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Evaluation of Ground Water in and Around Melapalayam, Tirunelveli District Using Water Quality Index

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Abstract

Melapalayam is a small western neighbourhood of Tirunelveli, a city in Tamil Nadu, India. It is one of the developing residential districts. The present study during the rainy season of December 2023, it involves thecollection of twenty groundwater samples, which were subsequently subjected to a thorough analysis of their physico-chemical parameters. The primary focus of this investigation encompasses the determination of key characteristics, including pH, Electrical Conductivity, Total Dissolved Solids, Dissolved Oxygen, Biochemical Oxygen Demand, Chemical Oxygen Demand, Calcium, Magnesium, Total Hardness, Chloride, Sulphate, Sodium and Potassium. Groundwater suitability for domestic and irrigation purpose was examined by using WHO standards. The main objectives are to study about by using the Water quality index, Wilcox diagram and Piper Diagram whether it is suitable for drinking and irrigation or not. The quality of groundwater samples were discussed with respect to these parameters and thus an attempt was made to ascertain the quality of groundwater is fit or not for drinking and other purposes.

Keywords: Groundwater, Tirunelveli, physico-chemical, parameters, Wilcox, Water quality index

1. Introduction

Water, the fundamental element of life, shapes and sustains all living beings on Earth [1]. Despite its ubiquity, the exact origins of water on our planet remain a subject of inquiry. Contemporary understanding posits that in the early stages of Earth's formation, it lacked vast oceans and had minimal atmospheric presence. Instead, volatile constituents within the Earth's crust gradually emerged through volcanic activity, tectonic shifts, and thermal springs, coalescing to form the oceans and atmosphere over time. The miraculous bonding of hydrogen and oxygen molecules gave rise to water, an essential component of the Earth's crust and the bedrock of existence [2].

The escalating demand for water across domestic, agricultural, and industrial sectors has led to a heightened reliance on groundwater for various purposes, including drinking and household use. To ensure the sustained availability and integrity of groundwater reservoirs, regular monitoring of water quality is imperative [3]. Thus, understanding the diverse physico-chemical parameters of groundwater and establishing corresponding water quality indices becomes paramount. Groundwater, a critical natural asset, assumes the role of both renewable and non-renewable resource depending on its utilization and replenishment rates [4]. Approximately one-third of global groundwater reservoirs are earmarked for potable consumption, underscoring its significance in meeting human needs. However, burgeoning population growth and rapid industrial expansion have engendered a surge in freshwater demand, exacerbating concerns over water scarcity and contamination. In

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water resource management, quality supersedes quantity, especially concerning drinking water provision. The chemical, physical, and microbiological attributes of groundwater dictate its suitability for myriad applications, spanning municipal, commercial, industrial, agricultural, and domestic domains. Against this backdrop, our study endeavours to analyse the diverse physico-chemical.[5]

2. Materials And Methods

a. Study Area

Melapalayam, a burgeoning western neighbourhood of Tirunelveli, Tamil Nadu, India, is witnessing rapid urbanization and population growth, necessitating a comprehensive understanding of its groundwater quality. As a primary source of drinking water and irrigation, the sustainability and safety of groundwater resources are paramount for the well-being and development of the community.

b. Sample Collection

The physico-chemical analysis for the ground water samples were performed during December-2023. The physico-chemical parameters such as pH, EC, TDS, DO, TH, BOD, COD, HCO3, Ca, Mg, Cl, Na, K, SO4 were analyzed. The areas in and around Tirunelveli were taken for our study twenty water samples were collected at various stations shown below. Water samples were collected in Polythene bottles of 2 liters. The samples were collected from bore wells as well as from deep hand pumps at December-2023. It was ensured that the concentrations of various water quality parameters do not changes in time that elapses between drawing of samples and the analysis in the laboratory. For DO, BOD and COD separate 2 liters polythene bottles were used. The bottles were thoroughly cleaned with hydrochloric acid and then washed with tap water rendered free of acid and then washed with distilled water twice and again rinsed with the water sample to be collected and then filled up the bottle with the sample leaving only a small air gap at the top, stoppered and sealed the bottle with paraffin wax. Some samples which were first cleaned with tap water thoroughly and finally with deionized distilled water. The pipettes and burette were rinsed with solution before final use. The chemicals and reagent were used for analysis were of annulargrade. The pH meter, conductivity meter, spectrophotometer, flame photometer instruments were used to analyze these parameters. The groundwater samples were determined using standard methods and the results were compared with the values of World Health Organization 2007.

