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Evaluation Of Groundwater Quality In And Around Ramanathapuram District, Tamil Nadu, India By Using Hydrogeochemical Facies Analysis And Wilcox Diagram

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ABSTRACT

Groundwater acts as a lifeline in the coastal regions to meet out the domestic, drinking, irrigational and industrial needs. Groundwater samples were collected from different locations in and around Ramanathapuram District and analyzed for their physicochemical parameters. To investigate the hydrogeochemical characteristics of groundwater and its suitability, thirty groundwater samples were collected from Ramanathapuam District for the period of January 2022 (winter) and April 2022 (summer) seasons respectively. The water quality assessment has been carried out by evaluating the physicochemical parameters such as Electrical Conductivity (EC), Bicarbonate (HCO_3), Calcium (Ca), Magnesium(Mg), Chloride (Cl), Sodium (Na), Potassium (K) and Sulphate (SO_4). The main objectives are to study about the spatial variations of cations and anions of the water type and by using USSL diagram whether it is suitable for irrigation or not.

KEYWORDS: Groundwater, Physico-chemical, Parameters, Hydrogeochemical, Coastal region.

INTRODUCTION

For the past few decades, there has been an acute demand for water resources. Industrial growth, population growth and other developmental activities have resulted not only in a high demand for water, but also in the degradation of quality, which aggravated the water crisis. Water pollution is a growing hazard in many developing countries including India [1]. Water, an echo to life, undoubtedly, is an unavoidable and undeniable component on earth. It is considered as an important resource key element to sustain life on the planet [2]. Water is universal solvent and renewable resource. These unique properties of water make it to get polluted. The knowledge of hydrochemistry is essential to determine the origin of chemical composition of groundwater. Water quality is influenced by natural and anthropogenic effects including local climate, geology and irrigation practices. The chemical character of any groundwater determines its quality and utilization. The quality is a function of the physical, chemical and biological parameters and could be subjective, since it depends on a particular intended use. Rapid increase in urbanization and industrialization leads in to deterioration in groundwater quality [3]. Water quality analyses are an integral part of an environmental

monitoring program for touristic beaches, and in general, present important information for the management of the coastal zone [4].

All over the world, many researchers have studied the hydro geochemistry of various coastal aquifers for quality analysis and seawater intrusion [5]. In several coastal cities, groundwater serves as one of the freshwater sources for drinking, domestic, irrigation, and industrial needs. Seawater intrusion is considered a common problem in most coastal aquifers worldwide [6,7,8]. Hydro geochemistry needs to be studied to identify the controlling factors and gain a comprehensive understanding of the source, origin, distribution, and driving force of organic and inorganic compounds in various coastal aquifers [9, 10, 11].

Water can be regarded polluted when it changes its quality or composition either naturally or as a result of human activities. The sources for ground water supply mostly depend upon the rainfall and the resulting percolation of the water into the earth. Another important factor is quality of the soil. A total of thirty ground water samples were analyzed Electrical Conductivity (EC), Bicarbonate (HCO_3), Calcium (Ca), Magnesium (Mg), Chloride (Cl), Sodium (Na), Potassium (K) & Sulphate (SO_4). The quality of groundwater was interpreted in terms of hydrogeochemical process.

MATERIALS AND METHODS

Study Area

The district of Ramanathapuram is an urban district in southern India in Tamil Nadu. The area of the district is 4123 km^2 and was populated in the 2011 census by 1,353,445 people. The district lies between $9^o05'$ and $9^o50'$ North Latitude and $78^o10'$ and 79^o 27' East Longitude. The Gulf of Mannar borders the south and the district of Thoothukudi to the west.

Ramanathapuram district comprises the Pamban Bridge, an eastern-west chain of elevated and medium coral islands extends between India and Sri Lanka, dividing Palk Straits from Mannar Gulf. Marine formation consists of varying proportions of coastal flat deposits of sand and clay. Marine hardpan calcareous occurs as small terraces and platforms, with admixture of quartz, limonite and garnet concentration.

RESULTS AND DISCUSSION

The results of the measured physicochemical parameter values with the cation and anion concentrations of groundwater collected in the month of January 2022 (winter) and April 2022 (summer) were given in Table 1 and 2.

