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Groundwater Chemistry Interpreation For Annamalai Nagar Cuddalore Taluk, Cuddalore District, Tamilnadu - Using Statistical Tcehnics

P. Anandhan

R. Manivannan

Soubhagya Ranjan Mohanty

Nibedita Jana

Departmen of Earth Sciences, Annamalai University Annamalai Nagar

S. Chidambaram

Research scientist, Water Research Center, Kuwait institute for Scientific Research, Kuwait

K. Srinivasamoorthy

Department of Geology Puducherry University

Abstract: Groundwater geochemistry is largely a faction of mineral composition of aquifer through which water flows thus, differences in aquifer composition and reflected as difference in groundwater chemistry. To understand water quality, multivariate importance in combining chemical variable and organizes voluminous data and group into variables of similar characters. R mode factor analysis in used in the field of hydrogeochemistry to decipher complex hydrogeological process. To attain a panacea for water chemistry, A total of 31 groundwater samples were collected during the pre monsoon and post monsoon for two seasons and analysed correlation and correlation coefficient was identified along with estimation of factor loading, principal component method was adopted for parameter estimation. Statistical packages for social sciences (SPSS) version 9 used to perform correlation and factor analysis. In general groundwater in study area is primarily influenced by leaching of secondary salts, anthropogenic impact and agricultural impact along with chemical weathering.

Keyword: Geochemistry, Pre monsoon, Post monsoon, Correlation, Factor analysis.

I. INTRODUCTION

Groundwater is one of the earth's most imporant resources for human life. It is a renewable natural resource having several inherent advantages over surface water like wide distribution, negligible evaporation loss and low risk of contamination. Dependence of groundwater has increased rapidly in many regions because of limited surface water sources, non perennial rivers and frequent failure in monsoon. Therefore, groundwater resources are often over exploited to meet the increasing demand thereby giving a heavy stress to aquifer system. Many studies have been conducted in different parts of the world on groundwater quality by various researchers (Edmunds et al., 2003; Mishra et al., 2005; Leung and Jiao, 2006; Chidambaram et al 2012; Singaraja et al., 2013; Anandhan et al., 2016; Paramaguru et al 2017; Chidambaram 2014). The water quality will also help us to obtain information regarding the environments through which the water has circulated (Janardhana, 2007; Chidambaram et al., 2011). Statistical analysis is a very useful tool for identifying groundwater quality of a region. Statistical association does not establish any cause and effect relationship but relationship of cause and effect can be deduced. Correlation of factor analysis is generally used in parametric classification of modelling studies (Balasubramanian and others 1989). Factor analysis and cluster analysis were used in groundwater chemistry interpretation by Ashley and Lloyd (1978). Statistical data has better representation than graphical representation due to finite number of variables, variables are limited by convention to major ions, and superior relationship may be introduced by using certain procedures (Razak m, Dazy J 1990). The present study using Statistical analysis is a very useful tool for identifying groundwater quality and groundwater conditions in the annamalai nagar, cuddalore taluk Cuddalore District, Tamil Nadu.

II. METHODOLOGY

STUDY AREA

Annamalinagar Cuddalore taluk of Cuddalore (Fig 1) district lies between latitudes of 11˚23'00'' and 11˚24'00'' and east longitudes 79˚42'30'' and 78˚43'00''. The northern part of the study area is bounded by Cuddalore district; Bay of Bengal in east; Perambalur in west; Mayiladuthurai in south.

