© 2017 IJSRST | Volume 3 | Issue 4 | Print ISSN: 2395-6011 | Online ISSN: 2395-602X
Themed Section: Science and Technology

Identification of Most Important Sources Controlling Groundwater Chemistry in Annamalai Nagar Cuddalore Taluk, Cuddalore District, Tamilnadu

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ABSTRACT

A hydrogeochemical study was conducted in a coastal region of Cuddalore district to evaluate suitability of groundwater for domestic and agricultural purposes. Understanding the geochemical evolution is important for sustainable development of water resources. A detailed investigation was carried out to evaluate the geochemical processes regulating groundwater quality in Annamalinagar, Cuddalore taluk, Cuddalore district of Tamilnadu, India. To attain a panacea for water chemistry, groundwater samples were collected during the pre monsoon and post monsoon for two seasons. A total of 31 groundwater samples were collected in each season and were analyzed for 14 different water quality parameters and the result indicates, that higher EC and TDS values are observed in the central and SW part of the study area. In PRM and POM seasons HCO3 + Cl dominates the anions, with few representations for SO4. In both seasons Na+ K are the dominant ions. Bicarbonates derived from silicate mineral weathering are noted in the SW and Southern region. The electrical conductivity (EC) value ranged (both season) from 197 to 9190 µs/cm. As per Sodium Adsorption Ratio values 50% of the samples are suitable for irrigation. The Residual Sodium Carbonate indicates 60% of the samples fall in safe and 40% of the samples fall in unsafe zones and prolonged usage of this water will affect the crop yield. The Permeability Index of the groundwater indicates groundwater from the study area is moderate to good for irrigation purposes. Thermodynamic studies reveal that groundwater of the region are stable with Kaolinite stability field in all the silicate systems. Comparison of water quality to standards shows that the water can be used for drinking and for irrigation purposes except in few locations. Over exploitation of groundwater for extensive agricultural and urbanization has resulted in increase to the demand of fresh water and contamination of aquifer by salt water intrusion and other anthropogenic activities.

Keywords : Geochemistry, Permeability index, Major ions chemistry, Thermodynamic, Water quality

I. INTRODUCTION

Groundwater is a large source of fresh water available on earth; water is widely distributed and plays a vital role in both environment and 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 (Celik and Yildirim, 2006; Edmunds et al., 2003; Mishra et al., 2005; Leung and Jiao, 2006; SubbaRao et al., 2012; Chidambaram et al 2012;Thivya et al., 2013; 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). The main purpose of this study is thus to understand the groundwater conditions in the annamalai nagar, cuddalore taluk Cuddalore District, Tamil Nadu, India by utilizing more systematic methods.

II. 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.

III. RESULTS AND DISCUSSION

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).

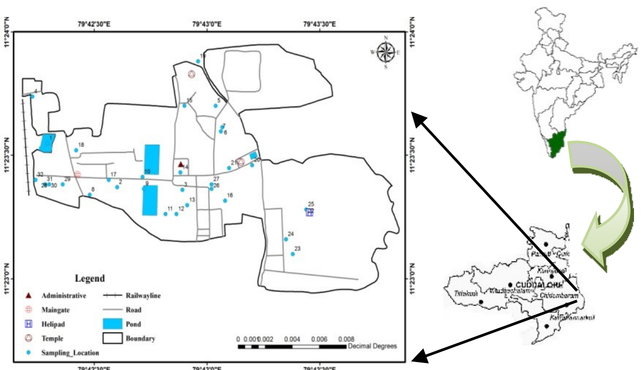

Figure 1. Location Map of the Study Area

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.

