308
				ΣWn = 0.425		ΣWnqn = 8.1598
Water Quality Index =Σ q n Wn/ ΣWn = 8.576						
Station 2: Thalappatti						
Sl. No.	Parameter	Observed value	Standard Value (S_n)	Unit Weight (W_n)	Quality Rating (q_n)	W_nq_n
1	pH	7.90	7.0 – 8.5 **	0.322	60	19.32
2	Total Dissolved Solids (TDS)	890	<300*	0.009	296.66	2.669
3	Electrical Conductivity (EC)	718	< 1500**	0.002	47.86	1.052
4	Calcium (Ca)	60.07	<75*	0.037	80.09	2.96
5	Magnesium (Mg)	3.56	<50*	0.055	7.12	0.391
				ΣWn = 0.425		ΣWnqn = 26.392
Water Quality Index =Σ q n Wn/ ΣWn = 62.099						
Station 3: Emur						

Sl. No.	Parameter	Observed value	Standard Value (S_n)	Unit Weight (W_n)	Quality Rating (q_n)	W_nq_n
1	pH	7.60	7.0 – 8.5 **	0.322	40	12.88
2	Total Dissolved Solids (TDS)	674	<300*	0.009	224.66	2.021
3	Electrical Conductivity (EC)	817	< 1500**	0.002	54.46	0.108
4	Calcium (Ca)	38.75	<75*	0.037	51.66	1.911
5	Magnesium (Mg)	3.19	<50*	0.055	6.38	0.351
				ΣWn = 0.425		ΣWnqn = 17.271
Water Quality Index =Σ q n Wn/ ΣWn =40.637						
Station 4: **Thaanthoni malai**						
Sl. No.	Parameter	Observed value	Standard Value (S_n)	Unit Weight (W_n)	Quality Rating (q_n)	W_nq_n
1	pH	7.18	7.0 – 8.5 **	0.322	12	3.864
2	Total Dissolved Solids (TDS)	390	<300*	0.009	130	1.17
3	Electrical Conductivity (EC)	610	< 1500**	0.002	40.66	0.0813
4	Calcium (Ca)	18.02	<75*	0.037	24.02	0.889
5	Magnesium (Mg)	2.54	<50*	0.055	5.08	0.279
				ΣWn = 0.425		ΣWnqn = 6.283
Water Quality Index =Σ q n Wn/ ΣWn = 14.783						
Station 5: Puliyur						
Sl. No.	Parameter	Observed value	Standard Value (S_n)	Unit Weight (W_n)	Quality Rating (q_n)	W_nq_n
1	pH	7.82	7.0 – 8.5 **	0.322	54.66	17.60
2	Total Dissolved Solids (TDS)	680	<300*	0.009	226.66	2.039
3	Electrical Conductivity (EC)	790	< 1500**	0.002	52.66	0.105
4	Calcium (Ca)	30.15	<75*	0.037	4.02	0.149
5	Magnesium (Mg)	3.56	<50*	0.055	7.12	0.391
				ΣWn = 0.425		ΣWnqn = 20.284
Water Quality Index =Σ q n Wn/ ΣWn = 47.725						

Table 5: WQI values for Station 6 to Station 10

Station 6: Melappalayam						
Sl. No.	Parameter	Observed value	Standard Value (S_n)	Unit Weight (W_n)	Quality Rating (q_n)	W_nq_n
1	pH	7.89	7.0 – 8.5 **	0.322	59.33	19.104
2	Total Dissolved Solids (TDS)	892	<300*	0.009	297.33	2.675
3	Electrical Conductivity (EC)	784	< 1500**	0.002	52.26	0.105
4	Calcium (Ca)	50.72	<75*	0.037	67.62	2.502
5	Magnesium (Mg)	3.86	<50*	0.055	7.72	0.425
				ΣWn = 0.425		ΣWnqn = 24.811
Water Quality Index =Σ q n Wn/ ΣWn = 58.378						
Station 7: Vaangal						
Sl. No.	Parameter	Observed value	Standard Value (S_n)	Unit Weight (W_n)	Quality Rating (q_n)	W_nq_n
1	pH	7.65	7.0 – 8.5 **	0.322	43.33	13.952
2	Total Dissolved Solids (TDS)	624	<300*	0.009	208	1.872
3	Electrical Conductivity (EC)	810	< 1500**	0.002	54	0.108
4	Calcium (Ca)	30.33	<75*	0.037	40.44	1.496
5	Magnesium (Mg)	3.90	<50*	0.055	7.8	0.429
				ΣWn = 0.425		ΣWnqn = 17.857
Water Quality Index =Σ q n Wn/ ΣWn = 42.016						
Station 8: Manavadi						
Sl. No.	Parameter	Observed value	Standard Value (S_n)	Unit Weight (W_n)	Quality Rating (q_n)	W_nq_n
1	pH	7.32	7.0 – 8.5 **	0.322	21.33	6.868
2	Total Dissolved Solids (TDS)	485	<300*	0.009	161.66	1.455
3	Electrical Conductivity (EC)	792	< 1500**	0.002	52.8	0.106
4	Calcium (Ca)	20.05	<75*	0.037	26.73	0.989
5	Magnesium (Mg)	3.10	<50*	0.055	6.2	0.341
				ΣWn = 0.425		ΣWnqn = 9.756
Water Quality Index =Σ q n Wn/ ΣWn = 22.96						
Station 9: Aathum						
Sl. No.	Parameter	Observed value	Standard Value (S_n)	Unit Weight (W_n)	Quality Rating (q_n)	W_nq_n
1	pH	7.90	7.0 – 8.5 **	0.322	60	19.32
2	Total Dissolved Solids (TDS)	790	<300*	0.009	263.33	2.369