Table 1: Sampling Locations and Sources

Sample no.	Sampling locations	Source	Sample no.	Sampling locations	Source
1.	MoolanahamedPillaiStreet	Bore well	11.	Nabinagar	Bore well
2.	Asura Street	Bore well	12.	Asantharagan Street	Bore well
3.	SappaniaaleemStreet	Bore well	13.	Periya Street	Bore well
4.	Kaatupudhu Street	Bore well	14.	Ekkinpillai Street	Bore well
5.	Kareemnagar	Bore well	15.	Athiyadi Street	Bore well
6.	Gnaniyarappanagar	Bore well	16.	Umarpulavar Street	Bore well
7.	VST Street	Bore well	17.	Selvakadhar Street	Bore well
8.	Bangalappanagar	Bore well	18.	Rahmaniyapuram Street	Bore well
9.	Methamarpalayam Street	Bore well	19.	Ganesapuram Street	Bore well
10.	Hameempuram Street	Bore well	20.	Thandalebbai Street	Bore well

3. Results and Discussion

Table 2: Physico-Chemical Parameters of Ground Water Collected From Tirunelveli During December 2023

Parameters	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20
pH	7.1	7.0	7.8	7.7	7.1	7.5	7.1	7.2	7.5	7.2	7.0.	7.2	7.0	7.4	7.1	7.4	7.8	7.8	8.2	7.0
TDS	1154	454	343	114	565	311	290	295	406	212	363	388	390	324	362	255	139	78	102	454
EC	2666	1002	686	204	1032	732	580	580	1138	476	650	852	964	608	578	472	264	156	194	1002
Ca	40	46	42	24	46	44	40	26	24	36	56	90	114	92	98	80	40	34	46	40
Mg	195	54	54	84	77	46	51	63	113	90	155	30	27	44	31	18	30	90	83	57
TH	800	350	250	175	400	260	250	325	425	260	51	380	480	285	375	285	215	125	200	350
SO_4	380	330	420	290	390	310	350	270	470	430	370	340	435	275	415	300	346	260	430	470
Na	20	14	07	09	08	11	7.9	8.6	22	06	15	18	19	14	11	08	06	05	10	21
K	6	3	1	4	2	3	2	1	3	1	03	04	04	02	01	05	02	04	04	06
DO	3	2	3	4	3	2	3	4	3	3	04	05	04	02	06	02	04	02	03	05
BOD	5	2	3	8	7	5	6	4	5	5	05	07	06	08	08	06	09	02	09	08
COD	13	7	5	9	10	6	4	12	6	9	04	05	08	11	14	07	12	11	13	08
HCO_3	`120	133	138	140	210	311	222	115	129	190	245	220	145	176	123	112	118	104	209	310
Cl	140	135	220	140	120	210	90	85	45	67	132	112	166	189	212	205	214	130	98	125

Note: All values are expressed in ppm except pH & EC – µmho/cm

Estimation of Water Quality Index (WQI)

Estimating the Water Quality Index (WQI) involves a technique for rating that amalgamates the influence of individual water quality parameters on the overall water quality. This assessment is conducted with a focus on human consumption.[6] The average concentration of physico-chemical parameters, including pH, turbidity, total dissolved solids, total alkalinity, total hardness, nitrate, chloride, calcium, magnesium, iron, and fluoride, is utilized in the computation of WQI.

