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Appraisal of the Quality Parameters of the Groundwater used for Domestic and Irrigation Purposes in the Hard Rock Aquifer System of the Vasishta sub- basin of the Vellar River, Tamil Nadu

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Abstract. This article presents an appraisal of the quality of groundwater in the hard rock aquifer system of the Vasishta sub basin, of the Vellar River Basin. Seventy nine representative groundwater samples were collected from dug and bore wells which are intensively used for domestic and irrigational purposes. The physical parameters viz. P^H , EC and TDS were estimated in the field using a portable multiparameter meter. The groundwater samples were transported to the laboratory for measuring major ionic concentrations viz. Ca, Mg, Na, K, CO_3 , HCO_3 , Cl, SO_4 , F and NO_3 . The hydrochemical data were graphically projected and spatial temporal thematic maps generated with reference to the World Health Organization (WHO) and Bureau of Indian (BIS) Standards. The peoples living in the sub basin engage in agricultural activities where the groundwater availability is sufficient. The groundwater is a major source for meeting their basic needs, such as for domestic, irrigational and industrial purposes. Good correlation is exhibited between EC and TDS. Cl, SO_4 . Cl exhibits good correlation with Mg and Ca (0.817), (0.751) indicating leaching of secondary salts. TDS and EC showed strong correlation with Cl, SO_4 . Clustering groundwater samples based on their similarity is known as Q-mode type clustering method. Spatial and temporal maps of the water quality index reveal that the majority of the groundwater samples fall under the categories excellent to good.

Keywords: groundwater quality, Vasishta sub basin, domestic and irrigational purposes, multiparameter, major ionic concentration, WHO and BIS Standard, Correlation matrix.

Оцінка параметрів якості підземних вод для побутових та іригаційних цілей у системі водоносних горизонтів твердих порід (Хард рок) суббасейну Васишта, річка Веллар Таміл Наду

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Анотація. Для даного дослідження було розглянуто оцінку якості підземних вод у системі водоносного шару твердих порід суббасейну Васишта, річка Веллар. Сімдесят дев'ять проб підземних вод були зібрані з викопаних і бурових свердловин, які інтенсивно використовуються для побутових і іригаційних цілей. Фізичні параметри: P^H , EC та TDS, оцінені в польових умовах за допомогою портативного мультипараметра. Зразки підземних вод транспортували до лабораторії для оцінки основних концентрацій іонів, зокрема Ca, Mg, Na, K, CO_3 , HCO_3 , Cl, SO_4 , F та NO_3 . Результати гідрохімічних досліджень графічно спроектовані та просторово-часові тематичні карти, сформовані з посиланням на Світову організацію охорони здоров'я (ВООЗ) та Бюро індійських стандартів (BIS). Люди, які живуть у підбасейні, займаються сільським господарством там, де достатньо підземних вод, підземні води є основним джерелом для задоволення основних потреб, таких як побутові, зрошувальні та промислові. Хороша кореляція виявляється між EC та TDS, Cl, SO_4 . Cl демонструє хорошу кореляцію з Mg та Ca (0,817), (0,751), що свідчить про вимивання вторинних солей. TDS та EC показали сильну кореляцію з Cl, SO_4 . Кластеризація зразків підземних вод на основі їх подібності відома як метод кластеризації типу Q-mode. Просторові часові карти індексу якості води показують, що більшість проб підземних вод підпадають під категорії від відмінної до хорошої.

Ключові слова: якість підземних вод, суббасейн Васишта, побутові та іригаційні цілі, мультипараметр, основна іонна концентрація, стандарт ВООЗ та Бюро індійських стандартів, кореляційна матриця.

Introduction.

Water is often considered to be one of the most important resources of our planet. It is the most abundant physical substance and transparent liquid on the earth.

Groundwater is the largest obtainable resource for fresh water. Ground water is commonly referred as water which lies below the surface of the earth occupying the interstices and voids in various formations (Todd,

1980). It is the major readily available source of fresh water on our earth (Ragunath, 1987). Nowadays ground water resources are being continuously exploited from the aquifers to meet industrial, agricultural and domestic needs. Rapid urbanization, industrialization, frequent failures in the monsoon and reduced surface water resources have created a major threat to the groundwater resource in terms of quantity and quality. Groundwater is always an underwater movement and the flow takes place from the higher potentiometric surface to the lower potentiometric surface. Groundwater geochemistry is a forensic tool which helps to understand the possible processes that control groundwater chemistry as well as helping with planning for efficient water management (Subramani *et al.* 2010). Therefore chemical fluxes in groundwater environment indicate the dynamic movement and prolonged hydrochemical interactions (Bernard *et al.* 2006). Sreedevi *et al.* (2001) have used the remote sensing and GIS techniques to understand the occurrence of groundwater in various geomorphological units of the study area. Water resources play a vital role in the growth and development of human civilization on the surface of the earth and play a key role in the economy of any country. Ground water resources in the Vasishta sub-basin, Tamil Nadu, India are being continuously exploited to meet the demand for the water supply and irrigation because the water available in surface water bodies such as wells, tanks and reservoirs is not sufficient, and thus the resulting rapid decline in the ground water head in many areas. Groundwater quality is also affected in many places of the sub-basin due to anthropogenic activities. In hard rock terrain

with arid and semi-arid climatic conditions, all the water requirements are met by sub-surface water due to reduction in surface water resources. Changing climatic conditions, growing population, industrialization, and intensive agricultural and urbanization activities have led to a high demand for groundwater especially in countries experiencing economic growth like India (Srinivasamoorthy *et al.* 2011). However, no systematic work has been carried out in this sub-basin to understand the ground water regime. Thus, it is essential to assess the ground water quality for extraction and management of the water resources, which is emerging as a great public concern in this region.

