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Research Paper

CHEMISTRY OF THE GROUNDWATER IN KARAJ PLAIN, ALBORZ PROVINCE, IRAN

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An attempt has been made in this present work to determine the groundwater quality in Karaj plain. Karaj plain is situated in the northwest of Tehran, Iran. Totally, 50 groundwater samples were collected from bore well during pre-monsoon and post-monsoon seasons and analysed for physicochemical parameters to understand the hydrogeochemistry of the groundwater. The analysis results were interpreted with various geochemical diagrams such as Piper trilinear plot and USSL classification and Gibbs diagram. To understand the geochemical facies interpreted with Piper Trilinear diagram and Gibb's diagrams. The graphical interpretation of the Piper trilinear diagram shows Ca, Na facies followed by Cl, So_4, and HCO_3 facies. Similarly, USSL and Gibb's diagrams represent C_3S_1 field and a considerable number of samples in rock-water interaction field. In the present study to understand groundwater quality of good in Karaj plain.

Keywords: Groundwater, Chemistry, Karaj plain

INTRODUCTION

Knowledge on hydrochemistry of groundwater is essential for understanding its suitability and optimum usage of domestic, industrial and agricultural purposes. Groundwater of an aquifer in any given area has a unique chemistry acquired as a result of chemical alteration of meteoric water recharging the system (Back, 1966; and Drever, 1982). Water is the prime natural resource for the development of the country depends on the rapid development of increasing population and industrialization. Water is flowing in two forms, namely, surface water and groundwater. Rapid urbanization, especially in developing countries like India, has affected the availability and quality of groundwater due to its overexploitation improper waste disposal, irrigation return water and lack of recharge. The Quality of groundwater is the function of its physical and chemical parameters which depend on upon the soluble products of weathering, decomposition, and the related changes that occur with respect to time and space (Srinivasamoorthy, 2011). The study area, Karaj plain is situated in the northwest of Tehran, Iran, lies between latitudes 34°502 to 35°302 N and

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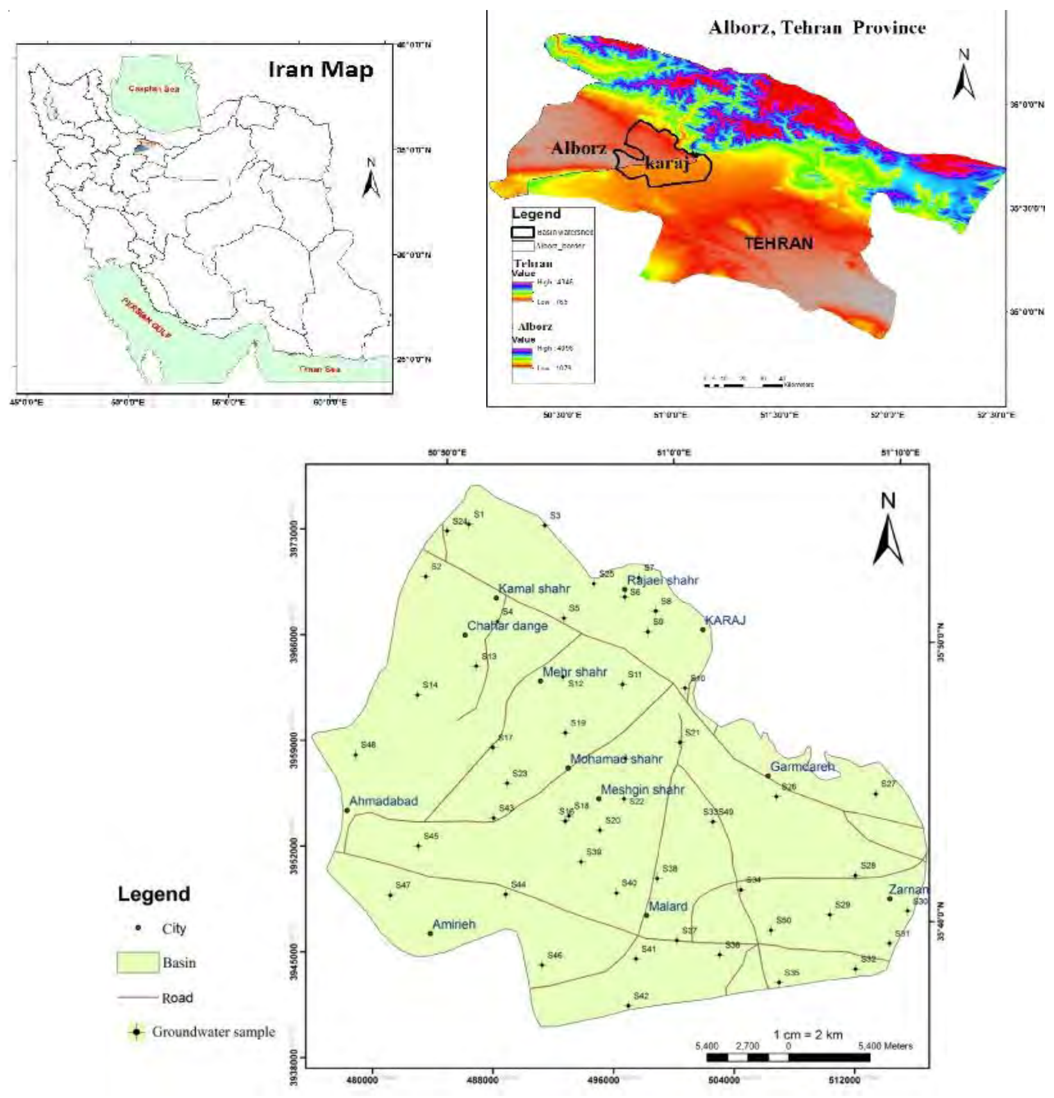
longitudes 47°122, to 48°102 E covering an area of 900 sq km. The average height of the region is 1500 m above MSL. The most important city located in this Alborz Province is Karaj. Figure 1 Intense agricultural and urban development has placed a high demand on groundwater resources, especially in the Karaj region, and these resources are now at greater risk of contamination. The increasing exploitation due to farming frequently causes deterioration in water quality. Therefore, variations in natural and human activities reflect spatial variations in the hydrochemical parameters of the groundwater. The importance of water quality in human health has also recently attracted a great deal of interest (Pazand *et al.*, 2011). The evaluation and management of groundwater resources require an understanding of hydrogeological and hydrochemical properties of the aquifer (Umar *et al.*, 2001). The importance of the ground waters in the area should not be underestimated because they are sources of water resource for drinking

