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Evaluation of groundwater quality and water quality index in the Palacode and Pennagaram Taluks, Dharmapuri district, Tamil Nadu, India

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Abstract
The aim of the present study is to assess the hydrogeochemical characteristics of groundwater in Palacode and Pennagaram taluk of Dharmapuri district, Tamil Nadu, India. In order to assess the groundwater quality, 158 groundwater samples were collected from bore well during monsoon and postmonsoon season in the year of 2013 and 2014. The groundwater samples were analyzed for different hydrogeochemical parameters such as pH, EC TDS,TH, Ca, Mg, Na, K, Cl, HCO_3, F, SO_4, PO_4, and H_4SIO_4 using standard procedure. The analytical result reveals that the physical parameters of TH (Total Hardness) EC (Electrical Conductivity), TDS and chemical parameters Na, K, Cl, F, showed the above permissible limit of WHO standards. Whereas pH, Ca, Mg, SO_4, H_4SiO_4 showed the below permissible limit. Based on the water quality index 8.9% of groundwater samples representing monsoon season exhibits "excellent water" 77.2% as good water, 13.9% as poor water whereas during post monsoon season 10.1% of samples represent "excellent quality" 72.2% of good quality water, 15% of poor water, 1.3% as very poor water quality and 1.3% as unsuitable for drinking purpose. On the basis of Sodium Adsorption Ratio (SAR) results with the values ranging from 0.6 to 3.9meq/l representing 77.3% of the monsoon season samples are suitable for irrigation purpose and in the post monsoon 85% of samples it ranges from 0.4 to 5.3 meq/l representing suitability for irrigation purpose.

Keywords: Water quality, groundwater, WQI, hydrogeochemical, Palacode

Introduction
Groundwater is considered as the major source of usable water, so that quality of water is the key factor in sustainable management of groundwater. In the previous couple of decades, reports of ground water defilement have expanded open worry about ground water quality [1]. Groundwater in shallow aquifer is a major source for drinking and irrigation water. Pollution of groundwater resulting from natural composition of aquifer material or from human activities reduces the supply of safe drinking water, posing a threat to public health and thereby a great challenge to water managers and policy makers. The groundwater pollution in different countries was mainly due to lack of proper waste management [2]. In this method the weightage for various water quality parameters is assumed to be inversely proportional to the recommended standards for the corresponding parameters [3]. The quality is a function of the physical, chemical 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. Water can be regarded polluted when it changes its quality or composition either naturally or as a result of human activities [4]. Thus, becoming less suitable for drinking, domestic, agricultural, industrial and recreational purposes.
Water quality record (WQI) is important and elite rating to delineate the general water quality status in a solitary term that is useful for choosing reasonable treatment strategy to meet the restless issues. Though, water quality record delineates the composite influence of various water quality parameters and imparts water quality data to the public and legislative decision makers. Ground water quality is a significant characteristic of water resource issue due to rapid increase in population and industrial development. Groundwater quality assessment through various graphical methods and interpreted different indices were attempted by many workers in the recent past [5, 6, 7, 8].

In this study, a simple methodology based on multivariate analysis is developed to create a groundwater quality index (GWQI), with the aim of identifying places with best quality for drinking within the study area.

Study area

The study area lies between the latitudes $12^{0}30'0''$ N to $11^{0}53'43''$ N and longitudes of $77^{0}40'0''$E to $78^{0}17'30''$E (fig: 1) and located at north western part of Tamil Nadu. Palacode and Pennagarm, are Taluks of the Dharmapuri district. Rainfall is the main source of groundwater recharge in this area. Groundwater is the only source for both irrigation and domestic purposes. Dug wells and bore wells are the most common groundwater abstraction structure. Geologically, the area is underlain by a wide range of Charnockite, Granitoid gneiss, Pinkmigmatite and Epidote of Archaean age. As the review range is underlain by the archaean crystalline rocks, groundwater happen in the broken rocks. The soil type in the study mostly covered haplustalfs to ustorthents. Chinnar River is the important tributaries of river Cauvery.