Study Area. The Vasishta sub-basin of the Vellar River Basin, in Tamilnadu covers in total an area of 1770.78 km². The Vasishta is a major stream river originating from the southern slope of the Kalrayan Hills and flows through Kurichi, Belur, Pethanaikenpalaiyam, Attur, Thalaivasal and Aragalur, habitations of Salem and Perambalur districts of Tamilnadu. Major and minor artificial recharge structures, constructed across the streams significantly contribute to groundwater recharge in the sub basin. Irrigation mainly depends upon the groundwater resources from dug and bore wells. Groundwater is the main source of water for agricultural activities and is pumped through dug and bore wells. (Poongodi and Venkateswarn 2018). The important plants cultivated are finger millet, jasmine, cucumbers, maize, groundnuts, celosia, betel trees, tapioca tubers, cotton grass, sugar cane, turmeric, coconuts, bananas and areca nut. The base map of the study area is given in Fig.1

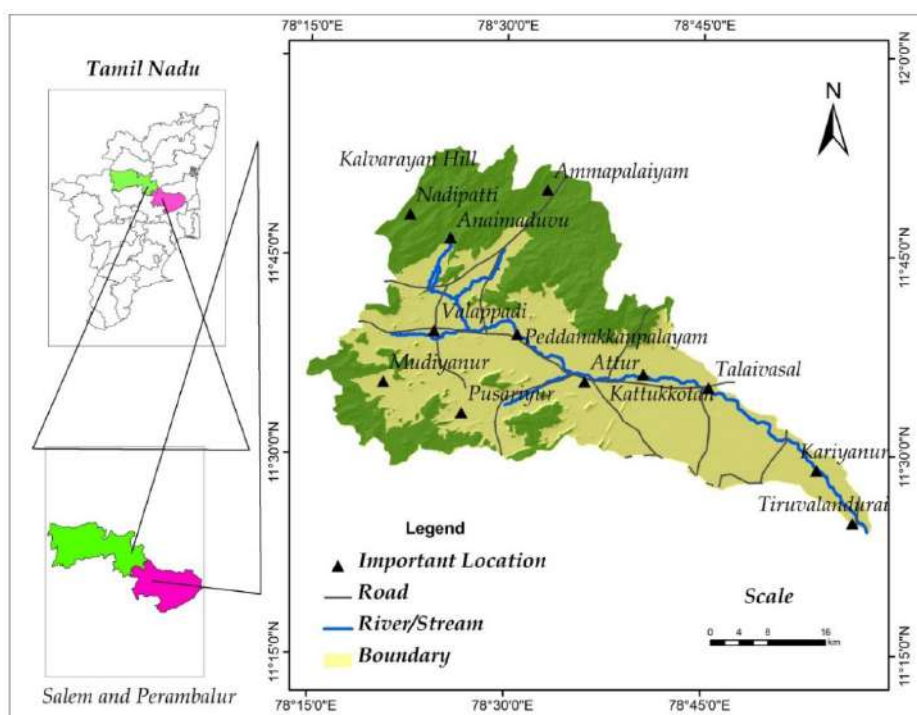


Fig.1. Base map of the Vasishta sub basin

Geology and hydrogeological settings. The Vasistha sub-basin is mainly underlain by crystalline rocks of Archean age, of gneissic rocks, charnockite, pyroxenite, amphibole pyroxene granulite and mylonite respectively. The geomorphological units are structural hills and pediplain denudation hills/pediments and floodplain. The structural hill is located in the northwestern parts of the study area whereas the southwestern and eastern parts of the study area are occupied by gently undulating and dotted relic isolated hillocks underlain by a hard rock crystalline aquifers system and groundwater phreatic condition. The occurrence and movements of groundwater through weathered zones is followed by occurrence of fissures, joints and fractures. The availability of groundwater in the sub-basin is greater in the river courses of paleochannels, foothills of the Kalrayan Hills, Bothumalai, and Sitheri Hills.

Materials and Methods.

A total of 79 groundwater samples was systematically collected from sources intensively

utilized by farmers. Physical parameters such as colour, odour, taste, turbidity, P^H and EC were estimated in the field itself. The samples were sent to the laboratory for further ionic concentration analysis. The ionic concentration was estimated using titration method, spectrophotometer and flame photometer. Shown in Fig.2.

Standardization of analytical data. The hydrochemical data were standardized graphically as shown in Fig. 3. It shows the total sum of cations versus the total sum of anions for groundwater samples, it also indicates all the samples on or near the aquiline in the graph. The quality of the analysis was documented by standardization using blank, spike, and duplicate water samples.

The hydrochemical data have been projected graphically using Piper's, Wilcox's, Donnen's and Gibb's plots for understanding the suitability of water for domestic irrigation and industrial purposes. A set up of spatio-temporal maps have been generated in the GIS platform with reference to the WHO and BIS Standards.