Figure 1: Location of the Groundwater Sample in the Study Area



and agricultural purposes, not only for the people living in this area but also for those who live in the surrounding areas. In the Karaj area, agriculture is the most important economic activity; thus, a hydrogeochemical investigation was carried out to identify groundwater geochemistry.

MATERIALS AND METHODS

Groundwater samples were collected in polyethylene bottles at 50 groundwater sampling sites for pre-monsoon and post-monsoon (Figure 1) from bore wells. Physico-chemical parameters, such as Electrical Conductivity (EC) and pH were measured in the field immediately after the collection of the samples using portable field meters. The preservation of the samples has been done according to published procedures by adding 65% of HNO_3 until the pH is 2 for major cautions and other bottle stored cool at 4 °C for major anions. Standard methods were adopted for the analysis of the water samples (APHA 1995). The study area map was prepared from the soft copy of the topographic map published by the National Cartographic Centre of Iran produced on a scale 1:25000. The topographic map was updated using Landsat ETM+ images. The produced map was digitized and isoline/ spatial variation/zonation maps were prepared using ArcGIS 10.2 version software. Microsoft Excel was used to transport data to ArcGIS project.

RESULTS AND DISCUSSION

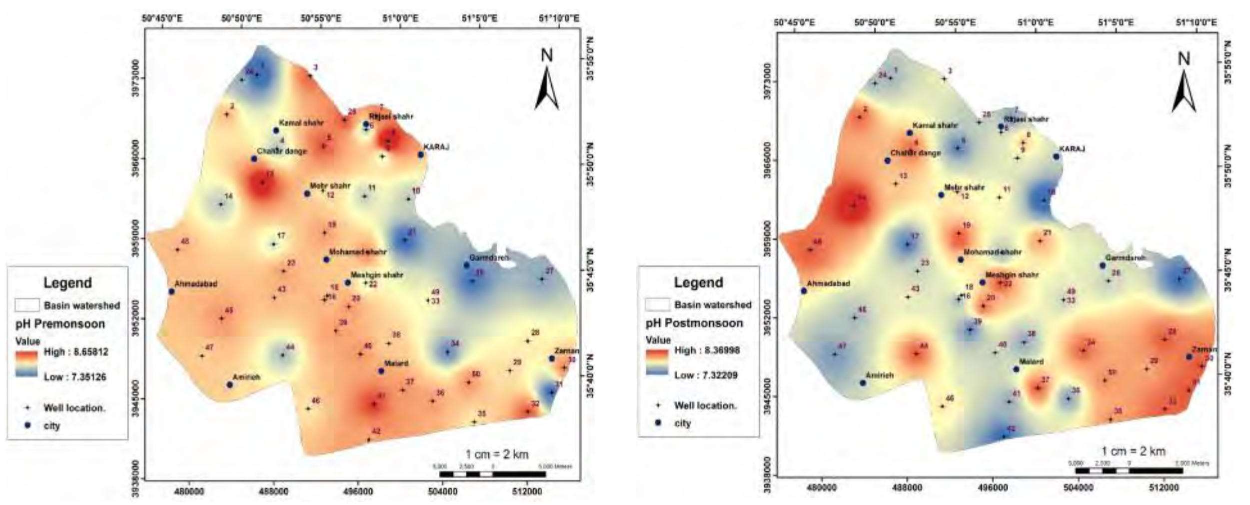
Potential Hydrogen (pH)

The pH of water is an important indication of its quality and provides important information on geochemical equilibrium or solubility calculation (Hem 1985). The Distribution of lesser value of pH indicates that presence of CO_2 in water. Out of 50 water samples for post monsoon permissible limit for drinking purpose. but for pre-monsoon, 48 water samples (96%) have pH values well within the permissible limit for drinking purpose (Figure 2) and only two water sample collected from the study area (4%) showing high pH value than prescribed by BIS.