Table 1: Physico - Chemical parameters of Groundwater collected in the month of January 2022 (winter)

Sample Station	EC	SO_4	HCO_3	Ca	Mg	Na	K	Cl

01	3010	81	246	120	65	82	2	750
02	4123	90	152	88	156	100	9	815
03	4401	714	341	112	125	62	30	818
04	467	413	915	45	35	25	1	467
05	2134	500	394	134	76	34	6	521
06	956	786	572	145	84	50	1	432
07	2987	251	765	98	43	65	20	710
08	3145	432	472	112	60	59	33	678
09	3941	101	362	100	151	57	29	943
10	2965	156	672	170	54	38	22	516
11	4145	412	258	115	20	100	2	698
12	1670	381	914	130	67	51	1	431
13	2119	48	194	107	59	49	2	601
14	678	63	261	154	67	30	ND	412
15	4513	104	302	90	75	87	1	843
16	3770	294	478	87	80	59	39	876
17	4510	429	295	167	167	93	ND	600
18	1478	281	623	95	30	41	2	543
19	3782	137	175	68	65	50	3	910
20	1519	269	472	76	76	21	14	439
21	3012	42	165	79	58	40	10	567
22	4981	301	283	120	78	79	7	943
23	4200	172	362	109	141	132	5	912
24	3519	283	426	61	59	43	ND	928
25	4091	72	111	105	91	67	15	865
26	911	345	392	50	75	119	12	200
27	1890	262	413	56	60	218	7	457
28	1986	73	267	81	87	221	38	503
29	534	69	245	58	69	12	6	345
30	1923	903	163	86	69	126	20	505

All the values are expressed in ppm expect EC (micromhocm^{-1})

Table 2: Physico - Chemical parameters of Groundwater collected in the month of April 2022 (summer)

Sample Station	EC	SO_4	HCO_3	Ca	Mg	Na	K	Cl
01	3744	94	213	80	29	73	3	700
02	5538	78	456	94	283	87	11	940
03	4788	1089	445	140	162	71	36	900
04	540	467	863	82	13	8	1	378
05	2924	410	399	138	62	42	8	599
06	1356	599	597	114	48	23	3	369
07	3948	312	654	110	45	59	26	815
08	3496	681	912	112	58	49	30	712
09	4758	145	345	144	101	65	30	980
10	3450	176	677	138	50	40	27	654

11	4790	465	456	88	7	86	1	789
12	1906	698	843	84	23	45	3	412
13	2540	55	121	92	14	55	1	604
14	780	69	319	136	36	22	ND	345
15	5324	110	250	126	42	75	1	998
16	3928	435	500	92	62	79	52	1002
17	3198	358	389	118	181	80	ND	550
18	1894	360	500	66	6	46	1	499
19	4508	42	234	72	66	68	4	985
20	1784	234	422	70	45	28	11	515
21	3468	62	267	76	72	46	9	621
22	3254	154	388	74	86	98	5	908
23	4190	167	245	96	194	139	8	895
24	4054	456	400	78	34	59	ND	765
25	3026	86	167	96	128	73	16	840
26	1010	345	445	26	43	122	10	213
27	2240	199	300	20	31	235	9	397
28	2610	68	323	52	106	278	47	502
29	540	41	278	28	41	13	7	295
30	2320	1000	231	90	57	144	22	456

All the values are expressed in ppm expect EC (micromhocm^{-1})

Hydrogeochemical facies analysis

Piper diagram

Water sampling analytical results plotted in the piper diagram. Pipers diagram includes construction of cation and anion triangles from the results obtained. The two data points from the cation and anion triangles are then combined into the quadrilateral field that shows the overall chemical property of the water sample. 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 mill equivalents per liter to evaluate the geochemical evolution**/** hydrochemistry of groundwater in the study area in the Piper trilinear diagram.

These diagrams reveal the analogies, dissimilarities and different types of waters in the study area, which are identified and listed in the concept of hydrochemical facies was developed in order to understand and identify the water composition in different classes [12].