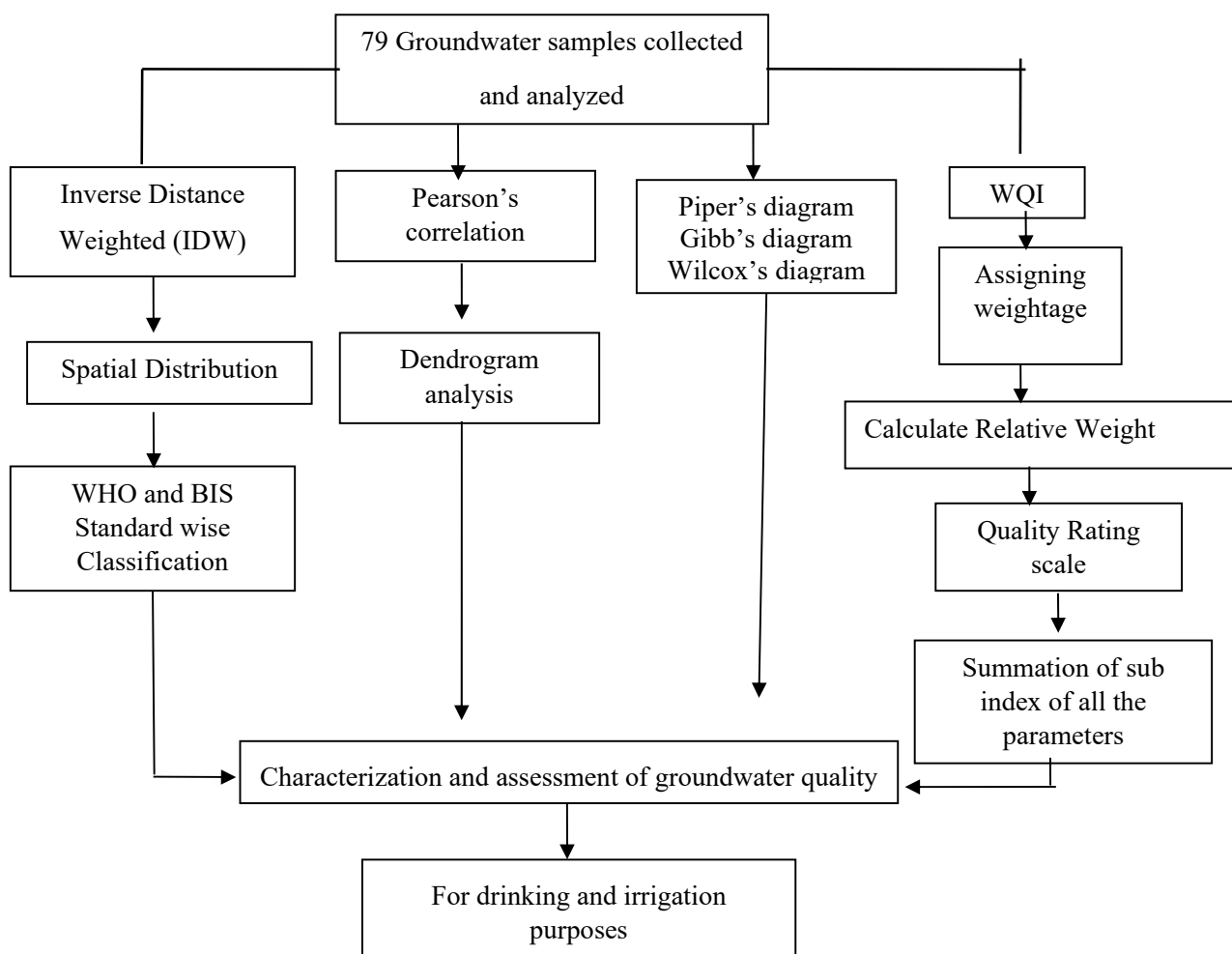


Fig. 2. Flow chart for the Methodology

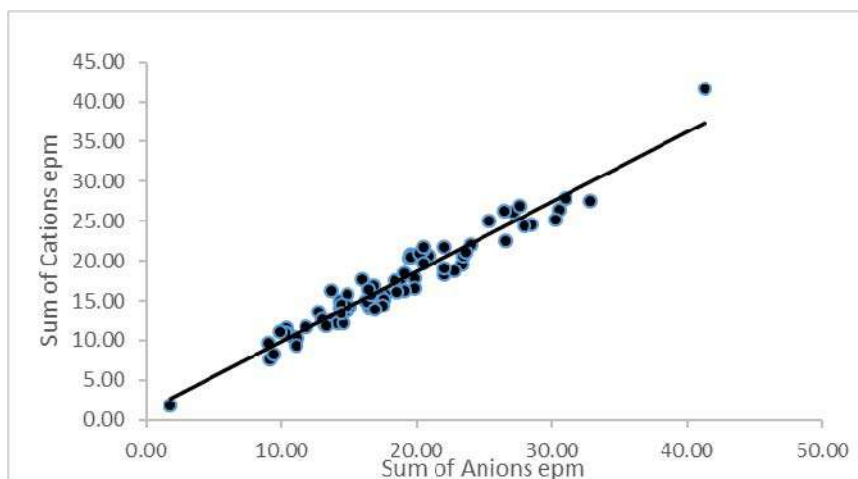


Fig. 3. Correlation co-efficient between total concentration of Cation epm and total concentration of Anion epm

Result and Discussion.

Water quality appraisal. The WHO standard was followed for the physical and chemical parameters for the groundwater samples of the study area. It was found that P^H limit varies from 6.74 to 8.41, which indicates that groundwater is acidic, alkaline, and 5 % to 95 % of the groundwater sample is of potable category, the P^H value within the maximum falls within the permissible category. *The groundwater through the quantity of transmitting electrical current.* WHO limit in EC 1500 $\mu\text{S}/\text{cm}^2$, The values varied from 190 $\mu\text{S}/\text{cm}^2$, to 5130 $\mu\text{S}/\text{cm}^2$. The high values of indicators of a huge quantity of salt occur in groundwater. 22 samples show a low amount of salt. Other samples covered high electric conductivity. TDS ranges between 373.52 mg/l to 4669 mg/l. The TDS varied from 124 to 3335 mg/l, which indicates rock water interaction in relation to groundwater, the TDS depending upon variation process such as domestic sewage and agricultural activities, The most common source of calcium and magnesium in groundwater concentration of Ca value varied from 16 to 281 mg/l. 96 % of the sample was of allowable category, 4 % of the sample only was not of potable category, Mg content value varied from 7 to 153 mg/l, 94 % of the sample was of potable category, 6 % of the sample was not of potable category. The Na values varied from 10 mg/l to 360 mg/l. It values Most of the samples (96 %) were of potable category, 4 % of the samples were not potable, K value varied from 0.5 to 43.9 mg/l .57 % of the samples were of allowable category, 32 % of the groundwater samples were not of potable category. WHO limit 200 mg/l of CO_3 HCO_3 , The values varied from 50 mg/l to 622.4 mg/l. The chloride range was 25 mg/l to 1110. The most desirable was 250 mg/l. This is explained by the drainage system and polluting environments of the study area. The sulfate range was from 10 mg/l to 380 mg/l. All