Electrical Conductivity

Electrical Conductance is a measure of the ability of water to conduct an electrical current-specific

Figure 2: Distribution of pH in Groundwater (Pre and Post-Monsoon) in Karaj Plain



conductance. It has directly proportional with the saltiness (Salinity) or dissolved salt contents in water. The electrical conductivity of water is a measure of the conductance of cubic centimeter of water at 25 °C in micro-Siemens. The range of EC of groundwater in the study area varies between 327-8820 µs/cm and 3389120 µs/cm during pre and postmonsoon respectively (Figure 3) which is detailed in Table 1 as follow:

According to Classification of groundwater based on EC for irrigation purposes (BIS) shown

Table 1: Classification of Groundwater Based on EC

EC Range (Mhos/cm) at 25 °C	Percentage		Water Quality
	Pre-Monsoon	Post-Monsoon	
< 250	Nil	Nil	Excellent
250 750	0.64	0.66	Good
750 2000	0.28	0.26	Permissible
2000 3000	0.06	0.02	Doubtful
>3000	0.02	0.06	Unsuitable

Figure 3: Distribution of EC in Ground Water (Pre and Post-Monsoon)

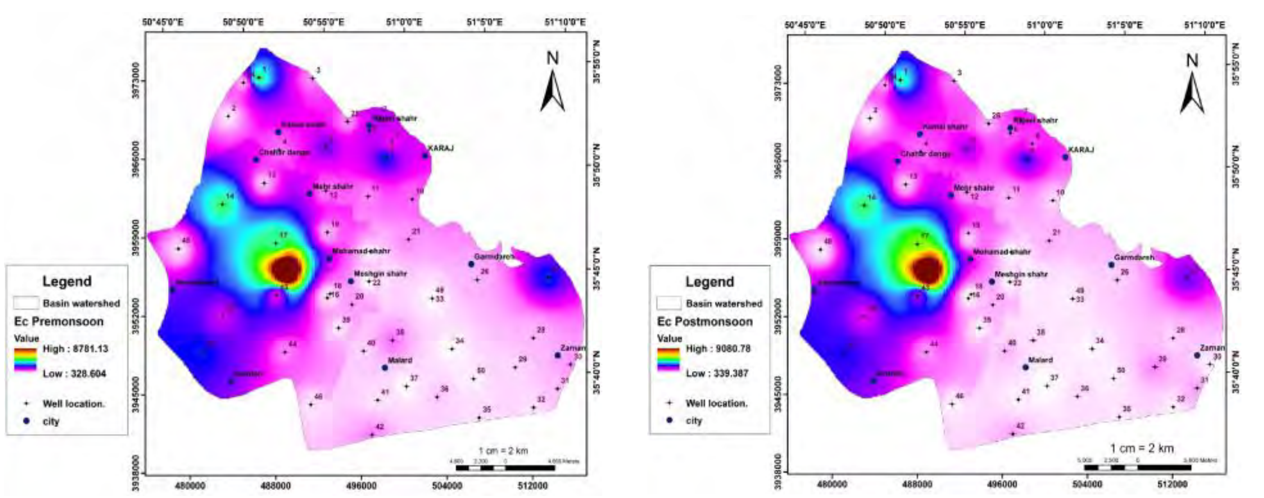


Figure 4: Classification of Groundwater Based on EC for Drinking Purposes (BIS), Pre and Post-Monsoon

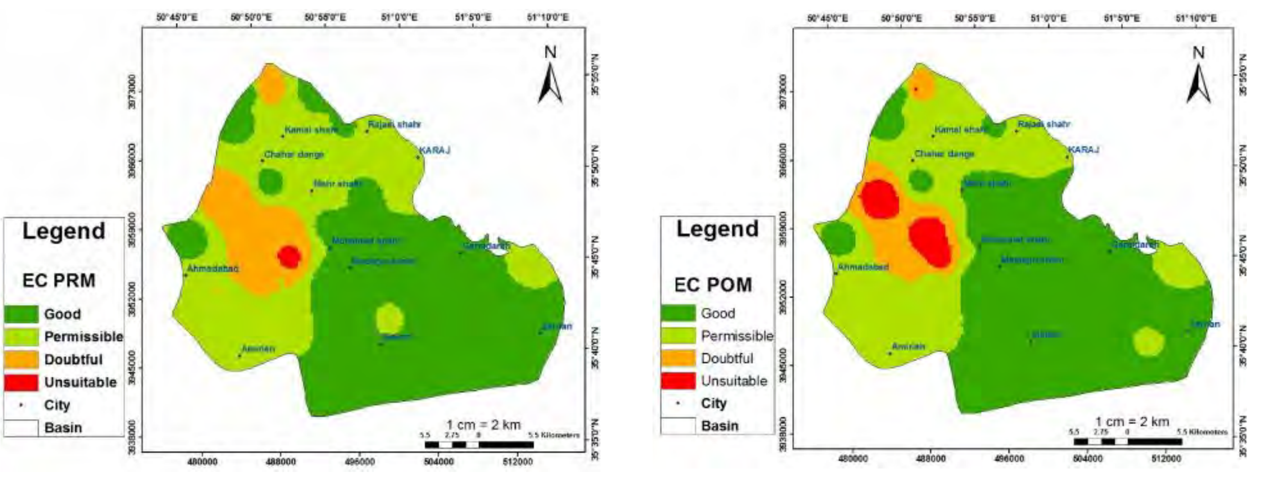


Table 2: Classification of Groundwater Samples of the Study Area

TDS (mg/l)	Class	Number of Samples		In Percentage	
		Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
up to 500 mg/l	Desirable for drinking	35	36	70	72
500 1000 mg/l	Permissible for drinking	8	7	16	14
Up to 3000 mg/l	Useful for irrigation	6	6	12	12
Above 3000 mg/l	Unfit for drinking and irrigation	1	1	2	2

that (Figure 4) in the west to north-west of my study area groundwater is permissible to unsuitable for irrigation.