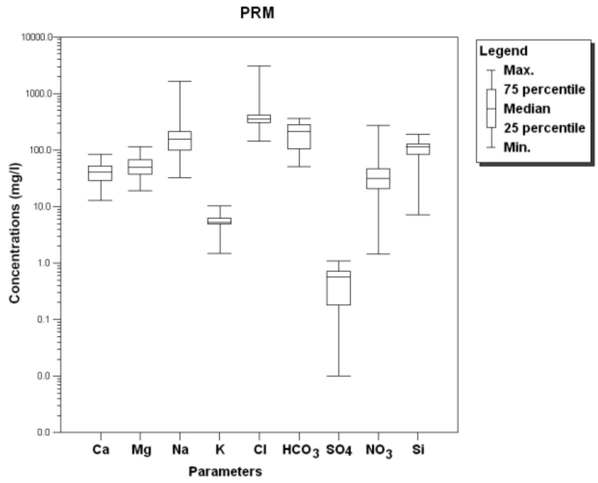

Figure 3. Maximum, minimum, and Average of groundwater samples from Pre-monsoon

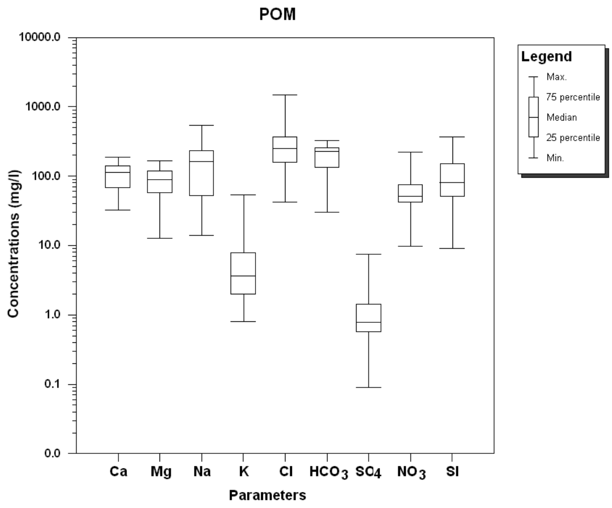

Figure 2. Maximum, minimum, and Average of groundwater samples from Post-monsoon.

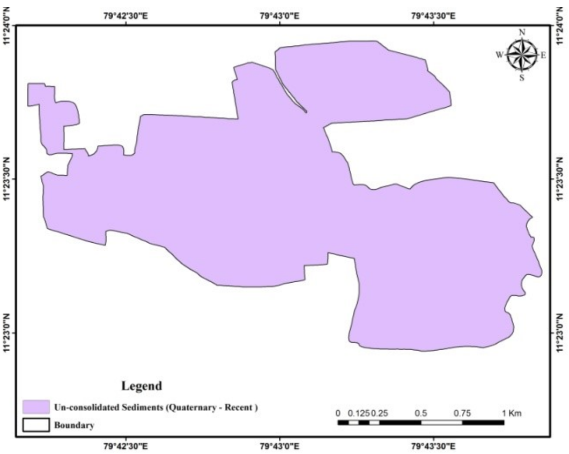

Figure 4. Geology of the study area

The voluminous raw hydro geochemical data analyzed is often processed manually for interpretation. To simplify the interpretation of the data a computer programme WATCLAST in C^{++} (Chidambaram, 2003), which was used for calculation and graphical representations (Table.1). The WATCLAST programme (Chidambaram et al 2003) requires ppm concentration of Ca^{2+}, Mg^{2+}, Na^{+}, K_{+}, Cl^{-}, HCO_3, SO_4^{2-}, H_4SiO_4, PO_4^{3-}, and other parameters include TDS, EC and pH.

The (Table.1) clearly reveals that the higher representations of the samples are noted in Fresh Brackish water type to brackish water type during both the seasons but there is an increase in the brackish water type and reduction in the fresh water type in POM groundwater. Higher TDS represented in the POM is mainly due to the leaching and dissolution of ions after monsoon.

During PRM the Na% for almost 33% of the samples, fall in Doubtful category (Table.1). Fair representations (27%) of samples are noted in unsuitable class and 22% in the Permissible category and the rest in good category. In the POM Na% of almost 27% of the samples, fall in Permissible category. Good representations (40%) of samples are noted in Doubtful class and 5% in the unsuitable category and the rest in good category. There is 15% representation of sample in the excellent category. In almost all the season's good representations are noted in doubtful category.

In Na% Eaton (1950) classification of groundwater for irrigation purposes, 68% of the samples fall in Safe category for irrigation purposes in both the seasons and rest in the unsafe category. The SAR indicates the relative proportion of Sodium to Calcium + Magnesium whereas; Residual Sodium Carbonate (Richards, 1954) is an index, which indicates the Sodium Hazards (Sodification of soil).

In RSC most of the PRM and POM samples fall in Good category respectively. (Table.1). Hardness refers to the reaction with soap and formation of scale. It increases the boiling point and do not have adverse effect on human health. In the study area 44% and 28% of the samples fall in the Moderately Hard category in PRM and POM, most of the remaining samples of both the seasons fall in Very Hard category (Table.1). 11% of PRM samples also represent Slightly Hard category. In POM, ther are no representations of samples in soft and slightly hard Category.

