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Advanced Computational Geostatistical Studies of Groundwater Quality of Vilathikulam Region, Thoothukudi District, Tamilnadu, India.

Kuttalingam U[1], Udayanapillai A.V [2], Murugan D [3] , Lakshmanan C [4]

[1,2] P.G Studies and Research Dept of Geology, V.O.C College,Thoothukudi , Affiliated to M.S.University,Tirunelveli

[3] Dept of Computer Science and Engineering, M.S University, Tirunelveli.

[4] PG studies and Research Dept of Botany, V.O.C.College, Thoothukudi , Affiliated to M.S.University,Tirunelveli

Abstract: - Fifty three representative ground water samples collected during pre-monsoon and post-monsoon seasons on 2015 from Vilathikulam region, Thoothukudi district, Tamilnadu, India were subjected to analysis for various major water quality parameter such as P^H, TDS, Cations Ca^{2+}, Mg^{2+}, Na^+, K^+ and Anions HCO_3^-, SO_4^-, Cl^-, F^- and No_3.The GIS based spatial distribution maps for the integrated parameters of cationsCa+Mg,Na-K and anions HCO_3^-, SO_4^-, Cl^- were prepared by the software ArcGIS 10.1. The advanced geostatistical evaluation such as Multiple Correlation, Principal Component Analysis and Cluster Analysis for the samples were performed by the geo-statistical software PAST.

Keywords: Water quality parameters, Arc GIS9.3 : PAST, BIS and WHO, Drinking water; Livestock and Irrigation.

INTRODUCTION

Ground water is the most important natural resources in the earth. The utility and necessity of ground water are being increased in day to day life of the human lives. In some areas, the severe water stress has been emerged as a real threat against human population (Kaliammal and Udayanapillai, 2016). During 21st century, many researchers have concentrated their research on geochemical studies of ground water not only in India, but also in various part of the world (Kumaresan and Riyazuddin, 2006; Sadashivaiah et. al., 2008; Biswajeet Pradhan and Saied Pirasteh, 2011; Nwankuala and Udam, 2011; Ghoraba and Khan et. al, 2013; Senthil kumar et. al. 2014; Abdullah Al-Zarah and Latif, 2014; Udayanapillai and Kaliammal, 2016). Different lithological condition in India makes tremendous change in hydrogeochemical characterization of ground water (Chanda and Chakraborly, 2001). The relations between ground water quality and rock-water interaction have been discussed (Udayanapillai et al. 2014) Many villages in and around Vilathikulam region of Tamilnadu are utilizing ground water long time for domestic and irrigation purposes. No much research works have been carried out previously in the area pertaining to geochemistry of ground water. This is the first attempt which has been made to evaluate ground water quality utilizing GIS application and geostatistical evaluation.

STUDY AREA:

The proposed research area Vilathikulam, encompasses 116 villages and bound between the latitudes and longitudes from 9º 5' 0'' to 9º 15' 0'', from 78º 0' 0'' to 78º 15' 0'' (Fig.1)

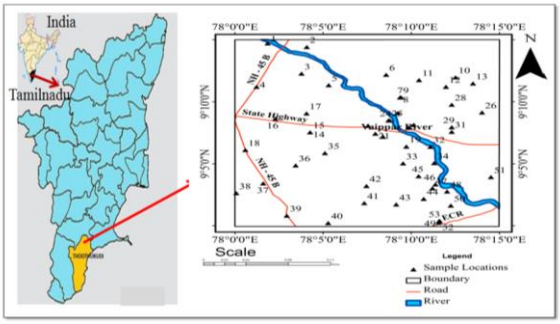


Figure.1.Location map of the study area

The various national and state highway road network connects the area with the main cities. The physiography of the area is generally flat and plain with the lack of any residual hill out crop. The area has the maximum elevation of 63 m. from the MSL. These are three physiographic divisions such as Proterozoic hard metamorphic crystalline terrain in the western part, Tertiary sedimentary rock in the eastern part and Sub Recent – Recent coastal sedimentary belt in south – eastern part. Drainage patterns are generally dendritic. The vaipar river is the major ephemeral river

running NW and SE. direction and all other small drainages merge with the vaippar river basin. (Fig.2)