Total Dissolved Solids

The principal ions contributing to TDS are bicarbonate, carbonate, chloride, sulphate, nitrate, sodium, potassium, calcium and magnesium (US EPA 2002).

The TDS in the ground water samples in the study area ranges from202 - 6172 mg/liter during pre-monsoon and 230 - 5478 mg/liter during post monsoon .TDS percentage for both pre and post monsoon season are given below (Table 2).

The spatial distribution of TDS in ground water (pre and post monsoon) in the study area is presented in Figure 5.

According to Classification of groundwater based on TDS for drinking and irrigation (BIS) shown that (Figure 6) in the south-west of my study area groundwater is Desirable for drinking and good for irrigation.

Cautions

The major caution concentrations (Ca+, Mg+, Na+, K) in the groundwater are below the WHO standards 1993. Magnesium is an alkaline-earth metal and in some aspects of water chemistry, calcium and magnesium may be considered as having similar effects, as in their contribution to the property of hardness. Olivine, biotite, hornblend and augite are among those minerals that make significant contributions in igneous rocks, and serpentine, talc, diopside and tremolite are amongst the metamorphic contributions.

Figure 5: Distribution of TDS in Ground Water (Pre and Post Monsoon)

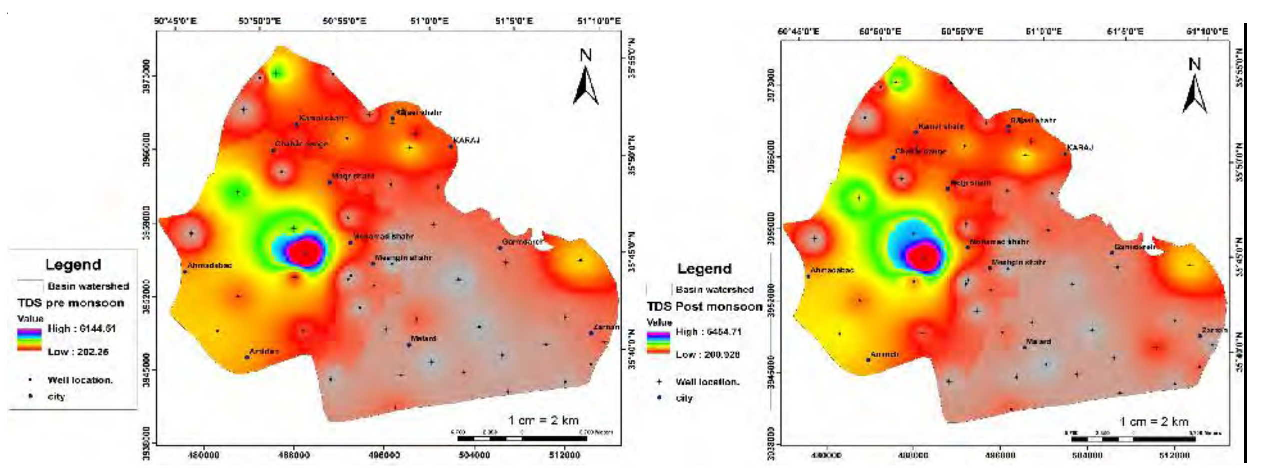
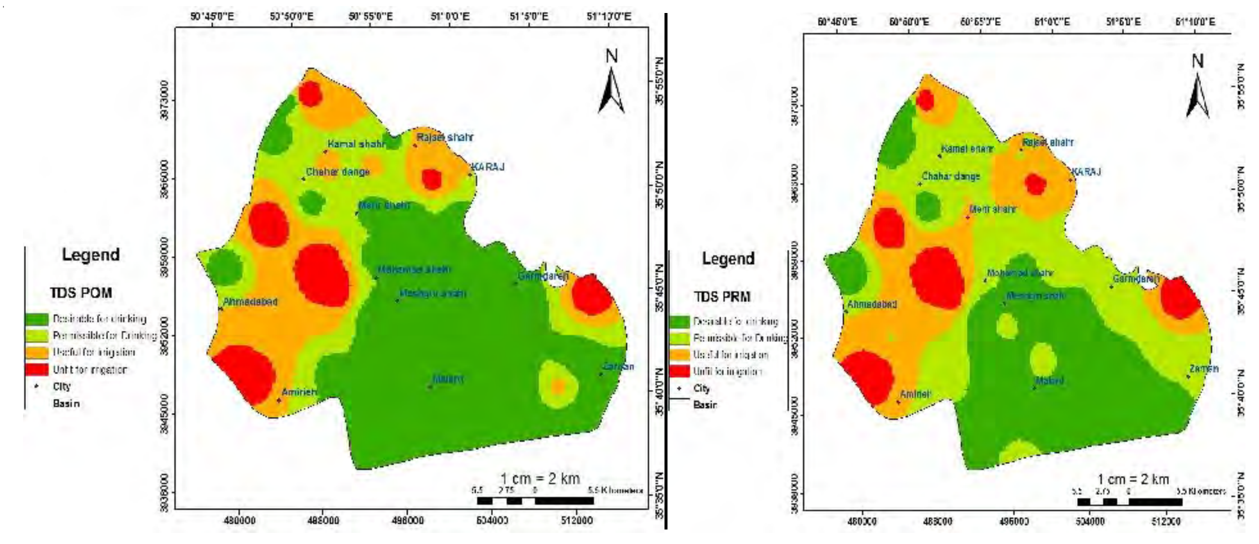


Figure 6: Classification of Groundwater Samples of the Study Area for Drinking and Irrigation, Pre and Post Monsoon



Despite the higher solubility of most of its compounds (magnesium sulphate and magnesium chloride), magnesium usually occurs in fewer concentrations in groundwater than calcium (Nilufer Arshad, 2009).

