



A Study on Groundwater Quality in and Around Salem City Tamilnadu using Applied Statistical Methods

Vijayakumar N.

Associate Professor, Department of Geology, Government Arts College (Autonomous), Salem -636007.

ABSTRACT

The Salem city is one of the fast developing cities in Tamil Nadu. The quality of Ground water is changing as a result of rapid Urbanisation. 40 ground water samples were collected from the places in and around Salem city, Tamilnadu. They were analyzed for major cations and anions comprising Ca, Mg, Na, K, CO₃, HCO₃, SO₄ and Cl. Apart from standard hydro geo chemical methods, applied statistical methods are also used to interpret the chemical relationship with specific process that controls the quality of ground water.

KEYWORDS : Ground water Quality, Statistical analysis, Salem city, Cations, Anions

INTRODUCTION

Salem is one of the fast developing city in Tamilnadu and population explosion and industrialization have contributed towards rising demand for ground water. The over exploitation of ground water lowers the water level and deteriorates the ground water quality. Thirumanimuthar River is the main and important drainage in Salem city. The urban sewages are mixed with the natural water which affect the aquifer chemistry.

Therefore, it is essential to evaluate the relationships among the chemical variables and to identify the local and regional processes, which influence the quality of groundwater, using principal component analysis.

STUDY AREA

The study area (Map 1) falls within the geographic coordinates of 11° 35' to 11° 47' N and E 78° 4' to 78° 22' E in the SOI Toposheets 581/1, 581/2, 581/6 and 581/6 cover part of Salem district. The elevation ranges from 500 ft to 1200 ft. above MSL with the exception of Yercaud which is at 4970 ft. above MSL.

GEOMORPHOLOGY

The study area is comprised of several hills and The Thirumanimuthar river flows from north upland division has a very high drainage density. The major source of groundwater is rainfall during monsoons. The average annual rainfall is about 852 mm.

GEOLOGY

The study area is mostly underlain by crystalline metamorphic rocks and Archaean rocks such as Charnockites, Garnet-Sillimanite-Gneisses, Hornblende Gneisses and Alkaline rocks.. The Peridotites and Dunites are exposed in 'Chalk hills' where vein type Magnesite occurs

SUITABILITY OF GROUND WATER FOR DOMESTIC USE

The ionic concentrations of water samples from the study are compared with BIS & WHO (Table.1) Standards to identify the suitability for domestic use.

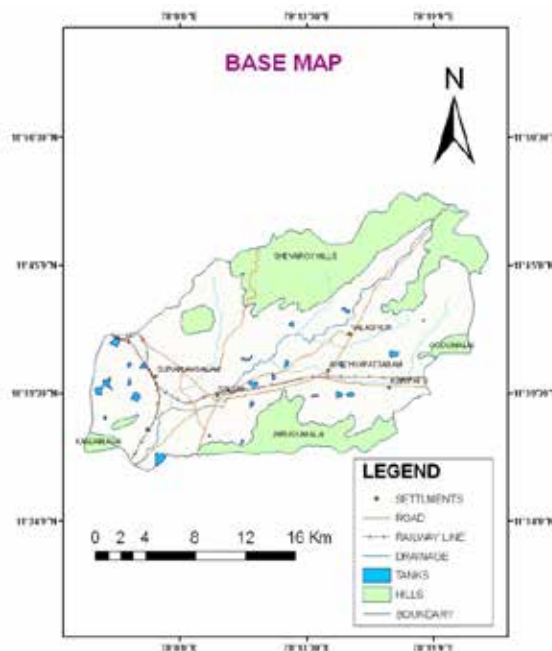
It is observed from the table that most of the water samples in the study area meet the acceptable limits to allowable limits of WHO and BIS guidelines, suggesting that the overall quality of groundwater in the study area is suitable for domestic use

TABLE-1.

Quality Parameters	WHO (2011) & BIS (2012) Standards	
	Max. acceptable limit	Max. allowable limit
pH	6.5	8.5
TDS	500	2000
TH	200	600
Calcium	75	200

Quality Parameters	WHO (2011) & BIS (2012) Standards	
	Max. acceptable limit	Max. allowable limit
Magnesium	50	150
Sodium	200	400
Chloride	200	1000
Sulphates	200	400

MAP-1



METHODOLOGY

In order to assess the groundwater chemistry, Forty groundwater samples (Map-1) were collected from dug and bore wells located in and around Salem city. These samples were collected analysed using standard procedures during post monsoon season of December 2012. The concentration of major cations (Na⁺, K⁺, Ca²⁺, Mg²⁺), anions (HCO₃⁻, CO₃⁻, SO₄²⁻, Cl⁻) and physico-chemical parameters (pH, EC) in the water samples were determined. The mathematical and statistical results have been commutated from statistical package for social sciences (SPSS V10) software.