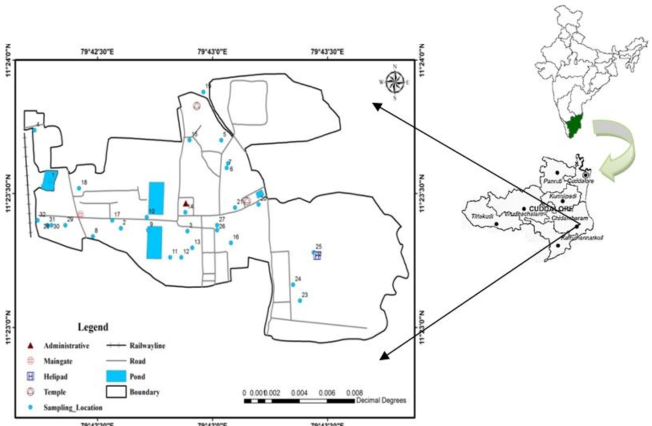

Figure 1: Location Map of the Study Area

SAMPLE COLLECTION AND ANALYSIS

Groundwater samples were collected in 1 liter polyethylene bottles. A total of 62 groundwater samples (two seasons) were collected from surface and subsurface representing the Annamalinagar, Cuddalore taluk. The samples were filtered using 0.45 µ Millipore filters and analyzed for chemical constituents. pH, Total Dissolved solid (TDS), Electrical Conductivity (EC) and temperature were measured in situ. Water analyses were carried out using standard procedures (APHA 1995, Ramesh and Anbu 1996). Bicarbonate, calcium, magnesium and chloride were analyzed by titrimetric method. Fluoride was determined by using Orion fluoride ion selective electrode model (94–09, 96–09). Sulfate, nitrate and silicate were determined by using Digital Spectrophotometer (ModelGS5 700A). Phosphate was determined by using ascorbic acid method; sodium and potassium were analyzed by flame photometer (Systronics mk-1/mk-III). To prepare all reagents and calibration standards, double-distilled water was used. Average chemistry of groundwater for two seasons is represented in (Fig 2 and Fig 3).

GEOLOGY OF THE AREA

The study area mainly consists of The Geology of the area plays a significant role in the determination of the ground water potential of a region. The area in a sedimentary formation composed of clays and sand of quaternary age. The area shows low undulating topography with the elevation of 5.75 m from the mean sea level. This comprises mainly of clay and sand of quaternary age, geologically, the area consists of younger Mio-Pliocene age sedimentary formations. The eastern parts are covered alluvium of recent to sub recent age and the western parts by the tertiary formations of Mio-Pliocene age represented by litho units - sand stones, grits, clays with lignite seams and pebble beds (Fig 4).The lower aquifer is cretaceous, according to unpublished reports of PWD. The cap rock for the first aquifer is clays and that of the next aquifer is Limestone. Geological succession of the nearby area (Lakshmanan, 1982) is given below.