samples were within the WHO allowable limit. Nitrogen ions contaminating subsurface endogenic activities originated in agricultural sources. The values varied from 1.5 mg/l to 18 mg/l. This groundwater samples of this study area all within desirable limits. Major ions were as follows in abundance; $\text{Ca} > \text{K} > \text{Mg} > \text{Na}$ and $\text{CO}_3 > \text{Cl} > \text{SO}_4 > \text{HCO}_3 > \text{NO}_3$ respectively. Multivariate statistical analyses display good correlation. Quality of groundwater for drinking purposes based on WHO and BIS standards are given in Table.2.

Water quality Index (WQI) for domestic purposes. Water Quality Index (WQI) has been utilized as a tool to assess the spatial and temporal changes in the quality of groundwater and its appropriateness for drinking purposes, Ketata et al.(2012) and is a method using individual water quality parameters on the overall quality of the water. This calculation based on WHO standards 2011 and BIS 1991. (Vasanthivigar et al 2010,) Shown in Table 1. Its computing followed the physico- chemical parameters analysis of each of the 12 parameters, for major cations and anions

$$W_i = w_i / \sum_{i=1}^n w_i \quad (1)$$

Where, W_i is the relative weight, w_i is the weight of the each parameter and n is the number of parameter. In the second step a quality rating scale q_i for the each parameter is assigned by dividing its concentration in each water sample (WHO 2011). Shown in Table 2.

$$q_i = C_i / S_i \times 100 \quad (2)$$

Where q_i quality rating, C_i is the concentration of each chemical parameter in mg/l, according to WHO guidelines (2011). For computing the WQI, the sub index of its parameter (SI) is first determined for each physico- chemical parameter WQI as per the equation, Shown in Table 4.

$$Sli = W_i \times q_i \quad (3)$$

$$WQI = \sum Sli \quad (4)$$

Where, Sli is the sub index of its parameter, q_i the rating based on concentration i th parameter, n number of the parameter.

Categorization of groundwater quality according to water quality index is as follows; <50 % Excellent water, 50 %-100 % good water, 100 %-200 % poor water, 200 %-300 % very poor water, > 300 % water unsuitable

for domestic purposes. The relative weight shown in Table, 1 quality rating, a total of seventy nine samples of groundwater samples was taken for water quality index in the sub- basin. Spatial distribution maps for water quality index showed 27.85 % of the sample as belonging to the Excellent water category, 59.50 % of the sample as belonging to the Good category and 12.65 % of the sample as belonging to the Poor water category for domestic purposes respectively in the sub-basin. The Water Quality Index spatial map is presented in Fig.4

Table 1. Percentage of groundwater samples exceeding limits for drinking purposes based on WHO and BIS standard

Sl.No	Parameters	Minimum	Maximum	Mean	WHO (2011)	BIS (1991)	Desirable (%)	Allowable (%)	Not potable (%)
1	P ^H	6.74	8.41	7.41	6.5–8.5	6.5–8.5	100	-	-
2	EC (μS/cm)	190	5130	2151.01	1500	-	2	60	38
3	TDS (mg/l)	124	3335	1398.42	500	500	2	64	34
4	Ca (mg/l)	16	281	110.53	75	75	18	78	4
5	Mg (mg/l)	7	153	64.76	50	30	38	56	6
6	Na (mg/l)	10	360	166.36	200	-	4	-	96
7	K (mg/l)	0.5	43.9	10.40	12	-	62	6	32
8	HCO ₃ (mg/l)	50	622.404	336.1	500	-	11	89	-
9	Cl (mg/l)	25	1110	298.74	250	250	66	32	2
10	F (mg/l)	0.2	1.9	0.89	1.5	1.5	61	30	9
11	SO ₄ (mg/l)	10	380	132.44	250	200	87.34	12.66	-
12	NO ₃ (mg/l)	1.5	18	9.93	45	45	100	-	-

Table 2. Relative weightage of the chemical parameter for water quality index

Sl.No	Physico- chemical parameter	WHO Standers (2011)	Weightage (w _i)	Relative weightage $W_i = w_i / \sum_{i=1}^n w_i$
1	pH	6.5–8.5	4	0.117647059
2	EC (μS/cm)	1500	3	0.147058824
3	TDS (mg/l)	500	4	0.117647059
4	Ca (mg/l)	75	2	0.058823529
5	Mg (mg/l)	50	1	0.029411765
6	Na (mg/l)	200	2	0.058823529
7	K (mg/l)	12	2	0.058823529
8	HCO ₃ (mg/l)	500	3	0.088235294
9	Cl (mg/l)	250	3	0.088235294
10	F (mg/l)	1.5	2	0.058823529
11	SO ₄ (mg/l)	250	3	0.088235294
12	NO ₃ (mg/l)	45	5	0.088235294
			$\sum w_i = 34$	$\sum W_i = 1.00$

Table 3. Water Quality Index is the groundwater sample in the Vasishta su-b basin