RESULTS AND DISCUSSION

Table 2 shows the results of chemical analysis of groundwater sam-

ples. The Electrical Conductivity of the ground water is varying from 454 to 6873 micromhos/cm at 25 °C. The pH varies from 7.1 to 8.3 indicating an alkaline nature. The concentration of TDS is in the range of 366 to 3861 mg /l. According to the classification of TDS (Fetter, 1990) the groundwater comes under both the fresh (TDS < 1000 mg/l) and brackish (TDS > 1000 mg/l) categories, in 30% and 70% of the total samples, respectively. Among the cationic concentrations (Ca^{2+} , Mg^{2+} , Na^+ and K^+) Na^+ is the dominant ion (19 to 1978 mg /l), followed by Mg^{2+} (20 to 350 mg/l) followed by Ca^{2+} (14 to 240 mg /l) and K^+ (1 to 18 mg /l). The Cl^- is the predominant ion (27 to 2090 mg /l) among the anionic concentrations (HCO_3^- , CO_3^{2-} , Cl^- and SO_4^{2-}) and is followed by HCO_3^- (317 to 885 mg /l), SO_4^{2-} (5 to 355 mg /l) and CO_3^{2-} (17 to 69 mg /l). The groundwater is generally characterized by Na: HCO_3^- facies in the fresh environment and by Na:Cl facies in the brackish environment, thus both the facies.

PRINCIPAL COMPONENT ANALYSIS

For a better understanding of the groundwater system and chemistry, multivariate analyses can be performed using both chemical species (major cations and anions) and physicochemical data such as EC, pH and alkalinity (Kazi et al. 2009). Statistical method is used as an analytical tool to reduce and organize large hydrochemical datasets into groups with similar characteristics. The basic purpose of such an analysis is to interpret relationship among the variables used for classification of original data set. Main advantage of principal component

analysis (PCA) is to identify patterns by compressing the data by reducing the numbers of dimensions without much loss of information (Irawan et al. 2009). It is designed to convert the original variables into new; uncorrelated variables (axes) called the principal components, which are linear combination of the original variables (Sarbu and Pop 2005). Principal component analysis (PCA) is widely used for analysis and ranking of variables, using SPSS-V10 software package. In general the first two or three principal components are taken on the basis of Eigenvalues, which explain the reasonable percent of variance. In the present study, the first three principal components were utilized, which have Eigenvalues greater than unity, following Kaiser (1958). Scatter plots between the component loadings and three selected principal components were used for the easy interpretation and the results.

The principal component solution obtained by Eigenvalues and percent (%) of the variances is given in Table 2. The output of the final rotated loading matrix obtained from the present data indicates that the three principal components explain 69.75% of the total variance, principal component-I (PC-I) contributes 39.10%, principal component-II (PC-II) 15.95% and principal component-III (PC-III) 14.70% with 11 chemical variables. The number of sampling location are 40 (Table 1) for all the data set. Each principal component can be used to interpret as a specific hydrogeochemical process or processes through an examination of their loadings.

Table-2. Hydrogeochemical Results of the Samples taken from StudyArea (in ppm)