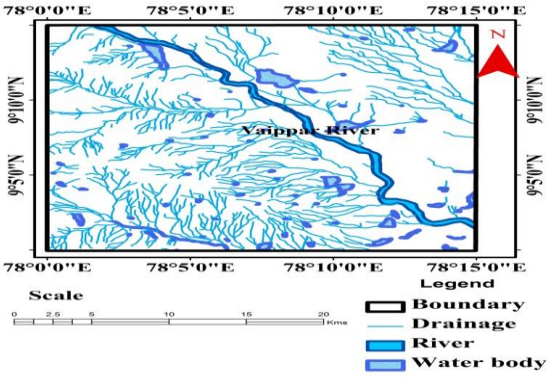


Figure.2.Drainage map of the study area

The area generally experiences of arid and semi arid climate and receives an average rain fall of about 661 mm, influenced by south west and north east monsoons.

Geology

Major part of the area is occupied by Proterozoic basement rocks, such as Quartzite, Hornblende-Biotite gneiss, Charnockite or Pyroxene Granulite, Granite and Pegmatite (Narayanasamy and Purnalakshmi, 1967). The basement rocks are overlain by Tertiary Argillaceous/Arenaceous limestone outcrop. The Recent and Sub-Recent teri soil and black soil out crops rest on tertiary out crop, contains intervening deposits of calcrete. The weathered zone, fissured cracks, shear zones and joints in the basement rock and teri soil out crop act as good ground water potential zones in the study area. The general stratigraphy of the study area is shown in table 1 and Fig. 3.

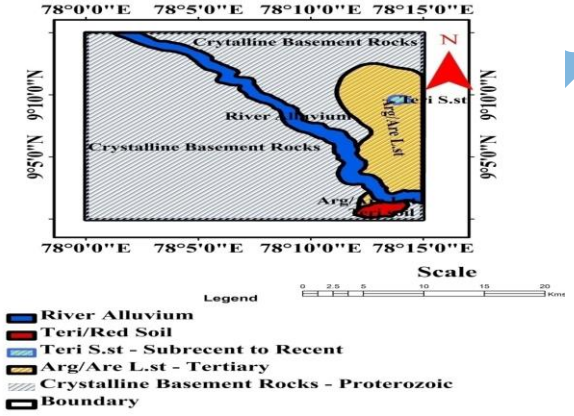


Figure.3.Geology map the study area

Table.1. The sequential stratigraphy of the study area

Age	Rock types/Lithology		
Recent	River alluvium, Black cotton soil and Beach sands		
Sub-Recent (Holocene to Pleistocene)	Red /Teri soils and Calcrete		
Pleistocene	Coral limestone		
Tertiary	Arenaceous and Argillaceous shell limestone		
Precambrian	Proterozoic	520 M.Y	Pink granite, White granite and Pegmatite
		550 – 650 M.Y	charnockite
		600 – 2000 M.Y	Composite gneisses, Calc-silicate rocks Crystalline limestone and Quartzite
	Archaean	Above 2000 M.Y	Archaean – basement rocks

MATERIAL AND METHODS:

Fifty three representative ground water samples collected during pre-monsoon and post-monsoon periods on 2015 were analysed by adopting the standard procedure of analytical techniques (APHA 1998) . Then, the well

inventory details such as location, lithology, well shape and dimensions and depth of water table have been observed, while collecting the samples. The cations Ca, Mg, Na and K, Anions HCO_3, SO_4, Cl, F and NO_3 along with the physical parameters PH, TDS and EC were analysed.

RESULT AND DISCUSSION:

Statistical evaluation

Multiple correlations are a statistical technique that predicts the values of one variable on the basis of two or more other variables **(Table 3).** Numerous researchers have applied this statistical evaluation in geochemistry of ground water (Hegde 2006, Srinivasamoorthy et al. 2010, Srinivastava et al. 2011; Ismail et al. 2015, Udayanapillai and Kaliammal 2016) The multiple diagonally symmetrical linear correlation matrices of Ca, Mg, Na, K, HCO_3, SO_4, Cl, F, NO_3, P^H, EC and TDS of the samples are given in bold. The relationship of the above variables generally show positive correlations except Ph vs K, P^H vs F, P^H vs NO_3, EC vs NO_3, K vs HCO_3 which shows a very low degree or insignificant values of negative correlation. Such similar positive correlation exist between the variables of Ca, Mg vs EC, Na+, K vs EC, HCO_3, Cl vs EC, Ca vs Mg and Na vs K have already been reported (Azasa et al 2009, Udayanapillai et al. 2012 Udayanapillai and Kaliammal 2016) The weathering of Calc-alkaline group rocks and insitu salinity from Tertiary and Recent marine limestone beds contribute Na and K content to ground water. The positive correlation exist between TDS vs Na, Ca, and Mg indicates that the combined operation of chemical weathering, inland salinity from the sedimentary rocks, groundwater movement and river basin recharge controlled the chemistry of ground water in the study area.

Table.3.Multiple correlation

	Ca	Mg	Na	K	HCO3	SO4	Cl	F	No3	TDS	PH	EC
Ca	1											
Mg	**0.95**	1										
Na	0.05	0.07	1									
K	0.30	0.24	0.05	1								
HCO3	0.15	0.15	-0.04	-0.07	1							
SO4	0.43	0.44	0.24	0.46	0.05	1						
Cl	0.46	**0.50**	**0.50**	0.20	-0.09	0.56	1					
F	0.18	0.09	-0.24	0.37	-0.04	0.00	-0.03	1				
No3	0.25	0.25	-0.14	0.46	0.06	0.15	0.05	0.53	1			
TDS	**0.65**	**0.60**	0.28	0.17	-0.07	0.38	0.50	0.15	-0.01	1		
PH	0.09	0.10	0.37	-0.27	0.05	0.09	0.08	-0.64	-0.50	0.48	1	
EC	**0.78**	**0.78**	0.32	0.08	0.12	0.44	0.54	-0.08	-0.10	0.86	0.53	1

Principal Component Analysis:

It is a statistical procedure that transforms a number of possible correlated variables into a smaller number of uncorrelated (Orthogonal) variable called as Principal Components. Many researchers during 20th century applied the PCA analysis in ground water studies (Anderson, 1958, Wilks 1963; Chachadi and Mahapatra 1983. In 21st century, many subsequent research works have been concentrated in ground water studies by many authors (Prashant et al. 2015 Sridhar kumar et al. 2014, Usman et al. 2014; Srivastava et al. 2013; Udayanapillai and Kaliammal 2016, Ravikumar and Somasekhar 2017). The result of PCA analysis depends on linearity, significance of mean and co-variance, dynamics of large variance and orthogonal fiting of the data of components.

The PCA reveals the data of Eigen value, % of variance cumulative variance and component loading scores. This data were obtained by performing a computer software programme 'PAST'. The Eigen value, % of variance, cumulative variance and the selected 4 principal component loading scores values above the eigen values 1 are presented in table 4a-b) The canonical representation diagram and scree plot of PCA components and its accounting total variances are given in (figure 4a and b). It is observed from the table 4a that the four PCA component accounts for 77.72% of cumulative variances. Each component is primarily associated with certain parameter and are given as follows;

I Component Ca+Mg+SO_4+Cl+TDS and EC = 36.17%

II Component K, F, NO_3 and P^H = 22.07%

III Component Na and HCO_3 = 11.12%

IV Component HCO_3 = 8.36%

The first PCA component weighted on positive direction of variable axis with positive loading scores of 0.87, 0.86, 0.65, 0.71, 0.84 and 0.91 for the parameter Ca, Mg, SO4, Cl, TDS and EC. These parameters show the maximum variance of 36.17% between the themselves. The second PCA gives 22.07% of variance and is loaded on the parameters of K, F, NO3 and pH with the positive and negative component loading scores axis values of 0.60, 0.80, 0.79 and -0.82 respectively. The third PCA component shows the variance of 11.12% and is loaded on the parameters of Na and HCO3 with the positive and negative score of 0.57 and -0.56 respectively. The fourth PCA component accounts for the variance of 8.36% solely on HCO3 parameter with the positive component score values of 0.76.