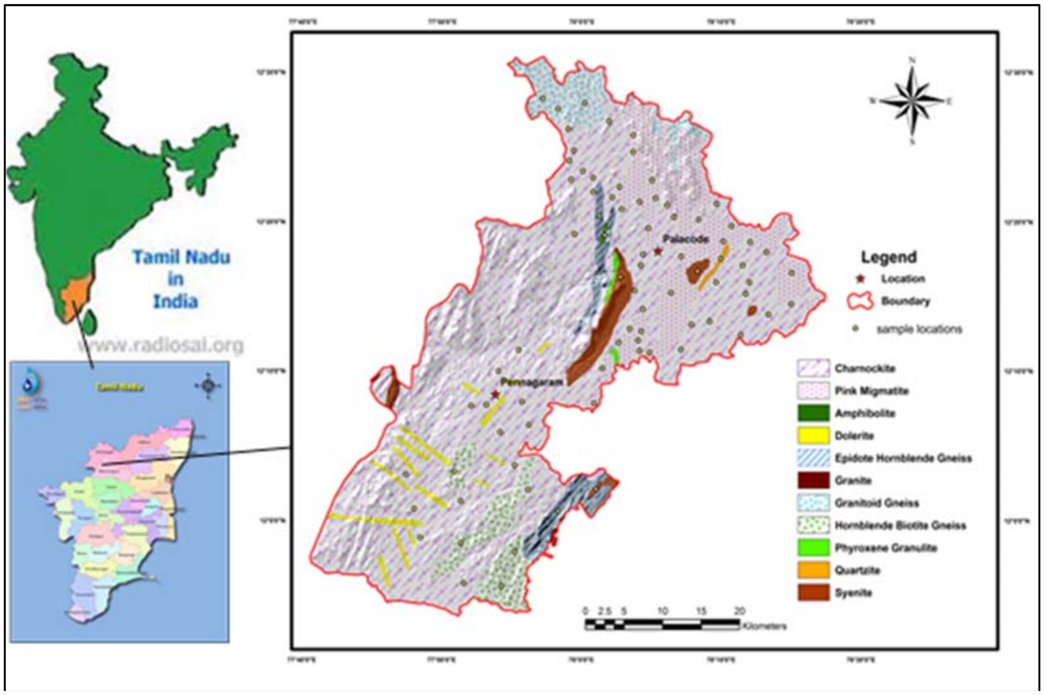

Fig 1: Geology and Sample location of the Study area

Materials and Methods

A Total of 158 Groundwater Samples were collected from bore wells representing Monsoon (MON) and Postmonsoon (POM) season during 2013 and 2014. Each sample was gathered in acid washed polyethylene bottles. The water samples collected in the field were analyzed for electrical conductivity (EC), pH, total dissolved solids (TDS), Major cations and Anions by using the standard procedures [9]. The samples collected were analyzed for major cations and anions like, Ca, Mg, Cl, HCO_3 by titrimetry, Na, K analysed by flamephotometer (CL378); and SO_4 analyzed by Spectrophotometer (UV- 1800). The secondary parameters of irrigation groundwater quality indices such as Sodium Adsorption Ratio (SAR), Sodium Soluble Percentage (SSP), Sodium Percentage (Na%) and Salinity hazard, were also derived from the primary parameter for irrigation water quality, Water Quality Index (WQI) for drinking purpose were arrived through relative weight of chemical parameters.

Result and Discussion

The physical and chemical parameters concentrations of water from various locations in two different seasons of the study area are given in tables 1.