The concentrations of Ca during pre-monsoon season vary from 0.31 to 31.20 mg/l with an average of 3.85 mg/l. The concentration of Ca during post monsoon season varies from 0.7 to 30.4 mg/l with an average of 3.99 mg/l. The limit of Ca for drinking water is specified as100 mg/l (WHO, 1993). Mg content in the study area varies from 0.20-12.80 mg/l with an average of 1.82 mg/l and 0.25-12.8 mg/l with an average of 1.93 mg/l during pre-monsoon and post-monsoon respectively. The limit of K for drinking water is specified as 25 mg/l (WHO, 1993).

Potassium in fertilizers is strongly held by clay particles in the soil. Therefore, leaching of potassium through the soil profile and into groundwater is important only on coarse-textured soils. Potassium is common in many rocks and is relatively soluble. Hence potassium concentrations in groundwater increase with time. The potassium content of groundwater in the area in pre monsoon ranges from 0.01 to 0.16 mg/l and 0.01 to 0. 08 mg/l in post monsoon.

Sodium does not occur as an essential constitute of many of the principal rock-forming minerals, plagioclase feldspar being the exception. Plagioclase is the primary source of most sodium in groundwater; in areas of evaporitic deposits halites important. In the area, pre-monsoon ranges from 0.4 to 50 mg/l and in post monsoon range from 0.43 to 47.5 mg/l. there is no health-based drinking water standard for Sodium and Potassium. High intake of Sodium may lead to hypertension and be a concern for people with heart conditions.

Anions

The major Anions concentrations (Cl, CO_3, HCO_3, SO_4) in the groundwater are below the WHO standards 1993. Chloride is present in all types of water, in most of rocks and minerals. The important sources are sodalite, apatite, connate water and hot springs. Chloride does not enter into ion exchange process and in water, it is a strong oxidizing agent (Kantharaj, 2001). The Cl concentration varies from 0.30- 45.60 mg/l with an average of 2.99 mg/l and 0.40-44.0 mg/l with an average of 3.21 mg/l during pre-monsoon and post-monsoon seasons respective. The limit of chloride concentration for drinking water is specified as 600 mg/l (WHO, 1993).

The concentration of Sulphate ions in water can be affected by Sulphate-reducing bacteria, the products of which are hydrogen sulphide and carbon dioxide. Hence, a decline is a Sulphate ion frequently is associated with an increase in bicarbonate ions (Fred Bell, 1998). Higher concentration of Sulphate could cause a cathartic action on human beings and also cause respiratory problems (Maiti, 1982; Subha Rao, 1999; and Subha Rao *et al.*, 2002).

The carbonate and bicarbonate ions combine with calcium and magnesium and precipitate as calcium carbonate or magnesium carbonate. This precipitation increases the SAR in the soil solution because it lowers the dissolved calcium concentration. The bicarbonate hazard of water may be express as Residual Sodium Carbonate (RSC) which is calculated as:

$$RSC = (HCO_3 + CO_3) - (Ca + Mg)$$

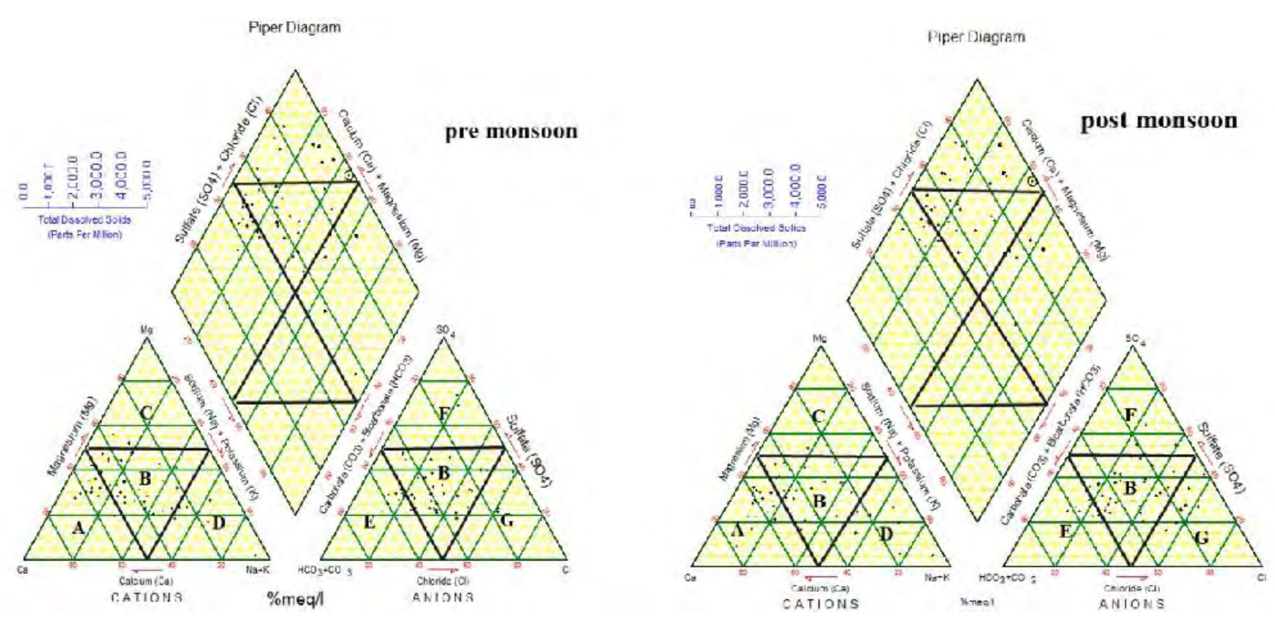
where, the concentration of ion mq/l.