S. No.	Location	Results in ppm									pH	TDS
		Ca	Mg ²⁺	Na	K	HCO ₃	CO ₃	SO ₄	Cl			
1	KATTUR-2	16	103	369	4	622	0	61	541	7.4	1399	
2	KATTUR-3	32	50	188	7	470	0	48	257	8.3	812	
3	PULAYUR	20	68	200	3	567	0	144	266	7.8	979	
4	REDDIPATTY	34	91	121	2	580	0	96	248	7.2	876	
5	VEDAKUTHAMPATTI	44	23	207	6	397	0	108	186	7.4	769	
6	ANDIPATTI	202	271	657	3	329	0	96	2090	7.1	3480	
7	REDIYUR	68	47	69	1	378	0	48	222	7.5	640	
8	ARISIPALAYAM 16	62	77	405	2	415	0	48	682	7.8	1479	
9	SHEVAPET	22	65	369	4	766	0	78	355	7.8	1268	
10	MANIYANUR-2	32	71	548	2	506	0	74	824	8.2	1799	
11	MALANKADU	66	40	338	1	494	0	129	337	7.3	1153	
12	MASINAICKENPATTI	68	53	344	2	512	0	144	532	7.6	1394	
13	D.PERUMAPALAYAM	112	190	133	2	641	17	355	496	7.4	1619	
14	SUKKAMPATTY	48	185	350	4	885	35	98	461	7.5	1614	
15	KUTTATHUPATTY	48	68	239	7	336	52	38	603	7.6	1220	
16	SENGATTOOR	56	97	242	1	488	69	18	284	7.4	1006	
17	ADIMALAIPUDUR	112	83	242	0	671	35	5	248	7.5	1053	
18	MINNAMPALLI-2	48	37	98	3	427	0	96	222	7.5	713	
19	S.NATTARMANGALAM	54	20	101	2	427	0	144	115	7.3	645	
20	P.KOUNDAPURAM-2	48	31	89	0	470	0	48	71	7.4	517	
21	KATTUR-1	36	108	357	2	464	0	172	594	7.5	1496	
22	M.KOLLAPATTI	54	284	978	6	781	0	144	2012	7.5	3861	
23	KOMANAICKENPATTI	14	113	173	2	610	0	144	479	8	1224	
24	MULLATHOPPU	28	30	19	2	329	0	96	35	7.5	371	
25	KODIMENTERUVU	54	68	377	1	519	0	96	532	7.9	1382	
26	ALAGAPURAM	46	49	187	7	397	0	96	301	7.6	881	
27	LEE-BAJAR	34	92	202	3	567	0	49	346	7.6	1004	
28	KANDAMPATTI	20	106	174	1	580	0	96	346	7.9	1027	
29	SANJEEVIRAYAN PET-w	34	24	342	1	628	0	144	177	7.5	1030	
30	GUGAI	40	224	269	4	519	52	164	567	7.4	1574	
31	KONDALAMPATTY	72	311	432	14	427	52	61	1170	7.4	2322	
32	AYOTHIYAPATTANAM	72	350	324	18	610	35	144	1277	7.2	2519	
33	PALLIPATTY	240	345	292	13	671	17	10	993	7.3	2240	
34	SUKKAMPATTY 2	48	229	232	7	580	35	78	1028	7.1	1941	
35	ANUPPUR	96	204	196	3	580	17	39	638	7.1	1477	
36	ACHANKUTTAPATTY	96	112	285	2	610	35	28	248	7.3	1105	
37	MINNAMPALLI-1	74	62	207	2	372	0	48	505	7.1	1080	
38	M.PERUMAPALAYAM	36	41	149	2	433	0	96	177	8	713	
39	P.KOUNDAPURAM-1	46	34	292	1	616	0	96	230	7.3	1001	
40	KARIPATTI	54	10	23	1	317	0	96	27	7.1	366	

Table 3. Rotated loading matrix of the chemical variables of groundwater

Rotated Component	Matrix(a)		
	Component		
	1	2	3
pH	-0.082	-0.209	0.744
TDS	0.984	0.053	-0.123
Ca ²⁺	0.411	0.155	-0.696
Mg ²⁺	0.807	0.452	-0.213
Na ⁺	0.866	-0.157	0.143
K ⁺	0.482	0.578	-0.100
CO ₃ ⁻	0.131	0.852	-0.040
HCO ₃ ⁻	0.44	0.204	0.527
Cl ⁻	0.934	0.026	-0.225
SO ₄ ²⁻	0.223	-0.44	0.111
Eigenvalue	3.910	1.595	1.470
% of variance	39.100	15.950	14.700
Cum. %	39.100	55.050	69.750
Extraction Method: Principal Component Analysis.			
Rotation Method: Varimax with Kaiser Normalization.			
A Rotation converged in 5 iterations.			

Principal Component Loadings

Scatter plots of the principal component loadings between PC-I and PC-II, PC-I and PC-III, and PC-II and PC-III are illustrated in Fig.1. This figure can be read for the variation from positive to negative loadings of each principal component and also the scatter between the principal components of the different pairs.

Principal Component - I

Principal component-I is dominated by TDS, Na⁺, Mg²⁺ and Cl⁻ on variables which show higher '+ive' loadings (0.807 to 0.984 Table 3). The TDS, Mg²⁺, K⁺, HCO₃⁻, Ca²⁺, Cl⁻ and CO₃⁻ plotted in the '+ive' region of PC-I in the figure 1b and only HCO₃ in figure 1c.