Physical parameters

pH in ground water is an imperative parameter, because it pedals many chemical and biological processes that occur in the water. The measured pH in the study area ranges from 6.6 to 7.6 and 7.0 to 8.3 during MON and the POM respectively and are mostly alkaline in nature. pH can be used as a substitute of water quality conditions, since water pH is easily changed by chemical pollution. The EC values ranges from 653.2 to 3815µS/cm during Monsoon and in Postmonsoon it varies from are 613.6 to 5088.0µS/cm.

EC indicated increasing pattern along the groundwater flow direction.

The Total Hardness is an imperative parameter of water quality whether it is utilized for local, industrial or farming reason. Total hardness varies from 149.0 to 536.5mg/l in Monsoon and in Postmonsoon it ranges from 214.0 to 716.5mg/l, as $CaCO_3$. Total hardness mainly a reflect the major ions, e.g, Ca, Mg, CO_3 and HCO_3, being present in the water. These ions enter the ground water by leaching from minerals like Calcite, Gypsum and Dolomite [10]. Ground water hardness is defined as the content of metallic ions, primarily Ca, Mg that react with sodium soaps to form ‘soap curd’ or that react with negative ions to form a scaly crust on pipe surfaces [11].

Chemical Parameters

Cations

Calcium is an abundant constituent in the waters that is associated with Calcite, Dolomite and Gypsum. Shale and other deposits usually contain calcium carbonate as cementing material. Calcium is also present in the form of adsorbed ions on negatively charged minerals in the surface soil and rocks. The calcium content of the groundwater samples ranges from 36 mg/l to 140 mg/l during MON and in POM it varies from 41 mg/l to 164 mg/l. similarly almost all the samples of each season also show within permissible limit. Magnesium is the most abundant elements in the natural surface and groundwater content and is varying from 2.4 to 52.8

mg/l during MON and in POM seasons it ranges from 27 to 93 mg/l. The maximum permissible limit of Mg Concentration of drinking water is specified as 150 mg/l [12].

Sodium is one of the dominant cations in ground water, with a concentration value ranges from 30.4 to 144.1 mg/l during MON and in POM seasons it varies from 27.7 to 319.2 mg/l. Potassium absorption in ground water ranges from 1.2 to 165.2 mg/l in MON and in POM seasons it ranges from 6.1 to 355 mg/l in the ground water for study area. The high sodium water may produce destructive levels of exchangeable sodium in most of the soil. The sodium concentrations in Monsoon and Post monsoon ground water samples show almost same level. The increasing sodium content in ground water is likely due to leaching of soaps and fertilizers from agriculture area. The source of potassium is likely due to weathering of feldspar and clay minerals from aquifer matrix [13]. The main reason for increased of potassium into groundwater is due to agricultural activities, and most of the ground water samples of the study area are under permissible limit.

Anions

It is noteworthy that bicarbonates ions produce alkalinity. Alkalinity is therefore a reliable measure of bicarbonate for most natural water. The Concentrations of bicarbonate vary from 195.2 to 463.6 mg/l during MON and in POM it ranges from 127.7 to 562.7 mg/l. It is clear that there is greater variation in the bicarbonate contents of the groundwater during Postmonsoon indicating variation in pH values fig 2.

Chloride concentration in groundwater vary from 44.3 to 351.4 mg/l during MON and in POM it ranges from 138 to 562.7 mg/l. In the study area 100% of samples were within the maximum permissible limit of 600 mg/l [12]. Also leaching of chlorine from acid igneous rocks cause variation of the Cl concentration. Chloride ion has a direct toxic effect on some plants and also contributing to the salinity of the soil.

Fluoride concentration in groundwater vary from 0.1 to 1.6 mg/l during MON and in POM it ranges from 0.2 to 2.6 mg/l because of draining of fluoride rich minerals like Biotite from rocks like Charnockite, Calc and Granulite metamorphic rock and that they are dominantly gift within the study area [14]. The fluoride content of ground water varies greatly depending on the geological settings and type of rocks. Dissolution of evaporative salts deposited in arid zone may be an important source of fluoride [15]. The WHO guideline value for fluoride in drinking water is 1.5 mg/l. Above 1.5 mg/l mottling of teeth may occur to an objectionable degree. In the study area it ranges from 0.1 to 1.6 mg/l and 0.2 to 2.6 in MON and POM respectively.