Sl.No	Water Quality types	Groundwater sample No
1	Excellent water	2,4,8,10,13,16,22,23,24,26,35,43,47,51,53,57,58,63, 74,77,78 and 79
2	Good water	1,3,5,6,7,9,11,12,14,15,17,18,19,20,21,25,29,30,31, 32,33,34,36,38,39,41,44,46,48,49,52,54,55,56,59,61, 62,64,65,67,68,69,70,72,73,75 and 76
3	Poor water	27,28,37,40,42,45,50,60,66 and 71

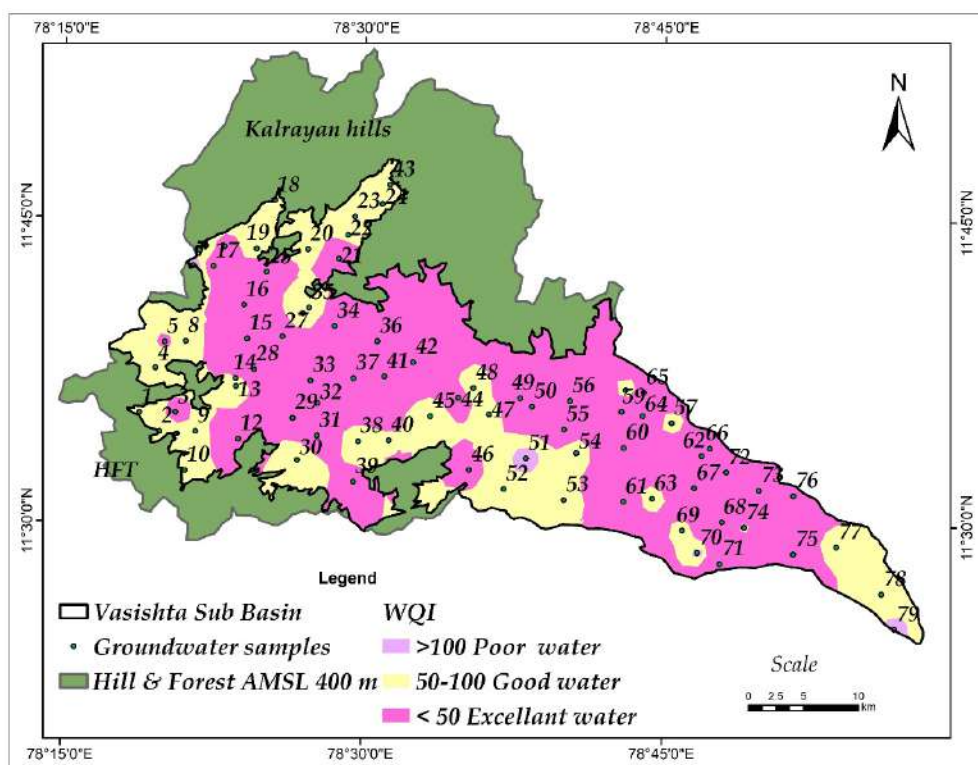


Fig. 4. Water Quality Index spatial map of the Vasishta sub- basin

Hydrogeochemical Facie. Piper's diagram (1944) includes two triangles, one for plotting cations and the other for plotting anions. The cation and anion fields are combined to show a single point in a diamond shaped field from which inferences drawn on the basis of hydro-geochemical facies concept are useful in bringing out the chemical relationship among groundwater samples in more definite terms rather than with other possible plotting methods.

The following groundwater facies have been identified in the sub basin; Na-K-Cl-SO₄ facies and Ca-Mg-HCO₃ type, cation ions fall under domain C-sodium and potassium facies, domain A-Magnesium type, anion such as, domain E-sulphate type, F-bicarbonate type. The majority of the groundwater samples fall under Ca-Mg-HCO₃ groundwater facies presented in Fig.5

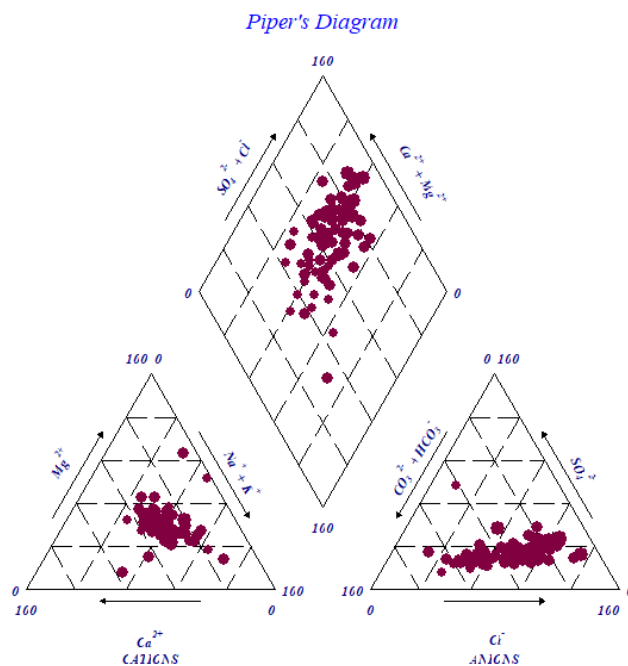


Fig. 5 Piper's hydrogeochemical facies of the Vasishta sub basin

Groundwater and Soil relationships. The Wilcox's diagram plotted against specific conductance is used in evaluating the irrigation waters Wilcox's (1955). Sodium is one of the important ions for irrigation and agriculture purposes. Sodium is computed to relative proportions of cations present in water. Percentage of Sodium greater than 60 % may result in sodium accumulations that will cause a breakdown in the soil's physical properties. Excess Na combining with carbonate leads to formation of alkali soils, whereas with chloride, saline soils are formed, and soil will not support plant growth Rao (2005). The ions' (Na%) values were obtained by the following equation:

$$\text{Na}\% = \frac{(\text{Na} + \text{K})}{\text{Ca} + \text{Mg} + \text{Na} + \text{K}} \times 100$$

Wilcox's Diagram is used to classify the water for irrigation, where EC plotted against Na% shows that 96.21 % of the groundwater samples are good to permissible and 3.79 % are in the not potable category. Sodium concentration disperses soil and increasing salinity flocculates soil (Hanson et al 1999). Wilcox's plot and groundwater classifications are presented in Fig.6 and Table 4. It is clearly stated that the water from the following villages is not of potable category; Iddaiyapatti, Vellaiyur and Thiruvallanthurai villages.