3	Electrical Conductivity (EC)	878	< 1500**	0.002	58.53	0.117
4	Calcium (Ca)	36.92	<75*	0.037	49.22	1.821
5	Magnesium (Mg)	3.45	<50*	0.055	6.9	0.379
				ΣWn = 0.425		ΣWnqn = 24.006
Water Quality Index =Σ q n Wn/ ΣWn = 24.518						
Station 10: Somur						
Sl. No.	Parameter	Observed value	Standard Value (S_n)	Unit Weight (W_n)	Quality Rating (q_n)	W_nq_n
1	pH	7.92	7.0 – 8.5 **	0.322	61.33	19.75
2	Total Dissolved Solids (TDS)	898	<300*	0.009	299.33	2.694
3	Electrical Conductivity (EC)	875	< 1500**	0.002	58.33	0.116
4	Calcium (Ca)	57.12	<75*	0.037	76.16	2.817
5	Magnesium (Mg)	3.80	<50*	0.055	7.6	0.418
				ΣWn = 0.425		ΣWnqn = 25.795
Water Quality Index =Σ q n Wn/ ΣWn = 26.360						

Based on the WQI calculated for the samples, it is determined that the water quality at Stations 1 (WQI- 08.576), Station 4, Station 8, and Station 9 (WQI-22.960) and Station 9 (WQI-24.518) can be rated as "Excellent" for use in drinking water, irrigation, and industry. Sample from station 2 (WQI-62.099) Station 6 (58.378), - Despite the industry's treatment efforts, it is still considered to be water of "Fair" quality and requires careful treatment to reduce the concentration of different parameters to within the concentration range and make it suitable for consumption. Rating scale for standard quality of water given in Table 6. Quality and purpose of analyzed water samples based on WQI value presented in Table 7.

Table 6: Rating Scale for Quality of water[16]

Value of WQI	Quality of Water
0-25	Excellent
26-50	Good
51-75	Fair
76-100	Poor
101-150	Very Poor
>150	Unfit for Drinking

Table 7: Quality and purpose of water samples based on WQI value

Location	WQI	Quality of water	Purpose
Station 1: Nanniyur	08.576	Excellent	Drinking, Irrigation and Industrial
Station 2: Thalappatti	62.099	Fair	Irrigation and Industrial
Station 3: Emur	40.637	Good	Domestic, Irrigation and Industrial
Station 4: Thaanthoni malai	14.783	Excellent	Drinking, Irrigation and Industrial
Station 5: Puliyur	47.725	Good	Domestic, Irrigation and Industrial
Station 6: Melappalayam	58.378	Fair	Irrigation and Industrial
Station 7: Vaangal	42.016	Good	Domestic, Irrigation and Industrial

Station 8: Manavadi	22.960	Excellent	Excellent: Drinking, Irrigation and Industrial
Station 9: Aathum	24.518	Excellent	Excellent: Drinking, Irrigation and Industrial
Station 10: Somur	26.360	Good	Domestic, Irrigation and Industrial

CONCLUSION

The correlation matrix indicates that Na^+, Ca^{2+}, and Mg^{2+} and Cl^- have an impact on the basic ionic chemistry and also suggests that the samples contain Na^+–Cl^-, Ca^{2+}–Cl^-, and mixed Ca^{2+}–Mg^{2+}–Cl^- kinds of water. Only four of the research area's blocks (Nanniyur, Thaanthoni Malai, Manavadi, and Aathum) were deemed suitable for drinking during the southwest monsoon season (June 2023), according to the Water Quality Index. Six additional blocks were discovered to be in good and fair condition. Therefore, it has been advised, to avoid using the groundwater in these areas for drinking directly before the necessary treatment.

Conflicts of interests

The authors declare no conflict of interest.

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