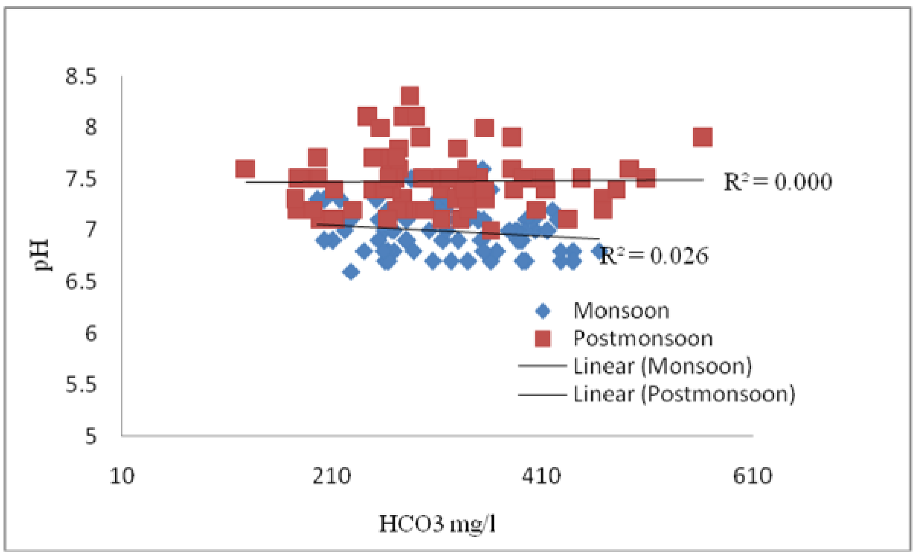

Fig 2: R factor Correlation of pH vs HCO_3

The sulphate ion causes no particular harmful effects to soil or plants; however, it contributes increase of salinity in the soil solution. Sulphate is one of the major anion, with a concentration varying between 11.1 to 134.5 mg/l during MON and in POM it ranges from 11.7 to 172.8 mg/l. Sulphate reacts with human organs, if the value exceeds the maximum allowable limit of 400 mg/l causes a laxative effect on human system with the excess magnesium in ground water.

Table1: The physical and chemical parameters concentrations in Study area all values in mg/l except pH and EC µs/cm

	MONSOON			POSTMONSOON			WHO (2011)	
	Min	Max	Mean	Min	Max	Mean	Desirable	Permissible
pH	6.6	7.6	7.0	7.0	8.3	7.5	6.5	8.5
EC	653.2	3815.0	1728.5	613.6	5088.0	1879.7	500	1500
TDS	338.7	1981.0	899.6	327.5	3382.0	989.1	500	1500
TH	149.0	536.5	286.6	214.0	716.5	468.2	100	500
Ca	36.0	140.0	85.7	41.0	164.0	95.4	75	200
Mg	2.4	52.8	18.1	27.0	93.0	56.8	30	150
Na	30.4	144.1	79.7	27.7	319.2	90.2	50	200
K	1.2	165.2	20.6	6.1	355.0	38.9	10	12
Cl	44.3	351.4	173.9	138.0	759.1	363.9	250	600
HCO_3	195.2	463.6	323.0	127.7	562.7	310.1	200	500
F	0.1	1.6	0.5	0.2	2.6	0.9	-	1.5
SO_4	11.1	134.5	38.1	11.7	172.8	32.7	250	400
PO_4	12.1	121.8	25.2	0.1	38.1	3.3	10	20
H_4SIO_4	21.0	61.5	41.5	27.0	67.6	43.5	50	100

Groundwater quality Parameters

Water quality index for drinking purpose

The 'WQI' has been calculated to evaluate the suitability of groundwater quality of the Study area for drinking purposes. The WHO standards for drinking purposes have been considered for the calculation of WQI. For computing WQI three steps are followed. In the first, each of the 14 parameters (pH, EC TDS, TH, Ca, Mg, Na, K, Cl, HCO_3, F, SO_4, PO_4, H_4SIO_4) has been assigned a weight (wi) as per its relative significance in the general nature of water for drinking purposes (table - 2).