According to Richard's classification of RSC (1954), almost the groundwater water samples fall under the safe for irrigation category. This is an indication that the carbonates and bicarbonates of the water samples are not in excess of alkaline earth metals.

Hydrogeochemical Facies

Hydrochemical characteristics of the groundwater of the pre-monsoon and post-monsoon can be evaluated based on the region of plots of the epm percentages of cations and anions on Piper's

Figure 7: Piper Trilinear Diagrams for PRM and POM Seasons Respectively



Note: Legend: A-Calcium type, B-No Dominant type, C-Magnesium type, D-Sodium and potassium type, E-Bicarbonate type, F-Sulphate type, G-Chloride type.

trilinear diagram (Piper, 1944). Chemical data of the study areas are presented by plotting them on a Piper tri-linear diagram for pre-monsoon and post-monsoon (Figure 7). Hydrochemical characteristics of the groundwater of the pre-monsoon and post monsoon can be evaluated based on the region of plots of the epm percentages of cations and anions on Piper's trilinear diagram (Piper, 1944).

USSL Classification

The USSL Diagram has been used to understand the alkali hazard of the groundwater samples for the study area, because this interpretation is very much useful for judging the quality of groundwater for the use of agricultural purpose (Todd, 1980). Where the sodium adsorption ratio is plotted against specific conductance. The sixteen classes in the diagram indicate the extent that waters can affect the soil in terms of salinity hazard as low (C1), medium (C2), high (C3), and very high (C4) and similarly sodium hazard as low (S1), medium (S2), high (S3) and very high (S4). Based on the quality of ground water on the basis of % of Na (Wilcox, 1955) and quality on the basis of SAR (USSL, 1954) the ground water in Karaj plain is classified into different categories (Figure 8 and Tables 3 and 4).

Figure 8: US Salinity Diagram (Pre and Post-Monsoon)

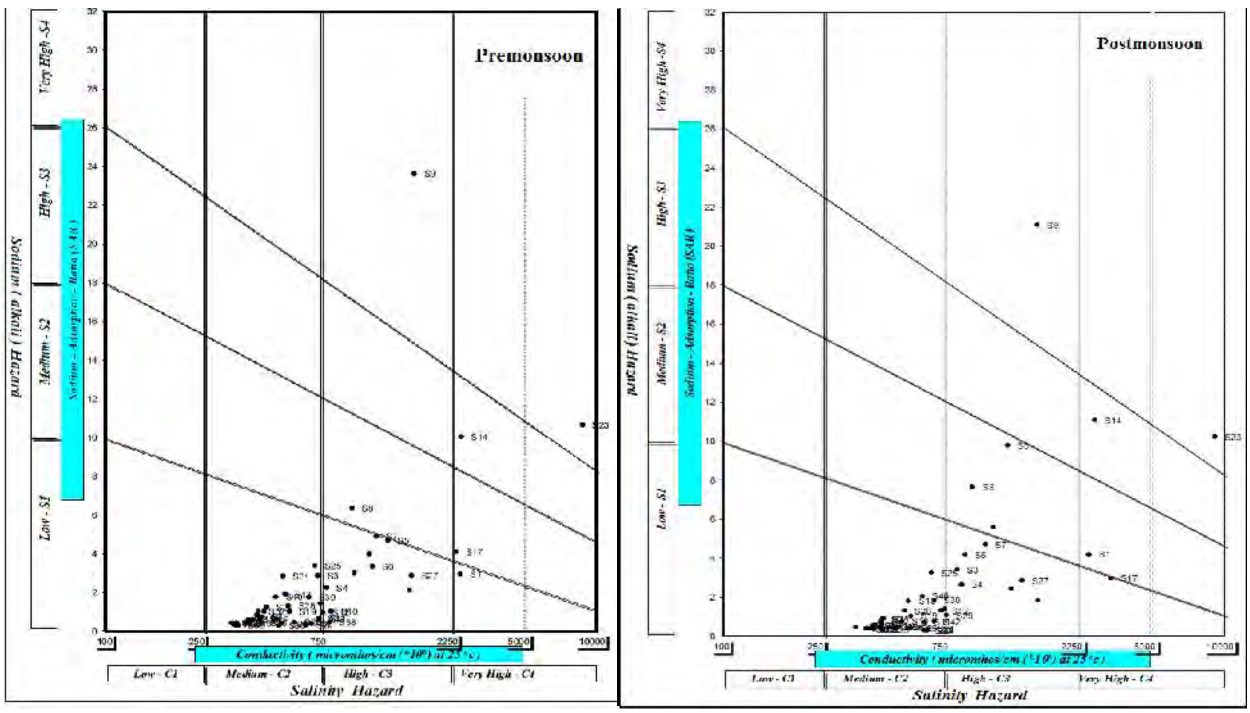


Table 3: Percentage of Each Class USSL Classification for Agricultural Purposes for Pre-Monsoon