A critical pollution index of 100 is considered unacceptable.[7]
The calculation of the Water Quality Index follows the procedure outlined below:

Individual quality rating is given by the expression

$$Qi=100V/Si \quad (2)$$

Water Quality Index (WQI) is then calculated as follows:

$$WQI = \sum_{i=1}^{n}(Qi \times Wi) / \sum_{i=1}^{n} Wi$$

Where, Q is the subindex of i^{th} parameter. Wi is the unit weightage for i^{th} parameter, n is the number of parameters considered. Generally, the critical pollution index value is100.[8]

Table 3: Calculation of WQI values for Ground Water Samples Collected in 2023

Parameters	Mean Value in ppm (Vi)	Highest permitted value – WHO (Si)	Unit weightage (Wi)	Qi	Wi × Qi
pH	6.7	8.5	0.117	79	9.24
EC	574	600	0.0016	96	0.15
TDS	286	500	0.002	57	0.11

Ca	69	200	0.005	35	0.18
Mg	56	150	0.006	37	0.22
TH	275	500	0.002	55	0.11
SO4	364	500	0.002	73	0.15
Na	13	25	0.04	52	2.08
K	4	5	0.2	80	16
DO	4	5	0.2	80	16
BOD	7	10	0.1	70	07
COD	9	15	0.066	60	04

$$WQI = \sum_{i=1}^{n} (Qi \times Wi) / \sum_{i=1}^{n} Wi = \mathbf{4.60 / 0.073 = 63}$$

Table 4: Calculation of WQI values for Ground Water Samples Collected in 2023

Parameters	Mean Value in ppm (Vi)	Highest Permitted Value -WHO (Si)	Unit Weightage (Wi)	Qi	Wi ×Qi
pH	7.32	8.5	0.117	0.117	10.07
EC	414	600	0.0016	0.0016	0.1104
TDS	910	500	0.002	0.002	0.364
Ca	37	200	0.005	0.005	0.0925
Mg	83	150	0.006	0.006	0.3198
TH	350	500	0.002	0.002	0.14
SO_4	364	500	0.002	0.002	0.146
Na	11	25	0.04	0.04	1.76
K	3	5	0.2	0.2	12
DO	3	5	0.2	0.2	12
BOD	5	10	0.1	0.1	5
COD	8	15	0.066	0.066	3.517

$$WQI = \sum_{i=1}^{n} (Qi \times Wi) / \sum_{i=1}^{n} Wi = \mathbf{4.5 / 0.073 = 62}$$

Table 5: Status Categories of WQI

WQI	QUALITY OF WATER
0-25	Very Good
26-50	Good
51-75	Poor
Above 75	Very Poor (Unsuitable for Drinking)

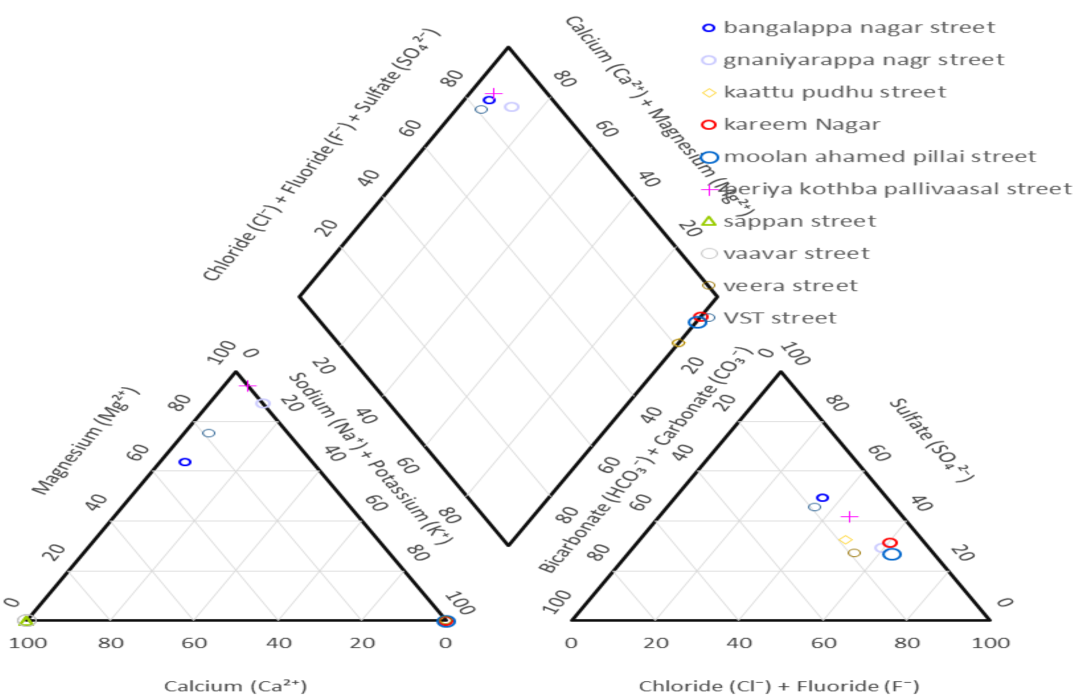
In the present study, the Water Quality Index is tabulated in Table: IV. The computed WQI values are 62 and 63. Thesevalue are found to be 51-75 as per WQI (Table: V) which shows the nature of the water quality of the areas seems to be poor. It is clearly understood that the groundwater of our study area is recommended not for drinking but other purposes as per the WQI standard values.