The most extreme weight of 5 has been relegated to the parameters like, total dissolved solids, chloride, fluoride, and sulfate because of their significant significance in water quality evaluation [16, 13]. Bicarbonate and Phosphate is given the base weight of 1 as it assumes an inconsequential part in the water quality evaluation.

Table 2: Relative weight of Chemical Parameter

Parameter	Monsoon			Post monsoon	
	Weight (w_i)	Relative Weight $W_i = \frac{w_i}{\sum_{i=1}^{n} w_i}$	WHO	Weight (w_i)	Relative Weight $W_i = \frac{w_i}{\sum_{i=1}^{n} w_i}$
pH	3	0.070	8.5	2	0.044
EC	4	0.093	1500	3	0.067
TDS	5	0.116	1500	5	0.111
TH	2	0.047	500	4	0.089
Ca	2	0.047	200	2	0.044
Mg	2	0.047	150	2	0.044
Na	2	0.047	200	3	0.067
K	3	0.070	12	4	0.089
Cl	5	0.116	600	5	0.111
F	5	0.116	1.5	5	0.111
HCO_3	1	0.023	500	1	0.022
SO_4	5	0.116	100	5	0.111
PO_4	1	0.023	20	1	0.022
H_4SIO_4	3	0.070	100	3	0.067
	$\sum w_i = 43$			$\sum w_i = 45$	

Different parameters like calcium, magnesium, sodium, and potassium were assigned weight in the vicinity of 1 and 5 relying upon their significance in water quality assurance. In the second step, the relative weight (Wi) is processed starting the going with condition:

$$W_i = \frac{W_i}{\sum_{i=1}^{n} W_i}$$

Where

W_i = relative weight,

w_i = weight of each parameter,

n = number of parameters.

Computed relative weight (Wi) estimations of all parameter are given table 3. In the third step, a quality rating scale (qi) for every parameter is relegated by isolating its fixation in each water tests by its individual standard as indicated by the rules set down in the WHO 2011 and the outcomes is multiplied by100:

$$Q_i = \frac{Ci}{Si} \times 100$$

q_i is the greatness rating, C_i is the convergence of every chemical parameter in each water test in milligrams per liter Si is the Indian drinking water standard for every chemical parameter in milligrams per liter as indicated by the rules of the WHO.

For registering the WQI, the SI is initially determined for every chemical parameter, which is then used to decide the WQI according to the accompanying condition

$$SI_i = Wi \times Qi$$

$$WQI = \sum SI_i$$

Where

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

qi is the ranking based on attentiveness of i^{th} parameter

n is the number of parameters

Water quality type, were resolved and the comparing values falls between 37.94 to 298 and 41 to 291 for MON and POM individually. The WQI range and type of water can be confidential in table - 3:

Table 3: WQI ranges, number of samples and percentage

Range	Type of water	No of samples		Percentage of samples	
		MON	POM	MON	POM
< 50	Excellent water	7	8	8.9	10.1
50 – 100	Good water	61	57	77.2	72.2
100 - 200	Poor water	11	12	13.9	15.1
200 - 300	Very poor water	0	1		1.3
>300	Water unsuitable for drinking Purposes	0	1		1.3

Computation of Water quality Index for samples is represented in table 3. During Monsoon, 8.9% of groundwater samples represent "excellent water", 77.2% indicate "good water", 13.9% shows "poor water". During Postmonsoon, 10.1% of samples represent "excellent quality" 72.2% of samples are good quality water", 15.1% shows Poor water", 1.3% very poor water and another 1.3% samples represent water inappropriate for drinking purposes. The post monsoon samples shows poor quality in greater entitlement when compared with monsoon. This might be because of viable draining of ions, over utilization of groundwater, direct expulsion of effluents, and agricultural effect [17, 13]. The water quality index was tested with chloride and EC selected as pollution indicators. The experiential high values of chloride and EC relate to the same WQI, showing the low quality of groundwater in the study region.