Table-4a. Eigen value, % of variance, cumulative variance and component loading scores

PC	Eigen value	% variance	Cumulative variance	PCA components
1	**4.34068**	36.172	36.172	Ca, Mg, SO_4, Cl, TDS and EC
2	**2.64774**	22.065	58.237	K, F, NO_3 and P^H
3	**1.33509**	11.126	69.363	Na and HCO_3
4	**1.00309**	8.359	77.722	HCO_3
5	0.726159	6.0513	83.7733	
6	0.669408	5.5784	89.3517	
7	0.521046	4.342	93.6937	
8	0.371454	3.0954	96.7891	
9	0.238663	1.9889	98.778	
10	0.060403	0.50336	99.28136	
11	0.053068	0.44224	99.7236	
12	0.033201	0.27667	100	

Table-4b.Component loading scores.

	Axis 1	Axis 2	Axis 3	Axis 4
Ca	**0.87**	0.22	-0.33	-0.07
Mg	**0.86**	0.18	-0.31	-0.01
Na	0.37	-0.39	**0.57**	0.22
K	0.34	**0.60**	0.36	0.14
HCO_3	0.08	0.00	**-0.56**	**0.76**
SO_4	**0.65**	0.14	0.35	0.34
Cl	**0.71**	-0.03	0.43	0.10
F	0.04	**0.80**	-0.04	-0.28
NO_3	0.13	**0.79**	0.01	0.11
TDS	**0.84**	-0.13	-0.06	-0.35
PH	0.33	**-0.82**	-0.08	-0.05
EC	**0.91**	-0.25	-0.20	-0.12

Figure 4a Canonial representaion diagram of PCA components

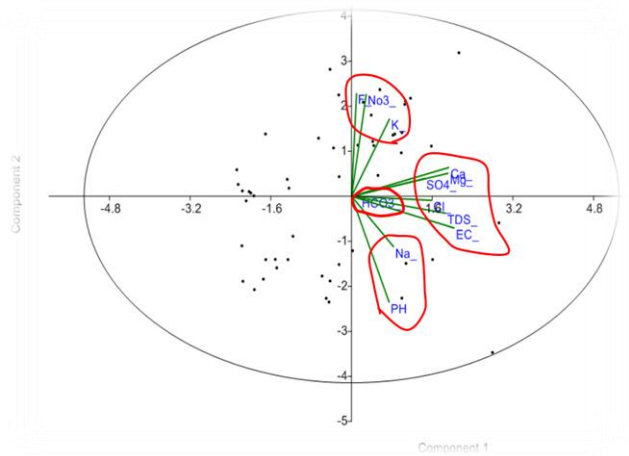
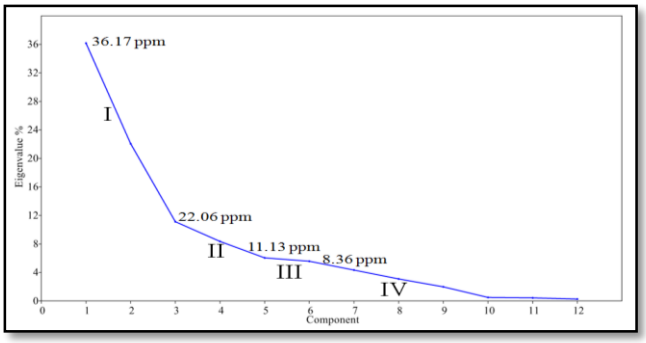


Figure 4b Scree plot



Cluster Analysis

It is a statistical classification technique for discovering homogeneous and heterogeneous groups on the basis of a definite set of variables and these groups are termed as Cluster. When compared to PCA, it points out a direct relation between parameters. Based on diagonal symmetrical correlation matrices and arithmetic average of correlation coefficient the cluster analysis is performed (Davis 1973) Many researchers have applied the cluster analysis for geochemical studies of ground water (Usman et al. 2014; Idris 2013, Srivastava et al. 2015; Praus 2007, Ismail et al. 2015, Udayanapillai and Kaliammal 2016.