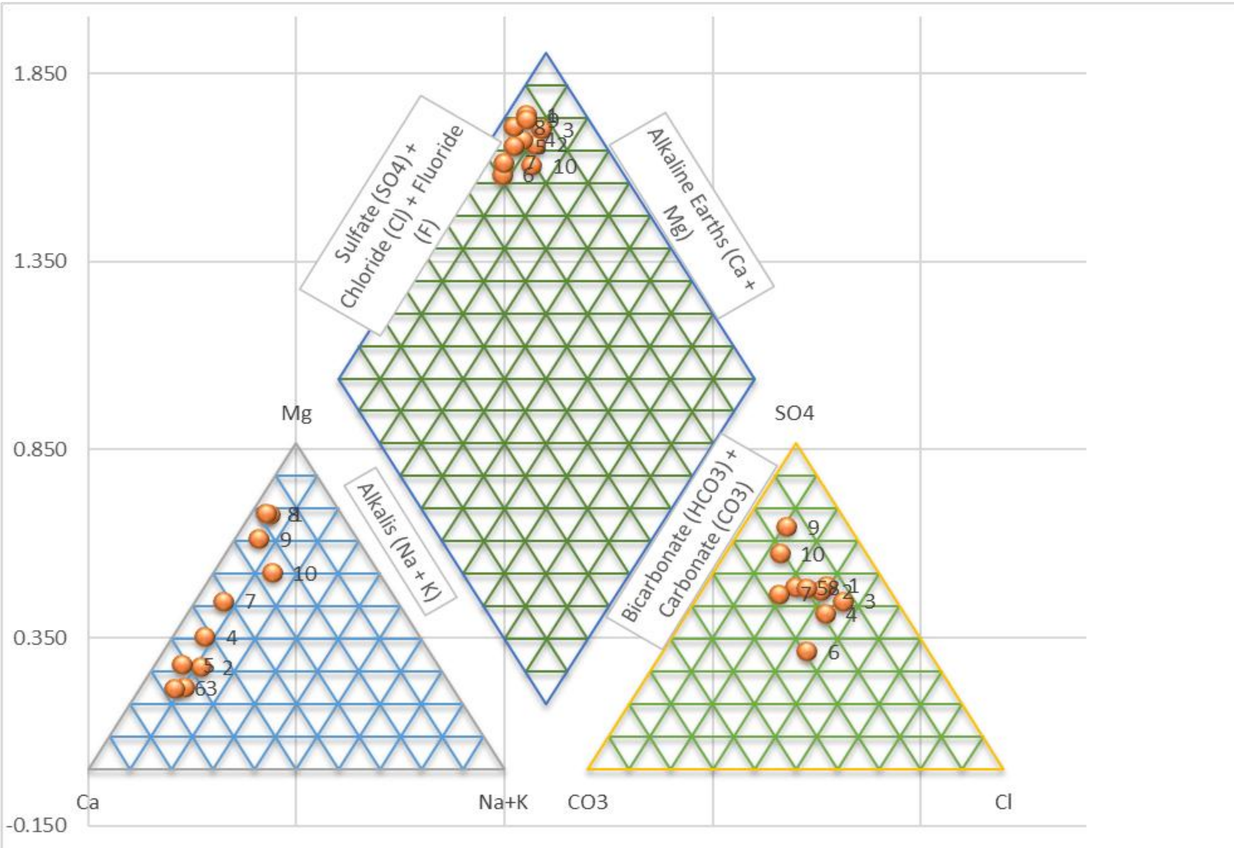
Piper Diagram

Water sampling analytical results plotted in the piperdiagram. Pipers diagram includes construction of cationand aniontriangles from the results obtained[9]. The twodata points from the cation and anion triangles are then combined into the quadrilateral field that shows the overall chemical property of the water sample.[10] The geochemical evolution of groundwater can be understood by plotting the concentrations of major cations (Ca, Mg,Na and K) and anions (CO_3, HCO_3, SO_4 and Cl) in milliequivalents per liter to evaluate the geochemical evolution/ hydrochemistry of groundwater in the study area in the Piper trilinear diagram.[11] These diagrams reveal the analogies, dissimilarities and different types of waters in the study area, which are identified and listed in the concept of hydro chemicalfacies was developed inorder to understand and identify the water composition in different classes. The Aquachem software was used forplotting the piper diagram.[12]

Water types

Using the analytical information from the hydrogeochemical facies analysis, a Piper diagram for the Salem District. Anion and cation dominance can be used to categorise the sample points in the piper diagram. A-Ca type, B-No Dominant type, C-Na and K type, and D-Mg type are all cation types.[13] E-HCO_3 type, F-Cl type, G-SO_4 type, and H-No dominating type are present in the anion triangle [14-16]. The cation triangle for the groundwater quality in January 2022 (winter) shows that Ca type water covers 10% of the total area, Na and K type water covers 3.3% of the total area, Mg type water covers 16.7% of the total area, and no dominating ion type water covers 70% of the whole area. In