Water quality for irrigation function

Sodium Adsorption Ratio (SAR)

SAR and Electrical Conductivity (EC) similarly used to approximation irrigation water quality. The sodium adsorption (SAR) optional by the salinity laboratory of the United States (US) Department of Agriculture [18] is calculated utilizing the formula;

$$SAR = \frac{Na}{\sqrt{Ca + Mg/2}}$$

SAR values >2 assign groundwater is unseemly for agriculture purposes. During monsoon, SAR was varies from 0.6 to 3.9 meq/l demonstrating 77.3% of water samples are suitable for irrigation purposes. In postmonsoon it ranges from 0.4 to 5.3 meq/l representing 83.5% of the samples are appropriate for irrigation purposes.

Soluble sodium Percentage (SSP)

Wilcox has proposed classification scheme for rating irrigation water on the basis of soluble sodium percentage (SSP) [18]. The SSP was calculating by

$$SSP = \frac{Na \times 100}{Ca + Mg + Na}$$

Where, the concentrations of ions are expressed in meq/l. The values of SSP less than 50 indicate good quality of water and higher values (i.e.> 50) show that the water is unsafe for irrigation [19]. Majority of the groundwater samples have SSP values greater than 50, which can be designated as unsuitable for irrigation. During Monsoon, SSP was observed, and 87.4% of samples were within Good quality. In postmonsoon, observed SSP was, and 79.8% and exhibits they are suitable for irrigation purposes.

Sodium percent (Na%)

The Na in irrigation waters is as often as possible indicated as percent of sodium. As per Wilcox (1955), in every common water Na% is a general parameter to assess its reasonableness for irrigational purposes. The sodium percent (Na%) qualities were acquired by using the associated with condition

$$Na\% = Na \times 100 / [Ca + Mg + Na + K]$$

where each ionic fixations are communicated in meq/l. The Wilcox illustration concerning sodium percent and whole concentration shows that 11.2% of the subsurface water samples fall in the field of very good to good and 52.9% of the groundwater samples fall in the field of good to permissible for irrigation, 25.3% of the samples descend in the meadow of doubtful to unsuitable, and 7.5% samples descend in the unsuitable and 3.7% of samples plunge in the permissible to doubtful class (Fig.3) during monsoon.

In postmonsoon season the sodium percent and total concentration shows that 6.4% of the groundwater samples fall in the field of very good to good and 64.4% of the groundwater samples fall in the field of good to permissible for irrigation, 24% of the samples fall in the field of doubtful to unsuitable, and 2.6% samples fall in the unsuitable, 2.6% of samples fall in the permissible to doubtful category.

Groundwater in the study territory is being researched for conceivable use for irrigation activities to supplement rain bolstered agricultural activities. In Fig.4, the US salinity laboratory arrangement shows in order to 3.8% of the groundwater samples fall in C_1S_1 (low salinity–low sodium sort) and 5.1% of the samples fall in the C_2S_1 class[20]. This uncovers the water sort in the study zone has medium salinity with low sodium substance and it can be utilized for water system on all kind of soil. Around 83.5% of the groundwater tests fall in the C3S1, demonstrating high saltiness low sodium sort, after that 7.6% falls in the high saltiness to low sodium classification (C_4S_1) amid MON season. In POM 3.8% of the groundwater tests fall in C_2S_1 (medium salinity–low sodium sort) and 73.5% of the examples fall in the C3S1 classification. Just 17.7% falls in the very high salinity to low sodium class (C_4S_1). This type of water can be used to irrigate salt forbearing and semi forbearing crops beneath sympathetic drainage state and 3.8% of the samples fall in the C_4S_2 category. Only 1.2% falls in the high salinity to medium sodium category (C_3S_2).