Table 1. Result of WATCLST for PRM AND POM

Na% Wilcox (1955)				**USGS Hardness**				**TDS Classification(USSL,1954)**		
Excellent	0-20	1	7	Soft	<75	0	0	<200	0	0
Good	20-40	7	9	Slightly Hard	75-150	3	0	200-500	0	1
Permissible	40-60	12	11	Moderately Hard	150-300	13	2	500-1500	19	16
Doubtful	60-80	9	4	Very Hard	>300	15	29	1500-3000	10	9
Unsuitable	>80	2	0	**IBE Schoeller (1965)**				**Cation Facies**		
Na% Eaton (1950)				(Na+k)rock->Ca/Mg g.w.		2	10	Ca-Mg Facies	1	8
Safe	<60	20	27	(Na+k)g.w.->Ca/Mg rock		29	21	Ca-Na Facies	30	23
Unsafe	>60	11	4	**Schoeller Classification (1967)**				Na-Ca Facies	0	0
S.A.R. Richards (1954)				Type I		31	31	Na Facies	0	0
Excellent	0-10	29	30	Type II		0	0	**Anion facies**		

Good	Oct-18	1	1	Type III		0	0	HCO3 Facies	0	0
Fair	18-26	0	0	Type IV		0	0	HCO3-Cl-SO4 Facies	0	0
Poor	>26	1	0	**Corrosivity Ratio (1990)**				Cl-SO4-HCO3 Facies	19	18
R.S.C. Richards(1954)				Safe	<1	31	24	Cl- Facies	12	13
Good	<1.25	31	31	Unsafe	>1	0	7	**Hardness Classification (Handa,1964)**		
Medium	1.25-2.5	0	0	**Chloride Classification (Stuyfzand,1989)**				**Permanent Hardness (NCH)**		
Bad	>2.5	0	0	Extremely fresh		0	0	A1	0	4
EC Wilcox (1955)				Very fresh		0	0	A2	13	21
Excellent	<250	0	1	Fresh		1	7	A3	17	5
Good	250-750	0	2	Fresh Brackish		6	11	**Temporary Hardness (CH)**		
Permissible	750-2250	15	17	Brackish		23	12	B1	0	1
Doubtful	2250-5000	15	8	Brackish-salt		1	1	B2	0	0
Unsuitable	>5000	1	3	Salt		0	0	B3	1	0
				Hyperhaline		0	0			

All the ionic concentration is expressed in epm. 66 % and 61% of the ground water samples of the study area exhibit exchange of (Na+K) in the rock to Ca+Mg in groundwater during PRM and POM respectively.

The Styfzands classification (1989) based on the Chloride concentration 6% and 15% of groundwater exhibits Fresh category during PRM and POM respectively. 12% and 20% of samples fall in Fresh Brackish Category in both PRM and POM seasons. 60% and 31% of samples fall in Brackish Category during PRM and POM seasons (Table.1). The higher concentration of Chloride in groundwater may be due to the sea water incursion into the aquifer or due to longer residence time of groundwater in host rock (Freeze and Cherry, 1979). More number of samples in fall in the brackish category during PRM this may be due to the leaching of the salt precipitates deposited in the pore spaces during the POM.

The Wilcox classification of ground water for irrigation purpose was applied by United State Salinity Laboratory for obtaining the classification of irrigation water. This diagram shows that during the POM the samples fall in C_2-C_3 category (High Salinity Hazard) and the samples of PRM fall in C_3-C_4 category. The level of Na and HCO_3 in irrigation groundwater affects permeability of soil and drainage of the area. In the diagram (Fig.5) representations of PRM are observed in C_4S_1, C_4S_2, C_3S_2 and C_2S_2 category. The POM (Fig.6) shows representations in C_2S_1, C_3S_1 and C_3S_2 category. The processes of fluctuation of the Shallow mineralized groundwater, or in flow regime processes if such groundwater is used for irrigation.