Water types

A Piper diagram for the Ramanathapuram District using the analytical data obtained from the hydro geochemical facies analysis. In general, we can classify the sample points in the piper diagram based on anion and cation dominance. Within the Cation triangle A-Ca type, B-No Dominant type, C-Na and K type and D-Mg type. Within the anion triangle E-HCO3 type, F-Cl type, G-SO_4 type and H- No dominant type [13, 14].

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The January 2022 (Winter) groundwater quality, the cation triangle A represents Ca type water with the coverage of 10% area, C represents Na and K type of water of 3.3% area, D represents Mg type of water of 16.7% area while B represents no dominant ion type water with the coverage of 70% area. The Anion Triangle F represents Cl type of water of 76.7% area, G represents SO_4 type of water of 3.3% area, while H represents the 20% area belonging to no dominant ion type of water (Figure 1).

The April 2022 (summer) groundwater quality, A represents Ca type water with the coverage of 13.3% area, C represents Na and K type of water of 10% area, D represents Mg type of water of 20% area while B represents no dominant ion type water with the coverage of 56.7% area in cation triangle.

F represents Cl type of water of 70% area, G represents SO_4 type of water of 3.3% area, while H represents the 26.7% area belonging to no dominant ion type of water in anion triangle. 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.

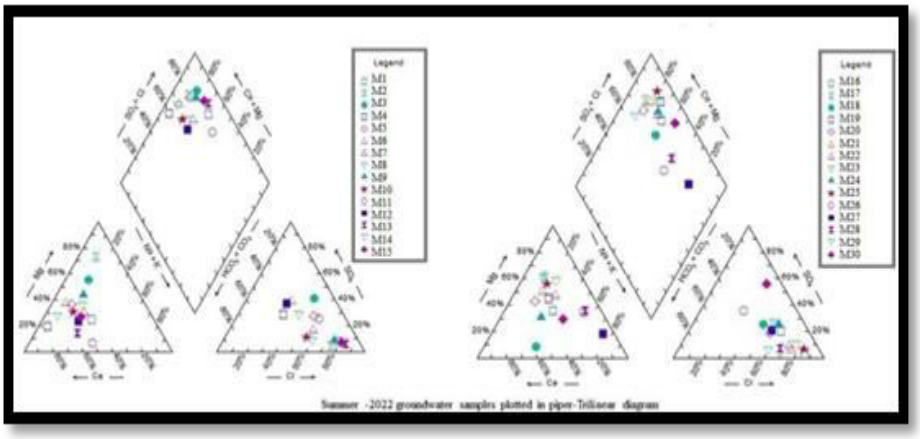

Figure 1

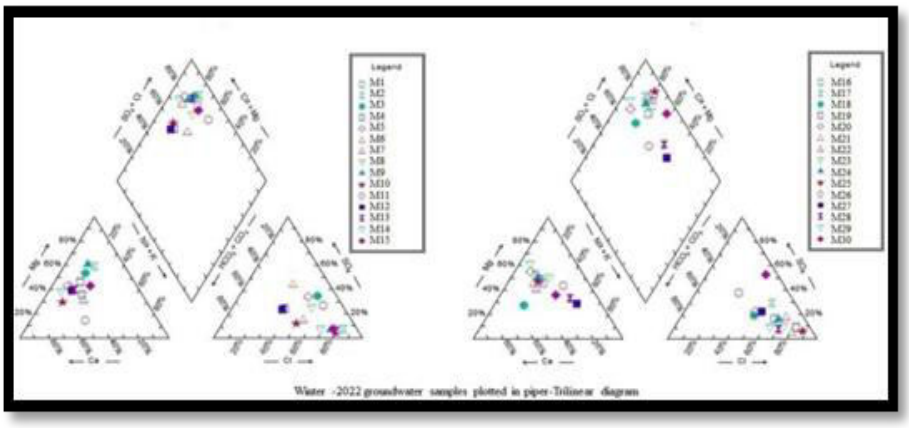

Figure 2

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WILCOX DIAGRAM

Percent Sodium vs. EC Plot (Na %)

Wilcox [15] plotted the percent Na value against the EC value to determine the suitability of groundwater for irrigation. According to his plot, he categorized groundwater as (1) excellent to good, (2) good to permissible, (3) permissible to doubtful, (4) doubtful to unsuitable, and (5) unsuitable.