Table 4. Wilcox's groundwater classifications

Sl.No	Water class	Groundwater sample No
1	Excellent to Good	48
2	Good to Permissible	1,2,4,6,8,10,11,17,13,16,19,20,21,27,28,30,33,35,37,39, 41,44,45,46,49,50,54,55,56,75 and 78
3	Permissible to Unsuitable	68 and 79
4	Doubtful to unsuitable	7,9,12,23,29,31,32,34,36,42,47,51,52,53,59,60,62,65, 66,67,70,71,73,74,76 and 77
5	Unsuitable	43,38,64,58,15,25,2,69,35,57 and 40

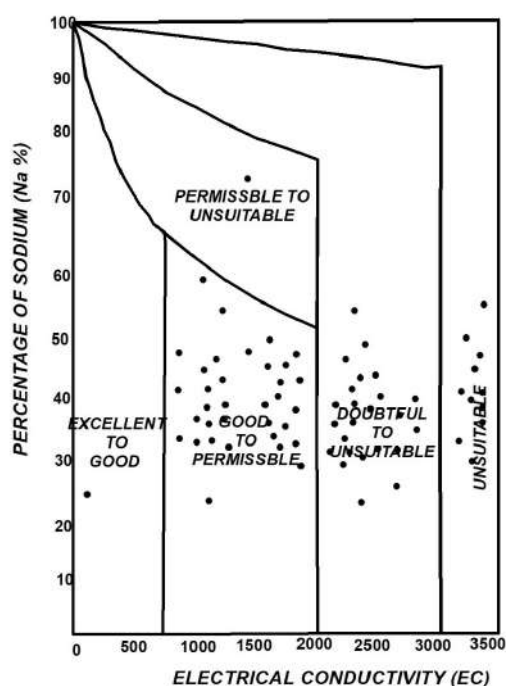


Fig.6. Wilcox diagram of the Vasishta sub- basin

Gibb's diagram. Gibbs diagram is mainly used to begin the affiliation of groundwater alignment and aquifer lithological characters. There are three domain fields, viz. precipitation dominance, evaporation dominance and rock–water interaction dominance domains in the Gibbs diagram (Gibbs, 1970). The maximum number of groundwater samples fall within the rock–water interaction domain and evaporation

domain. The rock–water interaction domain clearly shows that the groundwater chemistry is controlled by aquifer materials. Gibbs diagram is presented in Fig. 7(a), (b)

Gibb's ratio for cations = $\text{Na} + \text{K} / \text{Na} + \text{K} + \text{Ca}$

Gibb's ratio for anions = $\text{Cl} / \text{Cl} + \text{HCO}_3$

All values of ion concentration are stated in meq/l.