the anion triangle, F stands for the Cl type of water, which makes up 76.7% of the area, G for the SO_4 type of water, which makes up 3.3% of the area, and H for the 20% of the area that has no dominating ion type of water. (Figure 1). The Ca-Mg and SO_4-Cl contents of the water samples are confined in the triangles marked by the numbers 3 and 6 respectively in the diamond part of the diagram (Figure 1 & 2). The majority of the samples fall within the triangle 3 & 6 representing $CaMgSO_4Cl$ type water.





Wilcox Diagram

SAR vs. EC Plot

To assess the appropriateness of groundwater for irrigation, Wilcox plotted the percent SAR value versus the EC value. He classified groundwater into five categories in his plot: excellent to good, good to permissible, permissible to doubtful, doubtful to unsuitable, and inappropriate. Richards [18-21] offered the Wilcox diagram as a USSL diagram for assessing the quality of irrigation water by modifying it to include the SAR value as a sodium hazard and the EC value as a salt hazard According to the SAR and EC values, he also assigned the water quality the following ratings: low, medium, high, and extremely high for sodium and salinity concerns.

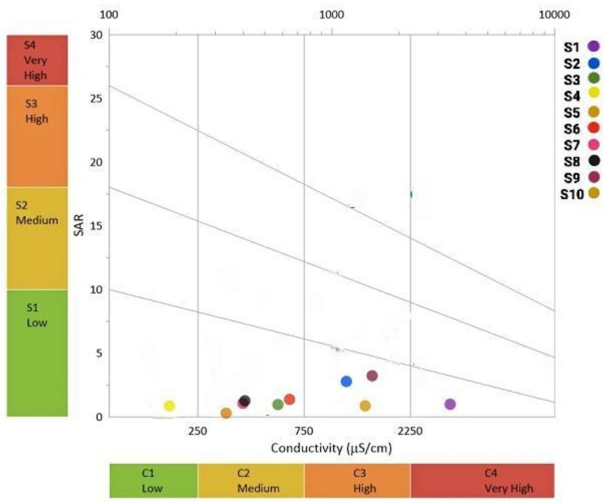
Sodium Adsorption Ratio: The sodium or alkali hazard in groundwater for irrigation is determined by the absolute and relative concentration of cations and is expressed in terms of Sodium Adsorption Ratio (SAR)[16,17]. There is a significant relationship between SAR values of irrigation water and the extent to which sodium is absorbed by the soil. If groundwater used for irrigation is high in sodium and low in calcium, the cation-exchange complex may become saturated with sodium.[14,15]