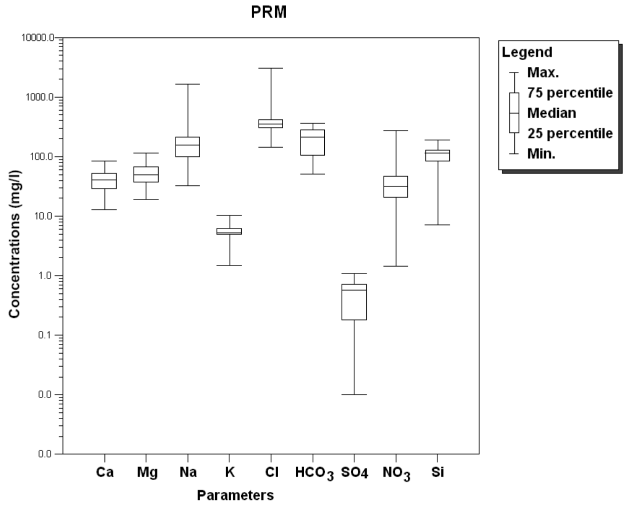

Figure 2: Maximum, minimum, and Average of groundwater samples from Pre-monsoon

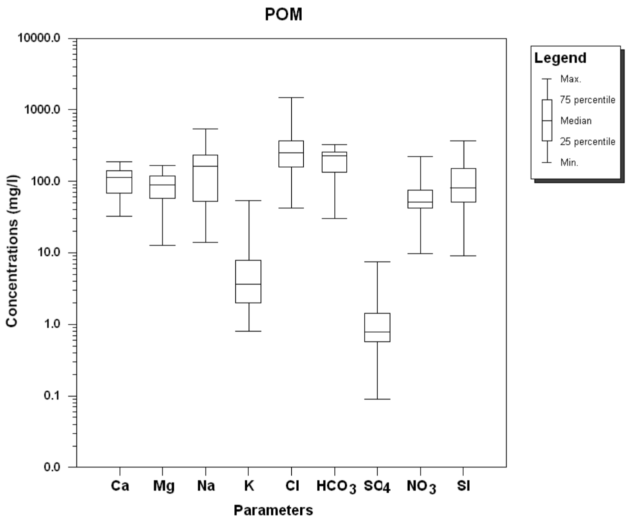

Figure 3: Maximum, minimum, and Average of groundwater samples from Post-monsoon

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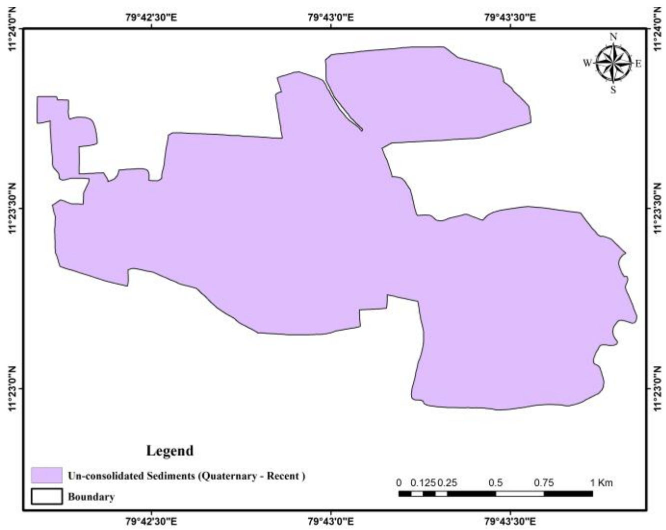

Figure 4: Geology of the study area

III. DATA PROCESSING

Statistical analysis is a very useful tool for identifying groundwater quality of a region. Statistical association does not establish any cause and effect relationship but relationship of cause and effect can be deduced. Correlation of factor analysis is generally used in parametric classification of modelling studies (Balasubramanian and others 1989). Factor analysis and cluster analysis were used in groundwater chemistry interpretation by Ashley and Lloyd (1978). In view of the limitations of the existing graphical methods an increasing number of chemical parameters now being measured in groundwater hydrogeochemical studies, there is a need for wide ranging statistical analysis of the data. Delineating relationship between geochemical water types is difficult, while it is almost impossible to visualise the impact of both the physical and chemical variables on the water chemistry (Melloul and Collin, 1992). Statistical methods especially factor and correlation analyses are often used to achieve the above objectives.

In the study area multivariable statistical method has been used. Correlation analysis was perfumed to identify chief ions controlling water chemistry. Correlation coefficient, measures of interrelationships for all pairs of constituents was determined along with estimation of factor loading. Principal component method was adopted for parameter estimation to transform a set of observed independent variables into orthogonal set variables called principal compounds. Each principal compound accounts for as much as possible for residual variance not accounted for by all the previous principal compounds. Kaiser scheme called Verimax rotation is used in this study. Factor score is estimated to find out spatial variation, zone of representation of each factor (Balasubramanian andothers 1989). Spatial variation by musing factor score values by all factors. Statistical packages for social sciences (SPSS) version 9 used to perform correlation and factor analysis.

IV. RESULTS AND DISCUSSION

CORRELATION

The correlation analysis of groundwater of Annamalai nagar region (Table 1) shows that in PRM good to excellent correlations are observed between Cl-HCO_3, Cl-SO_4, Cl-Na, Cl-Mg, Mg-Cl, Mg-SO_4, Mg-Na K-H_4SiO_4. Poor correlation exists between H_4SiO_4, NO_3 and PO_4 with other ions. In POM (Table 2) season good to excellent correlation observed between Cl-HCO_3, Cl-SO_4, Cl-Na, SO_4-Na, NO_3-Cl, Na-HCO_3, Na-Cl and K-H_4SiO_4. Poor correlation exhibits between Ca, PO_4 and NO_3. In general PRM good positive correlation between anions are well established and with a meagre correlation in cation between Mg and Na. In general

The overall view of correlation analysis indicates that the relationship between Cl, HCO_3 and SO_4 remains the same irrespective of the season, hence they form the spinal species (Srinivasamoorthy, 2005, Anandhan,2016) of the water chemistry of the region. Other species like (Ca, Mg, K, PO_4 and NO_3) are all having only seasonal relationship and they form the seasonal species. It's very clear that the anions trend to form the spinal species of the water chemistry. The relation ship of the cation to these spinal species varies according to the relative mobility of cation present in water as it varies according to the season. It's also evident that the cation establishes more relationship during the PRM than in POM. This may be due to the impact of rainfall over the relative mobility of the cation in the study area.