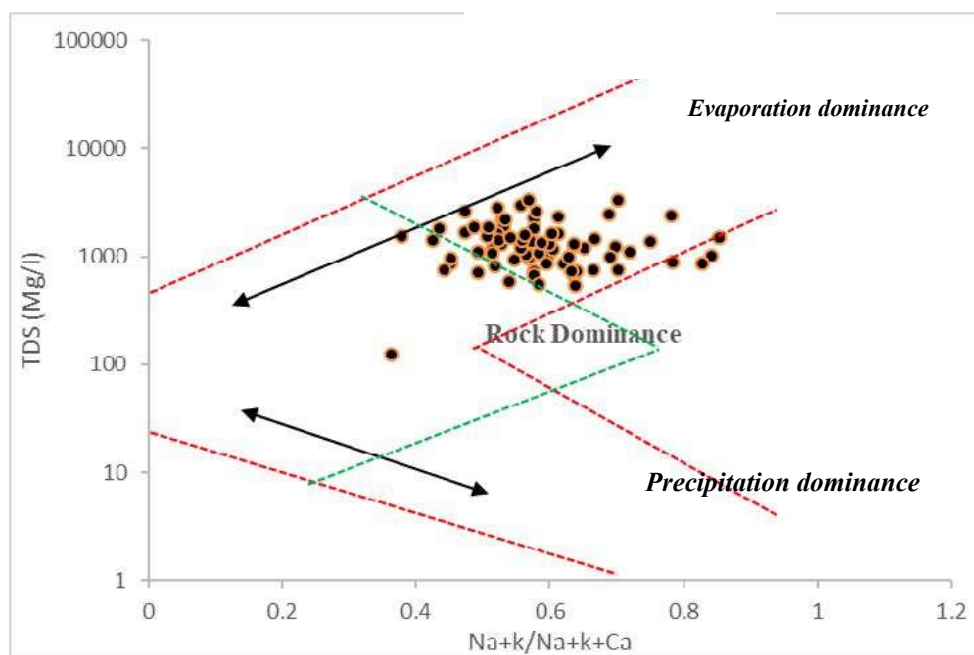


Fig.7. (a) Groundwater and rock interaction mechanism of Gibb's plot -cations

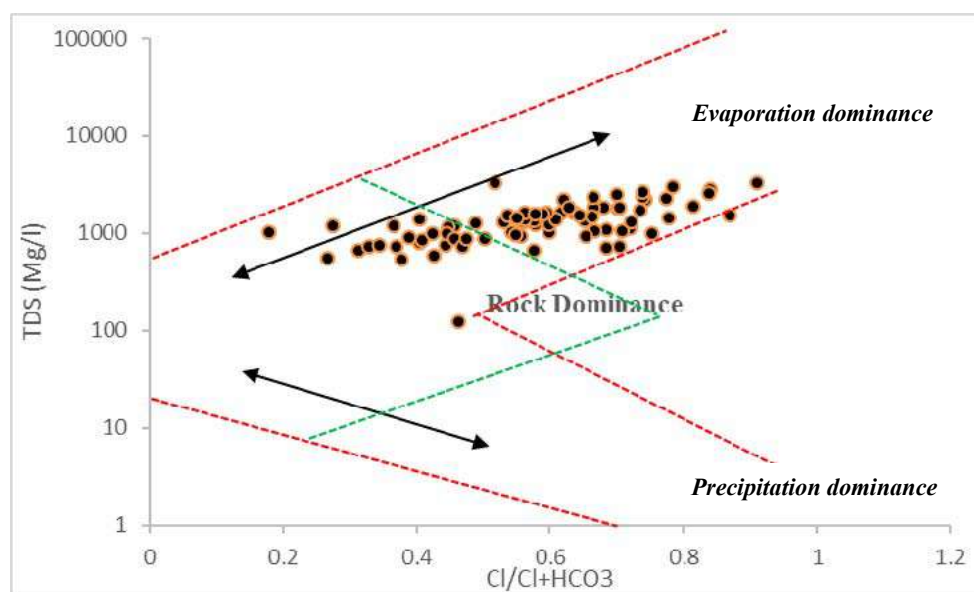


Fig.7. (b) Groundwater and rock interaction mechanism of Gibb's plot -anions

Results of the Correlation Matrix. The correlation analysis matrix involving statistical calculations was devised by Pearson (1896). It is commonly used to examine the degree of correlation between the different chemical parameters which affect the quality of groundwater. It is a simple measure to exhibit how well one variable predicts the other (Kurumbain and Greybill (1965). The Pearson correlation matrices (Swan and Sandilands 1995) are used to find the relationships between two or more variables. Coefficients ($r \geq 0.7$) are considered to be strongly correlated where (r) values between 0.5 and 0.7 show moderated correlation at a significance level $p=0.05$ while $r < 0.3$ is weak. It

also illustrates that EC and TDS show high positive correlation with Cl, SO_4 , HCO_3 , Ca, Cl show very high positive correlation with Ca ($r=0.817$). Good correlation is exhibited between EC and TDS Cl, SO_4 . Cl exhibits good correlation with Mg and Ca (0.817), (0.751) indicating leaching of secondary salts. TDS and EC showed strong correlation with Cl, SO_4 moderate correlation with Ca, Mg, K, F and Hardness indicating that most of the ions are involved in physicochemical reactions such as oxidation reduction and ion exchange and also indicating that they are from the same source Subba Rao, (2002). Difference in variation of major cations and anions correlation is shown in Table 5.

Table 5. Correlation analysis of the physico-chemical parameters

	<i>pH</i>	<i>EC</i>	<i>TDS</i>	<i>Ca</i>	<i>Mg</i>	<i>Na</i>	<i>K</i>	<i>HCO₃</i>	<i>Cl</i>	<i>F</i>	<i>SO₄</i>	<i>NO₃</i>
<i>pH</i>	1.000											
<i>EC</i>	0.102295	1.000										
<i>TDS</i>	0.101158	0.999999	1.000									
<i>Ca</i>	0.19725	-0.0184	-0.01873	1.000								
<i>Mg</i>	0.09596	0.012054	0.012061	0.604636	1.000							
<i>Na</i>	0.111688	-0.00992	-0.01003	0.591661	0.557501	1.000						
<i>K</i>	0.09227	0.064575	0.064409	0.61203	0.415096	0.559415	1.000					
<i>HCO₃</i>	0.100417	0.141909	0.141609	0.204394	0.127654	0.256821	-0.05897	1.000				
<i>Cl</i>	0.260742	-0.03523	-0.03553	0.825324	0.729007	0.696992	0.669742	-0.10684	1.000			
<i>F</i>	-0.77812	-0.23406	-0.23279	-0.14767	0.140104	0.030309	-0.04876	-0.22396	-0.08438	1.000		
<i>SO₄</i>	0.192453	0.003892	0.003762	0.656203	0.718156	0.720919	0.734585	-0.03408	0.794821	0.060281	1.000	
<i>NO₃</i>	0.207007	0.193818	0.193591	0.656602	0.556943	0.552107	0.601085	0.179881	0.620028	-0.10462	0.706081	1.000