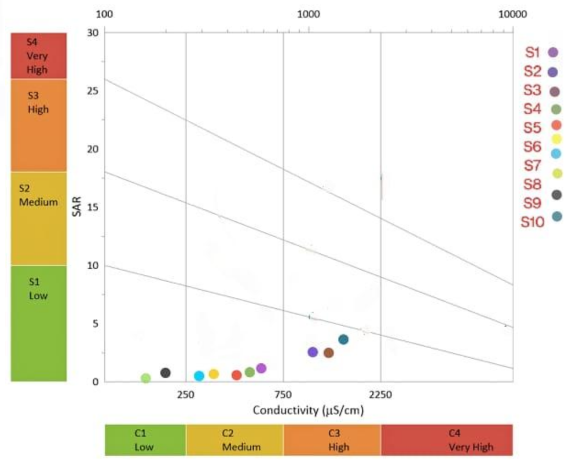
$$SAR = \frac{Na}{\sqrt{\frac{Ca+Mg}{2}}} \quad \text{(All ions in ppm)}$$

A simple method of evaluating the high sodium in water is the SAR. Calculation of SAR value for a given groundwater provides a useful index of the sodium hazard of that water for soils and crops.[15]Classification of water with reference to SAR is provided by Herman Bouwer (1978). A low SAR of 0 to 6 indicates no problem from sodium, increasing problem is between 6 to 9, and severe problem is above 9. The lower the ionic strength of solution, the greater sodium hazards for a given SAR.

Sample no.	SAR	EC	Sample no.	SAR	EC
S1	1.8	2666	**S11**	1.5	650
S2	2.8	1002	**S12**	2.3	852
S3	1.0	686	**S13**	2.3	964
S4	1.2	204	**S14**	1.7	608
S5	1.1	1032	**S15**	1.4	578
S6	1.6	732	**S16**	1.1	472
S7	1.2	580	**S17**	1.0	264
S8	1.3	580	**S18**	0.6	156
S9	2.6	1138	**S19**	1.2	194
S10	0.8	476	**S20**	3.0	1002

According to the USSL graphic, the groundwater quality for December 2023 (Rainy) was spread as follows:





Conclusion

This study investigated the physico-chemical properties of the groundwater to understand the status of water quality and also the ions sources. The combined diamond plot of the cationic and anionic triangular fields of the piper diagram shows that 90% of the groundwater samples fell in to the CaCl2 and Mixed NaCl types. Most of the calculated indices for irrigation water quality showed that the study area water quality is unsuitable for irrigation. The calculated irrigation water quality indices shows in the graphs SAR versus EC an USSL diagram showed the quality of the irrigation of the water in the study area during December 2023 (rainy seasons). The WQI calculated values ranged above 30 for seasons. This shows that the water quality of the study area is very poor and not suitable for drinking purpose. The study reveals that the investigation of hydrogeochemical process to approach the groundwater quality in and around melapalayam Tirunelveli district had the purpose of providing a simple, valid method for expressing the results of several parameters in order to assess the groundwater quality. The microbiological quality that adversely affected the quality of groundwater is likely to arise from a variety of sources. Hence it is important to apply strong prevention measures to save groundwater from contamination in these studied locations. In most of the states, the problem of groundwater depletion and quality deterioration has appeared in last few years. Monitoring of groundwater quality should be undertaken regularly to identify the sources of principal contaminants and other inhibitory compounds that affect the portability of water and also to identify the wells which are safe for drinking and irrigation water to protecting them from further contamination.

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