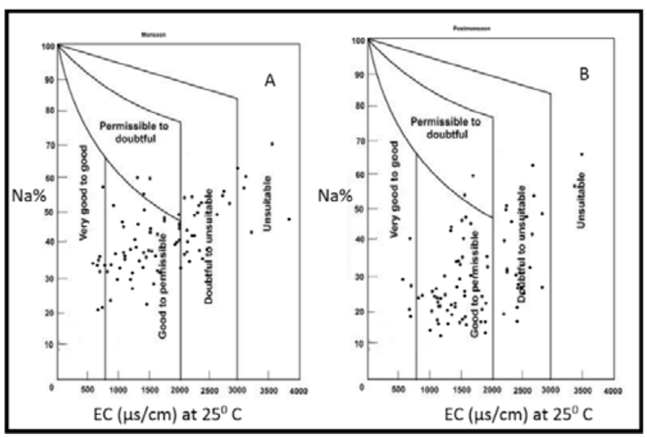

Fig 3: The Wilcox diagram relating sodium percent and EC

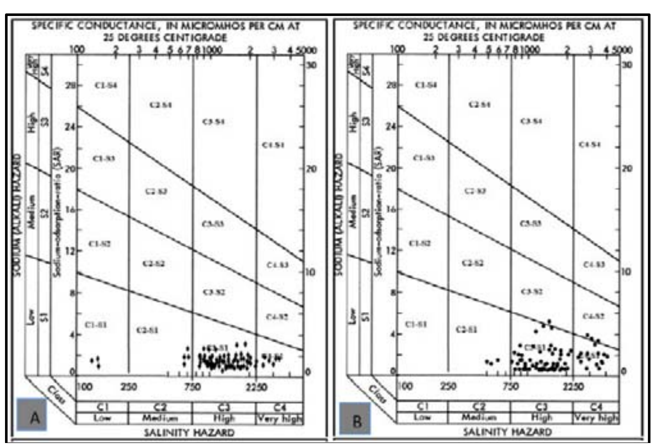

Fig 4: Salinity hazard diagram

Conclusion

This paper discussed about ground water quality of two taluk (Pennagaram & Palacode) which is located in Dharmapuri district of Tamil Nadu, India. Based on the hydrogeochemical results the physiochemical parameters TH (Total Hardness), EC (Electrical Conductivity), TDS and chemical parameters Na, K, Cl, F, showed the above permissible limit of WHO standards. Water quality index of groundwater samples representing 8.9% during monsoon season exhibits "excellent water", whereas during postmonsoon, season 10.1% of samples represent "excellent quality". Sodium percentage results showed that during postmonsoon season sodium percent and aggregate focus demonstrates that 6.4% of the groundwater samples fall in the field of very good to good, 64.4% of the groundwater samples fall in the field of good to permissible for irrigation, followed by doubtful to unsuitable and monsoon season showed that good to very good followed by doubtful to unsuitable. Wilcox diagram suggests that that the groundwater samples were fall in high salinity low sodium type followed by very high salinity to low sodium category (C_4S_1) during monsoon season and in post monsoon season most of the samples were fall in C_3S_1(high sodium- low salinity) followed by very high salinity to low sodium category (C_4S_1). The quality of groundwater were compared with WHO standards and suggested that the most of ground water samples are suitable for irrigation purposes but not for drinking. alarming situation of groundwater quality for inhabitants. Therefore, a great awareness should be given in order to reduce the avulsion in groundwater quality in the study area.

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