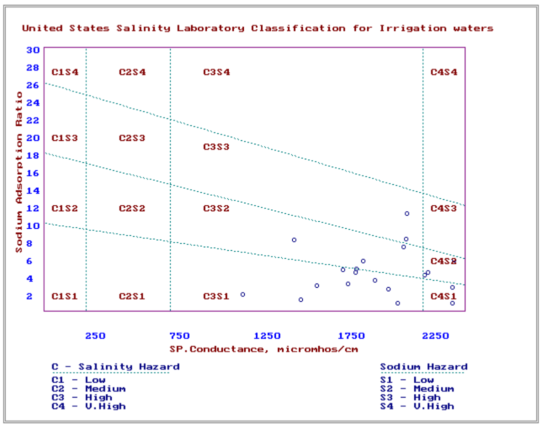

Figure 5. USSL classification for the groundwater (PRM)

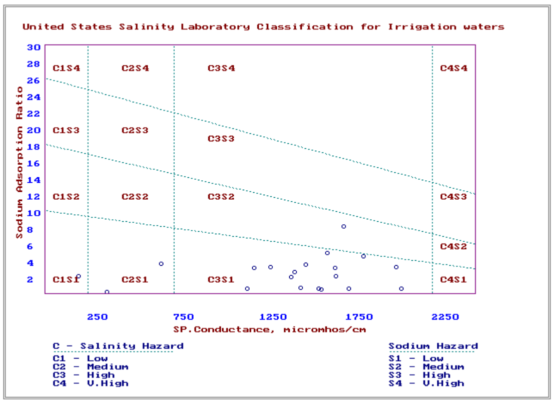

Figure 6. USSL classification for the groundwater (POM)

Permeability index is an important factor which influences quality of irrigation water, in relation to soil for development in agriculture. Based on permeability index, Doneen (1948) classified groundwater as Class I, Class II and Class III to find out suitability of groundwater for irrigation purpose. In study area PRM (Fig.7) majority of water samples fall in Class I and Class II. And POM (Fig.8) majority water sample fall in class I categories. It indicates water is moderate to good for irrigation purposes.

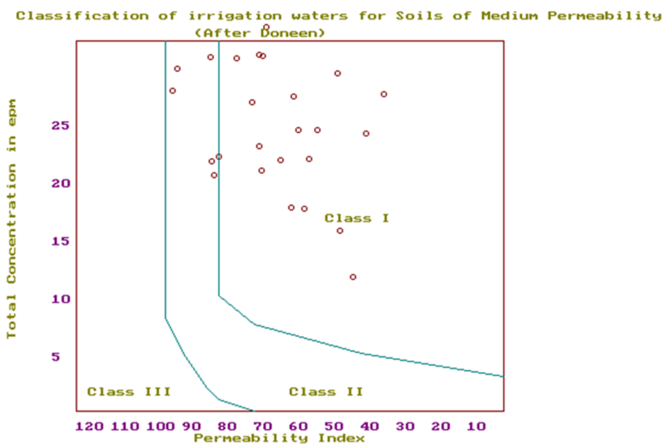

Figure 7. Doneens permeability index (PRM)

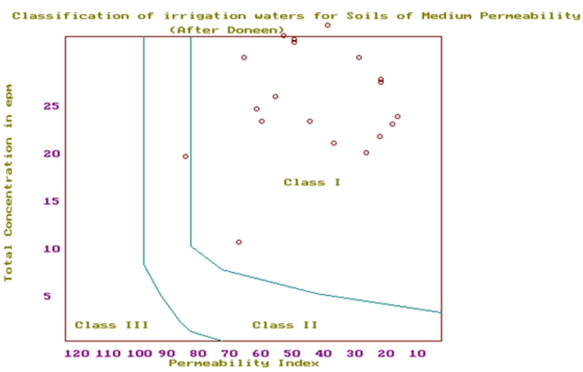

Figure 8.. Doneens permeability index (POM)

The Piper diagram shows the migration of the facies from Na-HCO_3 type during Post monsoon to Na-Cl type during Pre monsoon season (Fig.9). The monsoon adds HCO_3 to the groundwaters by dissolution of ions and the process of weathering. It thereby dilutes the system and reduces the impact of Cl^- which is the dominant anion during Pre-Monsoon.

The distribution of sample data points suggests that the chemical weathering of rock-forming minerals influences the groundwater quality during PRM and POM. In general the Gibbs plot reveals that rock water interaction is also a chief factor which controls the chemistry of groundwater in the study area (Fig.10 and 11) Minor representations in evaporation zone may indicate contribution from secondary leachates/ ion contribution from sea water during POM.