The correlation analysis shows that the weathering and leaching of secondary precipitate salts might be the major sources for these ions followed by agriculture and anthropogenic. This has been further examined by factor analysis.

V. FACTOR ANALYSIS

The aim of the factor analysis of hydrogeochemical data is to explain the observed relation in simple terms expressed as new varieties called factors. The factor analysis model is assumed to represent adequately all the variance of the data set and the structure expressed in the pattern of variance and covariance between the variables and the similarities between the observations (Davis 1986). The contribution of a factor is said to be significant when the corresponding Eigen value is greater than unity (Briz-Kishore and Murali 1992). In general factor I will be related to the largest Eigen vale and will explain the greatest amount of variance in the dataset. In the aquifer, the proportion of the total variance explained by the extracted factors of the data set 80% and 89%. The communality of the variable are generally with Eigen value >1. So the factor model is assumed to represent adequately the overall variable of the data set. The factor analysis for waters is given in the table.

In PRM (Table 3) factor I is dominated by Cl, HCO3, SO4, Na and Mg indicating the leaching of secondary salts after monsoon. Factor II is represented by CO3, HCO3, PO4, NO3 and Na indicating the dominance of anthropogenic impact and ion exchange. Factor III is represented by H4SiO4

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and Mg indicating the dominance of lithological influence. In POM (Table 4) factor I is dominated by Cl, SO4, Ca, Mg, Na indicating recharge of the leached water and K and factor II is dominated by pH and CO3 and factor III is dominated by HCO3 and SO4. This trend shows the leaching of secondary salts precipitates along with anthropogenic impact like agriculture, drainage.

	pH	EC	TDS	Ca	Mg	Na	K	Cl	HCO_3	SO_4	PO_4	NO_3	H_4SiO_4
pH	1												
EC	-0.01	1.00											
TDS	-0.10	0.80	1.00										
Ca	0.53	0.23	0.15	1.00									
Mg	0.01	0.36	0.26	0.28	1.00								
Na	-0.15	0.39	0.48	0.03	0.20	1.00							
K	0.13	0.02	0.10	0.21	0.15	0.20	1.00						
Cl	-0.14	0.38	0.47	0.10	0.27	0.99	0.22	1.00					
HCO_3	0.26	0.21	0.25	0.25	0.60	0.26	0.11	0.26	1.00				
SO_4	0.22	-0.19	-0.11	0.12	-0.20	-0.32	-0.03	-0.29	-0.15	1.00			
PO_4	0.04	-0.16	-0.23	-0.19	0.02	-0.11	0.05	-0.10	0.06	-0.02	1.00		
NO_3	-0.41	0.46	0.46	-0.29	0.55	0.39	-0.26	0.37	0.35	-0.30	-0.18	1.00	
H_4SiO_4	-0.06	-0.02	0.01	0.23	0.12	0.08	0.55	0.11	0.21	-0.24	0.07	-0.27	1.00

Table 1: Correlation matrix for the chemical composition of groundwater during PRM

	pH	EC	TDS	Ca	Mg	Na	K	Cl	HCO_3	NO_3	PO_4	SO_4	H_4SiO_4
pH	1												
EC	-0.09	1.00											
TDS	-0.22	0.84	1.00										
Ca	0.61	0.09	-0.04	1.00									
Mg	0.05	0.30	0.25	0.24	1.00								
Na	-0.10	0.39	0.46	0.02	0.21	1.00							
K	0.29	0.12	0.10	0.27	0.25	0.16	1.00						
Cl	-0.09	0.39	0.46	0.08	0.28	0.99	0.19	1.00					
HCO_3	0.28	0.20	0.26	0.17	0.56	0.26	0.20	0.26	1.00				
NO_3	-0.43	0.46	0.53	-0.31	0.56	0.39	-0.21	0.37	0.32	1.00			
PO_4	0.02	-0.17	-0.20	-0.08	0.03	-0.10	0.01	-0.08	0.10	-0.17	1.00		
SO_4	0.11	-0.20	-0.15	0.16	-0.20	-0.35	0.05	-0.33	-0.19	-0.30	-0.04	1.00	
H_4SiO_4	0.02	-0.01	0.03	-0.06	0.05	0.08	0.53	0.11	0.24	-0.26	0.07	-0.28	1.00

Table 2: Correlation matrix for the chemical composition of groundwater during POM

Water effluent etc. The factor analysis shows the region is complex hydrogeochemical system with proportional interplay of ions from leaching of ions, ion exchange, agricultural return flow, stagnant waters and weathering of minerals. This interplay varies according to the season and spatial distribution of the source.