Richards [16] modified the Wilcox diagram by including the SAR value as a sodium hazard and the EC value as a salt hazard and proposed the diagram as a USSL diagram for evaluating the quality of irrigation water.

He also classified the water quality as low, medium, high, and very high for sodium and salinity hazards with respect to the SAR and EC values. The January 2022 (Winter) groundwater quality (Figure 3) according to the USSL diagram was distributed as follows: 3 samples in S1C2 (low sodium–medium salinity), 3 samples in S1C3 (low sodium–high salinity), 1 samples in S1C4 (low sodium–very high salinity), 3 samples in S2C3 (medium sodium–high salinity) and 9 samples S2C4 (medium sodium–very high salinity), 2 samples S3C3 (high sodium– high salinity), 7 samples S3C4 (medium sodium–very high salinity) and 2 sample in S4C3 (very high sodium–high salinity). The April 2022 (summer) groundwater samples (Figure 4) fell into the S1C2 category (3 samples), followed by S1C3 (3 samples), S2C3 (3 samples), S2C4 (9 samples), S3C4 (7 samples), S4C3 (4 samples) and S4C4 (1 sample) for irrigation.

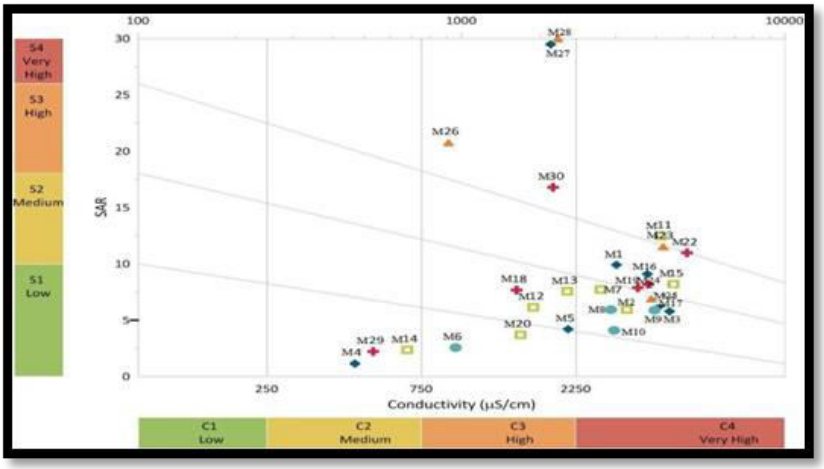

Figure 3

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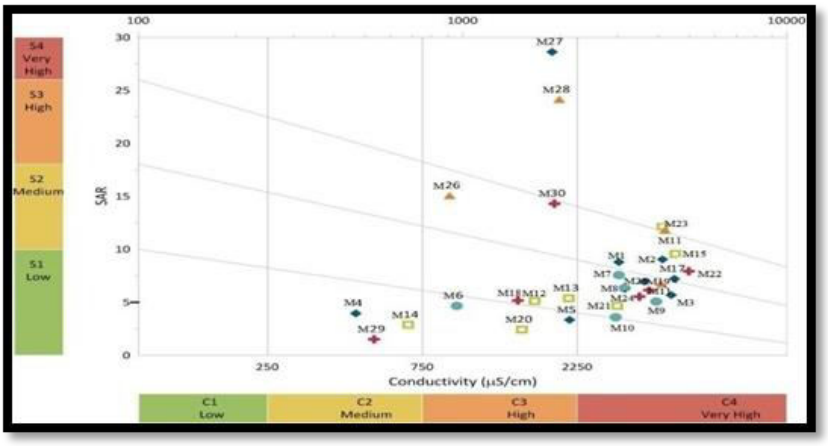

Figure 4

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 $CaCl_2$ 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 Na% versus EC an USSL diagram showed the quality of the irrigation of the water in the study area during both seasons. The study reveals that the investigation of hydrogeochemical process to approach the groundwater quality in and around Ramanathapuram District had the purpose of providing a simple, valid method for expressing the results of several parameters in order to assess the groundwater quality. 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 potability 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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