PC-I is taken as a salinity factor. Salinity is directly controlled by the content Na⁺ and Cl ions which is derived from the interaction of water and rock, and gets enriched in the groundwaters due to their higher solubility. Since TDS does not have a close positive relationship with Mg²⁺, Ca²⁺ and Cl ions the variation in the TDS of the groundwater samples cannot be used to discuss the regional influence of salinity factor and its modifications locally by the specific field settings of the samples. For example, in the groundwater samples located near the hill areas on the NE part of the study area shows higher TDS because of the fractures act as conduits for the storage of groundwater. Irrigation, return flows and anthropogenic activities are the additional contributors of ions especially Mg²⁺, K⁺, HCO₃⁻, Ca²⁺, CO₃⁻ and Cl. As the salinity process of PC-I is controlled by water - rock interaction and anthropogenic activity, PC-I is considered as a lithologically and non-lithologically controlled factor.

Principal Component - II

PC-II has higher positive loadings (0.578 to 0.852) of K⁺ and CO₃⁻. TDS, Mg²⁺, Ca²⁺, K⁺ and Cl plot on the negative loadings on PC-II (Figs. 1b and 1c). The PC-II is a process of alkalinity, in which dissolved CO₂ played a part. Eight samples (20%) of groundwater samples of the study area have pH > 8 and others (80%) have pH between 7 to 8. According to Hem (1991) the alkaline earth elements (Ca²⁺ and Mg²⁺) lost in waters through ion exchange may later participate in the chemical reaction and their by increased pH levels. PC-II is considered as a lithologically controlled factor.

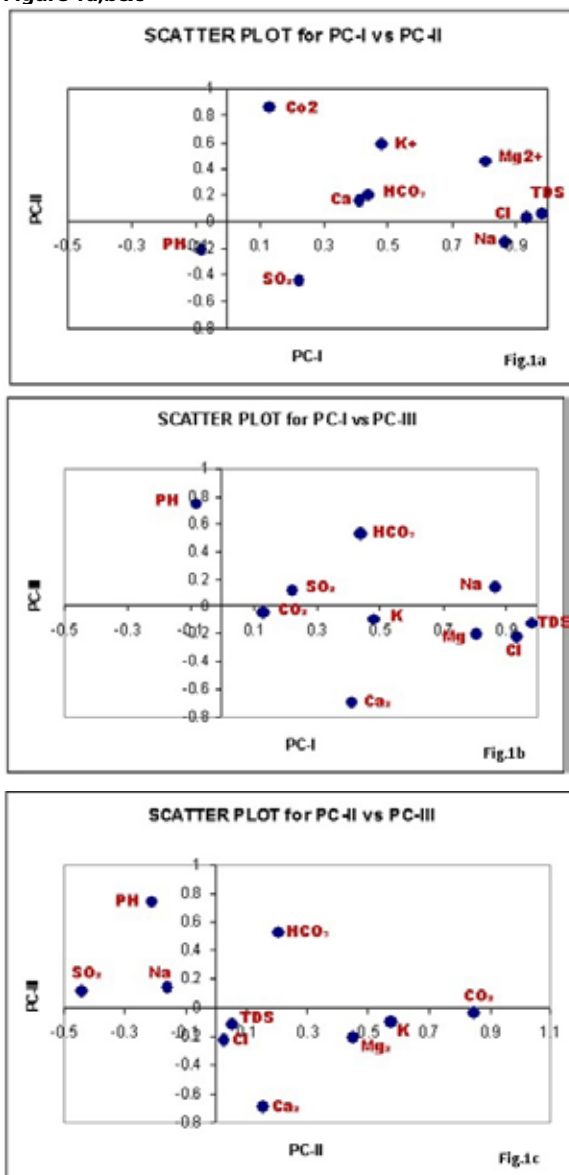
Principal Component - III

PC-III has a positive loading (0.527 to 0.744) of HCO₃ and pH (Figs. 1b and 1c). The variable HCO₃ falls on high positive region of PC-III. The higher concentration HCO₃ can be expected from the crystalline rocks

sources available in the study area.

PC-III is also considered as a lithologically controlled factor.

Figure 1a,b&c



Conclusion

The groundwater in this region is generally alkaline in nature because of concentration of Na % and the alkaline nature of pH increases for upper part to lower part. Based on major constituents, the lower part is affected by urbanization activities. Particularly the Uthamasolapuram and Pulavari are affected more because of sewages.