The cluster analysis study of geochemistry could be groundwater performed for 2 purpose of study

Grouping of ionic cluster concentration on the elements of geochemistry of ground water (fig. 5a)

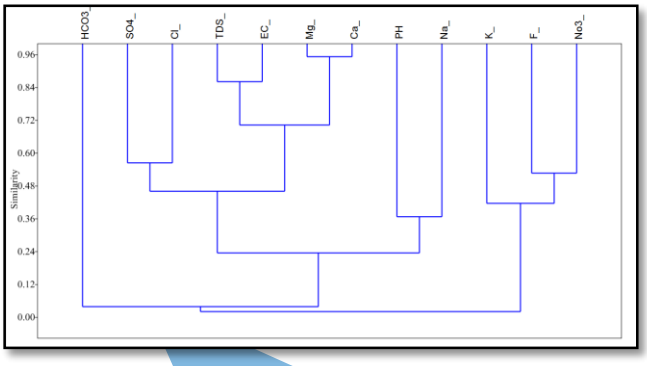
Similar aerial grouping of clusters of ionic concentration of elements of the study area (fig-5b)

The following results of average paired group of ionic clusters of geochemical parameters are established in the studies.

1. $NO_3 - F + K - 0.42$
2. Na – pH + Ca – Mg + Ec – TDS + Cl – So4 + HCO3- 0.24

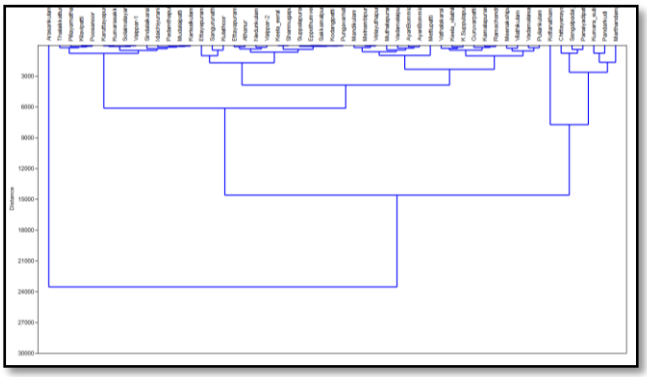
The dendrogram of Ionic cluster of geochemistry of ground water gives two ionic cluster which is given in the diagram. The above two cluster shows the average relative similarity values of 0.04.

Figure.5a. Paired group of ionic cluster



The similar aerial grouping of the clusters of ionic concentration of elements of the samples is represented in the dendrogram through wards minimum variance method or Euclidean method (Fig. 5b) The aerial grouping dendrogram represents 4 kinds of clusters. The first cluster consists of the sample locations Marthandampatti, Pandarakudi, Kumara Subramaniyapuram, Sengalpadai, Chittayanayakkanpatti and Kottanatham. The second cluster includes the sample location of Puliankudi, vadamalai samudram, Vilathikulam, Meenakshipuram, Ramachandrapuram, Kamalapuram, Guruvarpatti, K.Subbulapuram, K.Vilathikulam, Vathalakarai, Mettupatti, Ayan Bommiapuram1, 2, Vadamalaipuram, Muthalapuram, Velayuthapuram, Melnambipuram, Mandikulam. The third cluster represents the villages of Pungavarnatham, Kodangipatti, Sakkamalpuram, Eppodhumvendranm Suppalapuram, Shanmugapuram, Keela eeral, Vaippar 2, Nedungulam, Athanur, Ettayapuram, Kulathur, Sangurnatham and Ettayapuram entrance. The fourth cluster includes the samples of Karisalkulam, Mudalaipatti, Padanthapulli, Idauchiyurani, Sinthalakarai, Vaippar1, Solamaliyapatti, Kumarasakkarapuram, Karuttaiyapur, poosanur, Kilanpath, pillaiyarnatham, Thalaikattampur, Arasankulam, The overall relative distance of 4 clusters is established as 2300 (Fig. 5b).

Figure-5b. Paired group of aerial cluster



CONCLUSION

The study area consists of both Archaean crystalline and the Coastal Tertiary and Sub Recent – Recent deposit. The study area mainly consists of calc - alkaline and per - alkaline compositional rocks.. The advanced statistical evaluation such as multiple correlation, PCA and cluster analysis illustrate the association of geochemical affinity and its aerial distribution concentration. The ground water quality could be enhanced by river basin recharge, land use pattern plan, construction of check dam in river, construction of percolation ponds in the recharge zone and making rain harvesting process in the possible recharge zones in the study area.

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