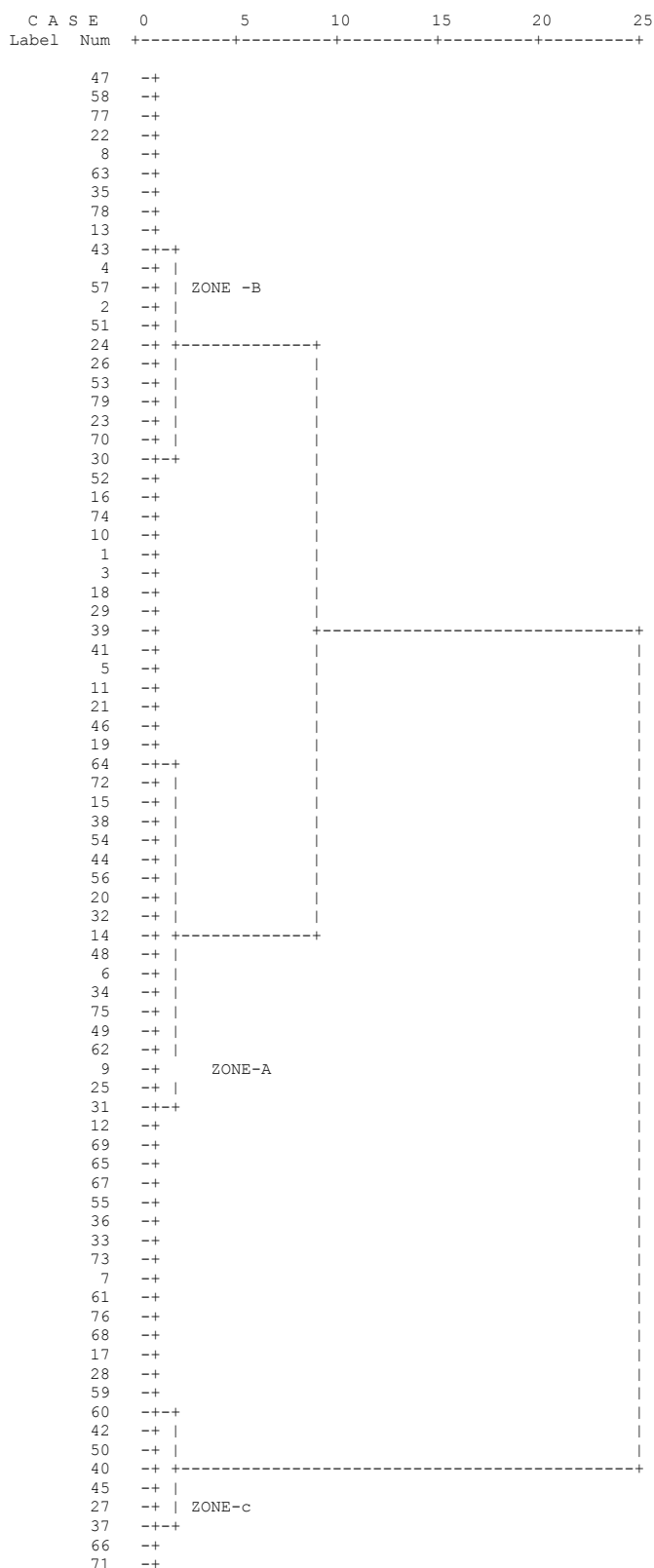


Fig.8. Cluster analysis in the dendrogram

Zone A grouped with the following groundwater samples (43, 4, 57, 2, 51, 24, 26, 53, 79, 23), Zone-B (64, 72, 15, 38, 54, 44, 56, 20, 32, 14, 48, 6, 34, 75, 49, 62, 9, 25, 31) and one C (60, 42, 50, 0, 45, 27, 37, 66, 71). TDS seems to be a major influencing factor in the following the order of dominance ; Zone C > Zone B > Zone A. The zone A comprises samples (32, 54, 74, 55, 66, 9, 8, 64, 72, 52, 53, 28, 10, 31, 35, 5). The result is presented as a dendrogram shown in Figure.8.

Cluster analyses.

Cluster analysis is a method for grouping individuals or objects according to their distinct characters. This method is used to group the groundwater chemical data. Each cluster indicates a particular groundwater character similarity. Clustering groundwater samples based on their similarity is known as Q-mode type clustering method. For the present study Q-mode clustering has been attempted to group the samples in terms of chemical characteristics. Ward's linkage uses the Pearson correlation method to produce the most distinctive groups where each member within the group is more similar to its fellow member than outside groups. All the 14 hydro chemical variables such as Electrical Conductivity (EC), Total Dissolved Solids (TDS), P^H , Ca, Mg, Na, K, Cl, SO_4 , NO_3 , HCO_3 and F were utilized in this analysis.

Conclusions.

The sub-basin is mainly comprised of Archean crystalline rocks such as gneisses, charnockite, pyroxinite, amphibole granulite and mylonite. Groundwater chemistry in the sub-basin is highly variable in nature. Groundwater occurs and movements in the sub-basin are mainly in the weathered rocks, fissures, fractures and joints. The TDS values varied from 124 to 3335 mg/l. TDS depends upon the groundwater interaction with different aquifer materials, and anthropogenic activities such as application of fertilizer, domestic sewage, and industrial effluent. The groundwater ionic concentration sequences are $Ca > K > Mg > Na$ and $CO_3 > Cl > SO_4 > HCO_3 > NO_3$. Groundwater categories are fresh to brackish in nature, Ca and Mg are mostly within the allowable category, NO_3 and SO_4 are also within the allowable limit for domestic purposes, The dominant water quality index falls into

the excellent to good categories based on WHO and BIS standards. According to Piper's trilinear diagram the groundwater facies are Ca-Mg and SO_4 type. In Wilcox's diagram it is clearly shown that most of the groundwater samples are suitable for irrigation purposes, however 3.79% of groundwater samples (from the villages Iddaiyapatti, Vellaiyur and Thiruvallanthurai) are not suitable for irrigation purposes, which may be due to geogenic and anthropogenic activities. In Gibb's diagram it is clearly revealed that groundwater chemistry is mainly controlled by rock water interaction domain and evaporation domain. In the hydrochemical correlation matrix, high positive correlation is exhibited between EC-TDS ($r=0.9$), Ca-Cl ($r=0.82$), and moderate correlation between Na-Cl, K-Ca, NO_3 -Ca, Na-Mg, Cl-Mg, SO_4 -Mg, SO_4 -Cl, NO_3 - SO_4 , with correlation value of 0.5 to 0.7, weak correlation exists between Ca-EC ($r=-0.0184$), F-K ($r=-0.04$). The correlation results projected in the dendrogram show that three groups were classified based on visual interpretation the dendrogram. Total dissolved solids seems to be a major influencing factor in the following order of dominance; Zone C > Zone B > Zone A.

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