Principal component-I is dominated by TDS, Na⁺, Mg²⁺ and Cl⁻ on variables which show higher '+ive' loadings (0.807 to 0.984) in Table 3. As the salinity process of PC-I is controlled by water - rock interaction and anthropogenic activity, PC-I is considered as a lithologically and non-lithologically controlled factor.

PC-II has higher positive loadings (0.578 to 0.852) of K⁺ and CO₃⁻. TDS, Mg²⁺, Ca²⁺, K⁺ and Cl plot on the negative loadings on PC-II. PC-II is considered as a lithologically controlled factor.

PC-III has a positive loading (0.527 to 0.744) of HCO₃ and pH. PC-III also considered as a lithologically controlled factor.

REFERENCES

- (1) APHA, 1996. Standard methods for Examination of water and waste water analysis, 17th Edition, American Public Health Association, Washington DC. | (2) Arumugam K, Elangovan K (2009) Hydrochemical characteristics and groundwater quality assessment in Tirupur region, Coimbatore District, Tamil Nadu, India. *Environ Earth Sci* 58:1509–1520 | (3) Davis JC (1986) *Statistics and data analysis in geology*. Wiley, New York | (4) DRINKING WATER – BIS SPECIFICATION - | (Second Revision of IS 10500:2012) may 2012 | (5) Fetter, C.W. (1990), *Applied hydrogeology*, Second edition, CBS Publishers, New Delhi, 592p. | (6) Freeze RA, Cherry JA (1979) *Groundwater*. Prentice Hall, Englewood | (67) Gale IN, Robins NS (1989) The sampling and monitoring of groundwater quality. *British Geol Surv Hydrogeol Report no. 89/37* | (8) Gupta S. P., *Statistical Methods* Sultan Chand & Sons. | (9) Hem, J.D. 1991. *Study and Interpretation of the Chemical Characteristics of Natural water* USGS Water Supp. Paper no. 2254, 263 P. | (10) Irawan DE, Puradimaja DJ, Notosiswoyo S, Soemintadiredja P (2009) Hydrogeochemistry of volcanic hydrogeology based on cluster analysis of Mount Ciremai, West Java, Indonesia. *Journal of hydrology* 376 (1), 221–234 | (11) John C. Davis, (1986) *Statistical and Data Analysis in Geology*, Second Edition John Wiley & Sons, Inc | (12) Kazi TG, Arain MB, Jamali MK, Jalbani N, Afridi HI, Sarfraz RA, Baig JA, Shah AQ (2009) Assessment of water quality of polluted lake using multivariate statistical techniques: a case study. *Eco-toxicol Environ Safe* 72:301–309 | (13) Kaiser, H.F. (1958) The varimax criterion for analytic rotation in factor analysis, *Psychometrika*, v.23, pp.187–200 | (14) Lakshmanan E, Kannan K, Senthil Kumar M (2003) Major ion chemistry and identification of hydrogeochemical process of groundwater in part of Kancheepuram District, Tamil Nadu, India. *J Environ Geosci* 10(4):157–166 | (15) Laxman Kumar D and et al. *Hydrochemical Characteristics and Groundwater Quality | Assessment in Southeastern part of Ranga Reddy District, Andhra Pradesh, India. INDIAN JOURNAL OF APPLIED RESEARCH* pp 231–235 Volume : 4 | Issue : 6 | June 2014 | ISSN - 2249-555X | (16) Robert L. Miller and James, *Statistical Analysis in the geological sciences*, Wiley, 1962 | (17) Subba, Rao N et al., *Principal Component Analysis in groundwater quality in a developing urban area of A.P.* *Jour. Geol. Soc. India*, V.69, pp 959–969. | (18) Sarbu C, Pop (2005) *Principal component analysis versus fuzzy principal component analysis. A case study: the quality of Danube water (1985–1996)*. *Talanta* 65:1215–1220 | (19) Gupta S C & V. K. Kapoor, *Fundamentals of Applied Statistics* Sultan Chand & Sons. | (20) Vasanthavigiar, M, Srinivasamoorthy, K, Prasanna, M.V. (2012) Identification of groundwater contamination zones and its sources by using multivariate statistical approach in Thirumanimuthar sub-basin, Tamil Nadu, India, *Environ Earth Sci* DOI 10.1007/s12665-012-1868-8 | (21) World Health Organization (WHO) 2011. *Guidelines for drinking water quality*. Geneva: World Health Organization. |