C1				C2				C3				C4			
S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4
0	0	0	0	64	0	0	0	24	2	0	2	2	2	2	2

Table 4: Percentage of Each Class USSL Classification for Agricultural Purposes for Post-Monsoon															
C1				C2				C3				C4			
S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4
0	0	0	0	66	0	0	0	18	6	0	2	2	2	2	2

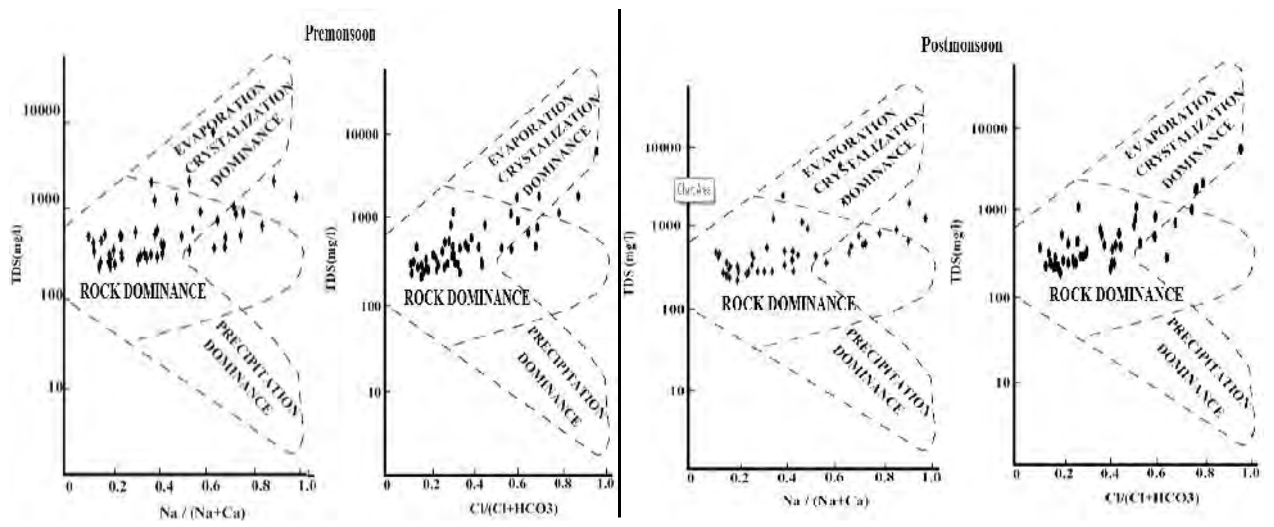
Sodium Absorption Ratio (SAR)

Sodium concentration in ground water is important since the increase of sodium concentration in water effect deterioration of the soil properties reducing permeability (Kelley, 1951). The relative activity of sodium ion in the exchange reaction with soil is expressed in terms of a ratio known as sodium adsorption ratio. It is an important parameter for determining the suitability of irrigation water, because it is a measure of alkali sodium hazard for crops (Richards, 1954). Groundwater of the study area could be also classified based on SAR as excellent (10), good (10-18), doubtful (18-26) and unsuitable (>26). According to SAR analysis, almost all the water samples (pre and post monsoon) have the good quality and suitable for irrigation.

Gibb's Diagram

The mechanism controlling chemical relationships of groundwater based on aquifer Lithology and nature of geochemical reactions and solubility of interaction rocks has been studied following Gibbs (1970) and Viswanathaiah *et al.* (1978). The source of the dissolved ions in the groundwater can be understood by a Gibbs diagram (Gibbs, 1970). It is a plot of $(Na^{+} + K^{+})/(Na^{+} + K^{+} + Ca^{+2})$ vs. TDS and $Cl_{-}/(Cl_{-} + HCO_{3-})$ vs. TDS. The Gibbs plot of data from the study area (Figure 9) indicates that the rock is the almost dominant processes controlling the major ion composition of groundwater for PRM and POM. Indicate that the groundwater samples of the study area overlap in the rock-water interaction and evaporation dominance categories. Recharge of the aquifers of the study area takes place by the river water and/or rainwater and water table in

Figure 9: Mechanism Controlling the Chemistry of Groundwater During Pre- and Post-Monsoon Season



most part of the study area is shallow. These factors might have caused the groundwater samples to fall in the overlapping zone of rock-water interaction and evaporation dominance categories.

CONCLUSION

For this study, 50 groundwater samples were collected from dug and bore wells during May 2012 (Pre-monsoon) and October 2012 (Post-monsoon) and analyzed for pH, electrical conductivity and major ions. Results suggest that the abundance of the major ions in groundwater is in following order: Mg > Ca > Na > K and HCO_3 > SO_4 > Cl > NO_3 > CO_3 respectively for per-monsoon and post-monsoon.

The concentration in the study area shows good correlation with Na, Cl, Mg and also K, which indicates that these ions had been derived from the same source.