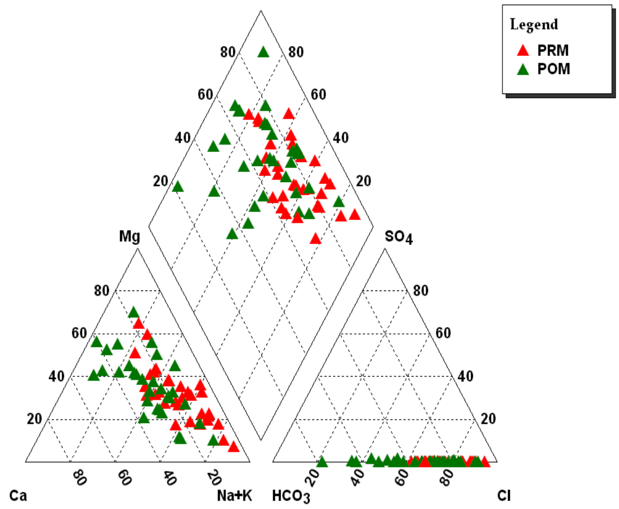

Figure 9. .Hill Piper diagram for water samples in all seasons.

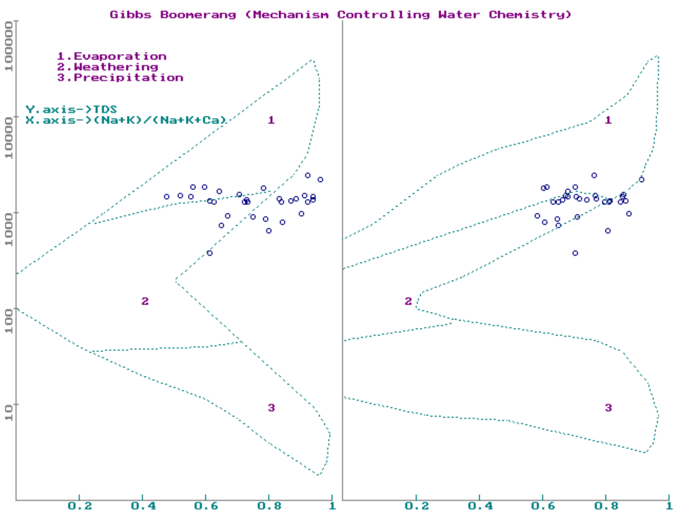

Figure 10. Gibbs plot for water samples in PRM

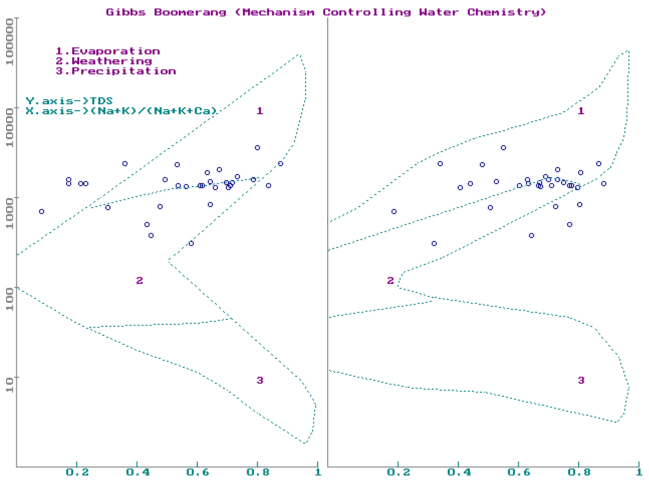

Figure 11. Gibbs plot for water samples in POM

Thermodynamic stability Diagram for Na System this is witnessed by samples the PRM samples (Fig.12) fall in the Na-Montmorillonite stability field and along this Kaolinite boundary they move towards the Kaolinite Field during the POM. The K-System Majority of PRM (Fig.13) samples fall in. The diagram delineates stability field of Clay minerals that co-exist in matrix phase at a constant composition of water during chemical reaction of rock and water. It is evident that movement of chemical composition from Muscovite to Kaolinite has released Silica. Ca-System PRM (Fig.14) the plot exhibits that migration from Kaolinite to Ca-Montmorillonite Field. Most of the samples of POM and few samples of PRM fall in Ca-Montmorillonite field which may be due to higher concentration of Silica. But during POM and PRM cluster of samples fall in Gibbsite filed and along the boundary between Kaolinite and Gibbsite due to the lesser of Silica in the groundwater. This include to the fact that the concentration of Ca^{2+} is higher in POM than the other seasons. Mg-System PRM seasons to (Fig.15), the samples are stable with Kaolinite field and few samples of PRM and POM exhibit high Mg and H_4SiO_4. Hence, these samples fall in Chlorite Stability Field. During POM few samples are shifted from Kaolinite Field to Chlorite field due to the increase in concentration of Mg^{2+}. Seasonal variations indicate that the shift of samples between two Fields.