Factor 1	Factor 2	Factor 3	Factor 4
-0.28	-0.86	0.58	-0.35
-0.44	0.02	1.15	-1.27
0.22	2.28	-2.01	-2.37
1.85	1.88	-0.69	-1.51
0.76	-0.11	0.70	-0.45
-0.66	0.57	0.08	0.70
-0.72	0.30	0.64	0.09
-1.13	1.60	-0.09	0.19
-0.77	1.78	1.40	2.37
1.13	0.49	1.94	-0.30
-0.07	-0.16	-0.08	0.77
-0.94	0.54	0.22	0.21
0.82	0.89	0.66	0.11
-0.13	-0.69	-0.86	-1.50
-0.18	-0.29	-0.70	1.06
-0.03	-0.63	0.41	-0.37
0.69	-1.68	1.22	-1.65
-0.19	0.53	1.13	-0.22
0.27	-1.35	1.11	-0.33
-1.34	1.03	-0.38	0.52
0.53	0.16	0.96	-0.17
-0.66	-0.04	0.05	-0.03
3.83	0.00	-1.31	2.24
-0.08	-0.51	0.44	0.76
-0.39	-0.16	-1.03	0.44
-0.83	-0.35	-1.01	0.27
-0.11	-1.09	-1.16	0.55
-0.35	-0.85	-1.15	0.39
-0.88	-1.24	-1.50	0.22
0.47	-1.27	0.35	0.13
-0.41	-0.77	-1.08	-0.50

Table 3: Factor analysis for the chemical composition of groundwater during PRM

Factor 1	Factor 2	Factor 3	Factor 4
-0.40296	-0.72517	0.86149	-0.08158
-0.33931	-0.14151	1.14308	-0.46812
0.21294	2.48431	-1.70473	0.13425
-0.27029	2.18409	-1.25561	2.52901
0.53569	-0.31587	1.16818	0.70981
-0.14532	0.54758	0.14293	-0.72386
0.19987	0.46251	1.20513	-1.18443
-0.52523	1.66228	0.29706	-1.03026
-0.23906	1.62127	1.29223	-0.78336
-0.87886	0.47911	1.09863	2.13145
0.28479	0.03032	0.84335	-0.52687
-0.44123	0.48944	0.2397	-0.82788
-0.05656	0.7202	0.37905	1.13855
0.00908	-0.51113	-0.63374	-0.35391
-0.63235	-0.22984	-1.00506	0.73302
0.08998	-0.57325	0.55016	-0.45589
-0.40649	-1.47977	1.23068	1.01309
-0.19762	0.34226	1.28787	-0.12996
-0.73723	-1.25242	0.75913	0.95177
0.13507	0.90047	-0.0839	-1.71338
-0.63397	-0.21965	-1.1608	0.85411
-0.26622	-0.01463	0.09926	-0.70853
4.97069	-0.13101	0.23651	1.0349
0.19176	-0.6275	0.50642	-0.27775
0.25642	-0.11831	-1.32432	-0.62875
0.27046	-0.36504	-0.74551	-1.18154
0.62569	-1.1307	-1.07218	-0.4512
-0.31487	-0.98342	-1.1692	0.02544
-0.14476	-1.29166	-1.763	-0.81011
-0.86522	-1.01853	-0.13414	1.27586
-0.2849	-0.79441	-1.28866	-0.19388

Table 4: Factor analysis for the chemical composition of groundwater during POM

VI. CONCLUSION

The overall view of correlation analysis indicates the relationship between Cl, HCO_3 and SO_4 remains the same irrespective of seasons; hence they form the spinal species of water chemistry in the study area. Other species like Ca, Mg, K, PO_4 and NO_3 are all having only seasonal relationship and they form the seasonal species. Factor analysis shows the region is complex hydrogeochemical system with proportional interplay of leaching of ions, ion exchange, agricultural return flow, stagnant waters, retai gulam tank water, influence of drainage water and weathering of minerals. This interplay varies according to season and spatial distribution of the source.

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