Gibb's plot reveals that the mechanisms responsible for controlling the chemical composition of the groundwater are both rock-water interaction and evaporation. Box plat shows that the concentrations of major ions in groundwater for the post-monsoon are greater than for the pre-monsoon. Na, Cl and SO_4 show an increasing trend during POM, due to the effective leaching from rock matrix along with anthropogenic activities.

Piper trilinear diagram shows a majority of water samples irrespective of seasons fall in mixed Na-Cl type with minor representations from mixed Ca-Mg-Cl, mixed Ca-Na-HCO_3, Ca-Cl, and Ca-HCO_3 types.

Schoeller diagram shows that groundwater acceptable for drinking purposes in the area of study for POM and POM.

US salinity diagram reveals that US salinity diagram illustrates that almost 65% of the groundwater samples fall in the field of C2S1.

REFERENCES

1. APHA (1995), *Standard Methods for the Examination of Water and Wastewater*, 19th Edition, American Public Health Association, Washington DC.
2. Back W (1966), "Hydrochemical Facies and Groundwater Flow Patterns in the Northern Part of the Atlantic Coastal Plain", USGS Prof., pp. 498- A.
3. Drever J I (1982), "The Geochemistry of Natural Waters", Prentice-Hall, Englewood Cliffs, NJ, USA.
4. Fred G Bell (1998), "Environmental Geology-Principles and Practice", p. 594, Blackwell Science Ltd.
5. Gibbs R J (1970), "Mechanism Controlling World's Water Chemistry", *Science*, Vol. 170, pp. 1088-1090.
6. Hem J D (1985), "Study and Interpretation of the Chemical Characteristics of Natural Water", *USGS Water Supply Paper*, Vol. 2254, pp. 117-120.
7. Kantharaj T (2001), "Integrated Water Resources Studies in Hemavathi and Yagachi River Basins Around Alur Taluk, Hassan District, Karnataka, India", Ph.D Thesis, Geology Department, Mysore University.
8. Kelley W P (1951), "Alkali Soils-Their Formation Properties and Reclamation", Reinold Publ. Corp., New York.
9. Maiti T C (1982), "The Dangerous Acid Rain", *Sci Report*, Vol. 9, No. 6, pp. 360-363.

10. Nilufer Arshad (2009), "Environmental Management of Water Resources for Sustainable Development in Western Part of Hunsur, Karnataka, India", Using Remote Sensing and Gis., Ph.D. Thesis, Geology Department, Mysore University.

11. Pazand K, Hezarkhani A, Ghanbari Y and Aghavali N (2011), "Groundwater Geochemistry in the Meshkinshahr Basin of Ardabil Province in Iran", *Environ Earth Sci.,* Vol. 65, pp. 871-879.

12. Piper A M (1953), "A Graphic Procedure in the Geochemical Interpretation of Water Analyses", *Trans. US Geol. Surv. Groundwater Notes*, Vol. 12.

13. Richards L A (1954), "Diagnosis and Improvement of Agriculture Handbook", *Saline and Alkali Soil*, US Department of Agriculture, p. 60.

14. Srinivasamoorthy K, Nanthakumar C, Vasanthavigar M, Vijayaraghavan K, Rajivgandhi R, Chidambaram S, Anandhan P, Manivannan R and Vasudevan S (2011), "Groundwater Quality Assessment from a Hard Rock Terrain, Salem District of Tamilnadu, India", *Arab J Geosci*, Vol. 4, pp. 91-102.

15. Subba Rao N and Prathap Reddy R (1999), "Groundwater Prospects in a Developing Satellite Township of Andhra Pradesh, India", *J. Indian Soc Remote Sensing*, Vol. 27, No. 4, pp. 193-203.

16. Subba Rao N, Prakasa Rao J, John Devadas D, Srinivasa Rao K V, Krishna C and Nagamalleswara Rao B (2002), "Hydrogeochemistry and Groundwater Quality in a Developing Urban Environment of a Semi-Arid Region, Guntur, Andhra Pradesh, India", *Journal of the Geological Society of India*, Vol. 59, pp. 159-166.

17. Todd D K (1980), *Groundwater Hydrology*, 2nd Edition, p. 535, John Wiley and Sons, New York.

18. Umar A, Umar R and Ahmad M S (2001), "Hydrogeological and Hydrochemical Framework of Regional Aquifer System in Kali-Ganga Sub-Basin India", *Env Geol,* Vol. 40, Nos. 4-5, pp. 602-661, doi:10.1007/s00254000021.

19. US EPA (2002), "Methods for Chemical Analysis of Water and Waste", EPA-600/4-79-020, US Environ, Protection Agency, Cincinnati, Ohio, USA.

20. US Salinity Laboratory (1954), "Diagenesis and Improvement of Saline and Alkali Soils", US Dept. Agriculture Handbook, Vol. 60, p. 160, Washington DC.

21. Viswanathaiah M N, Sastri J C V and Rame Gowda B (1978), "Mechanisms Controlling the Chemistry of Groundwater of Karnataka", *Indian Mineralogist*, Vol. 19, pp. 65-69.

22. WHO (1993), "Guidelines for Drinking-Water Quality", Recommendations, Geneva: WHO, Vol. 1, pp. 1-4.

23. Wilcox L V (1955), "Classification and Use of Irrigation Water", p. 969, US Dept. of Agriculture, Circular.