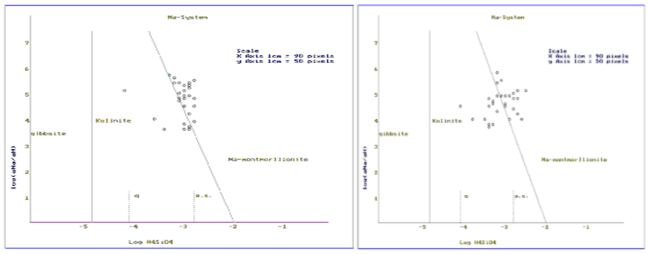

Figure 12. Equilibrium Plot for Na silicate system (PRM and POM)

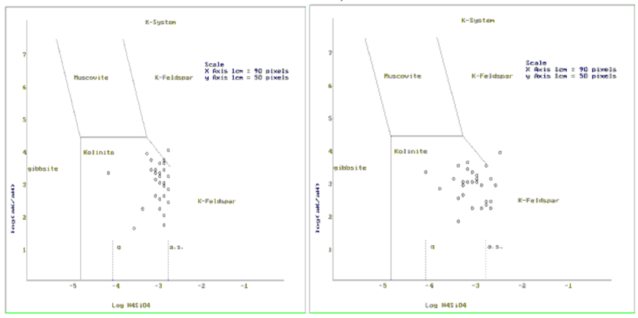

Figure 13.. Equilibrium Plot for K silicate system (PRM and POM)

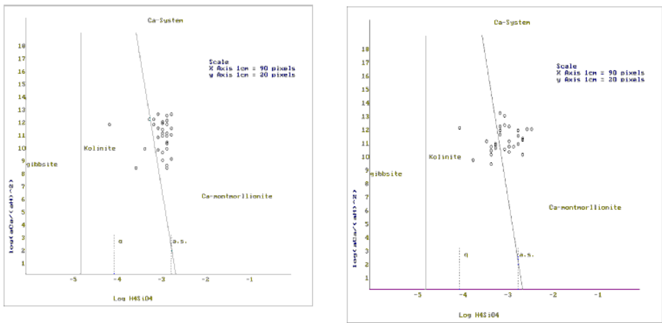

Figure 14. Equilibrium Plot for Ca silicate system (PRM and POM)

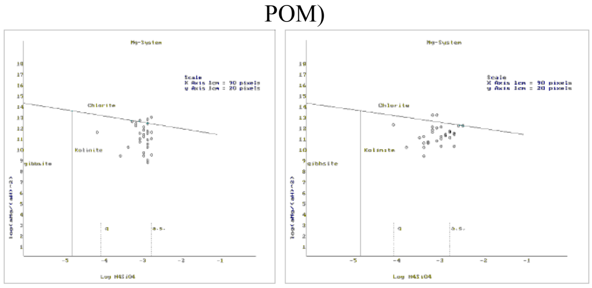

Figure 15..Equilibrium Plot for Mg silicate system (PRM and POM)

IV. CONCLUSION

Groundwater in the study area is generally acidic to alkaline in nature with pH ranging from 5.91 to 7.9. It was higher in POM and lower in PRM period. Highest values of EC were observed in POM and drop in PRM. In PRM season HCO3 + Cl dominates the anions, with few representations for SO4. POM season Na + K – Ca + Mg is the dominant. USSL classification shows most of water samples irrespective of seasons fall in C_4S_1,

C_4S_2, C_3S_2, C_2S_2 few indications of POM are also noted in C_2S_1 zone indicating wide range of salinity and alkalinity. Doneen Permeability index classification of groundwater shows majority of water samples fall in Class I and Class II. It indicates water is moderate to good for irrigation purposes. Gibbs boomerang shows that majority of samples falls in weathering dominant zone in all seasons but few representations of POM fall away from boomerang zone shows impact of secondary salt precipitation and mine water chemistry. Thermodynamic stability of Na system shows that samples of POM periods fall in Kaolinite stability field. Similar condition is noted in Ca system. In POM it shifts of samples from Kaolinite to Montmorillonite. Shift in stability from Kaolinite to muscovite zone is noted in few samples of PRM in K system. Shift in stability from Kaolinite to Chlorite zone is noted in few samples from PRM in Mg system.

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