



Characterisation of Groundwater Quality and its Suitability Study in Parts of Lower Vellar Watershed, Cuddalore District, Tamilnadu

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ABSTRACT

Groundwater quality from a part of lower Vellar watershed has been examined to characterize the geochemical conditions and its suitability for domestic and agricultural uses. The water samples were collected from shallow bore wells at different locations of the study area. The physico-chemical attributes such as pH, electrical conductivity, Ca^{2+} , Na^+ , Mg^{2+} , K^+ , HCO_3^- , Cl^- , SO_4^{2-} , hardness, total dissolved solids (TDS) and nitrate were analysed using standard laboratory tests. The other determinants such as sodium adsorption ratio, percent sodium (Na %), residual sodium carbonate (RSC) were calculated from the observed data. The pH and electrical conductivity varied from 4.47 to 9.46 and 500 $\mu\text{mhos/cm}$ to 6710 $\mu\text{mhos/cm}$ respectively. The TDS and total hardness ranged from 323.0 mg/L to 4363.0 mg/L and 18.2 mg/L to 964.0 mg/L respectively. The range of chemical concentration of cations such as Ca^{2+} , Na^+ , Mg^{2+} , K^+ was traces to 62.2 mg/L, 19.4 to 196.9 mg/L, 6.3 to 333.90 mg/L, 0.08 to 167.70 mg/L, while that of anions HCO_3^- , Cl^- and SO_4^{2-} was traces to 6.0 mg/L, 38.0 to 1392.0 mg/L and 5.0 to 80.0 mg/L respectively. Nitrate varied from traces to 1.0 mg/L. The graphical interpretation of modified Piper trilinear, USSL and Gibb's diagrams represent $\text{Ca}^{2+} > \text{Na}^+$ and $\text{Cl}^- > \text{SO}_4^{2-}$ facies, C_1S_1 field and rock-water interaction respectively. The result shows that most of the samples were not exceeded the maximum permissible limit of prescribed standard for drinking by ISI and hence, it is suitable for drinking, industrial and irrigational purposes. The level of precipitation, interaction with formation and discharge nature of the study area could have considerable contribution.

INTRODUCTION

Groundwater is a precious natural resource for several vital functions such as public, industries and agricultural water supply. Now-a-days, the increasing effects of pollution due to overexploitation of groundwater have become serious threats. Hence, water is going to become major issue and chief commodity in the coming decades. Safe drinking water is a vital requirement for human beings and its availability is important for the overall socioeconomic development of a nation (Llamas 1993). The quality of the water is equally essential to assess its suitability for different purposes. The quality of the surface water and groundwater depends upon variation in geological formation and soil types. In the initial period, the water quality deterioration was low, but if it is not controlled at the right time this water will not be suitable for most of the purposes (Ragunath 1983). It is impossible to control the dissolution of the constituents in water after they enter the ground (Pojasek 1977, Johnson 1979).

STUDY AREA

The study area lies at the latitude of $11^\circ 25'$ to $11^\circ 3'$ and the longitude of $79^\circ 36'$ to $79^\circ 40'$ located in the Cuddalore district of Tamil Nadu state (Fig. 1). The charnockites and magmatic gneisses (basement) of Archaean age is the oldest

formation whereas the older sedimentary rocks of the Cretaceous age and younger sedimentaries of the Mio-Pliocene age followed it. Lateritic soil cover over Mio-Pliocene sediments is widely distributed in central part of the district. Fresh groundwater has been observed in the tertiary semi-consolidated sandstone and sands of the Cuddalore series. Most of the aquifers in the Cuddalore series are extensive and interconnected, and due to this water can move to greater distances through them. Laterite and lateritic gravels overlie a large part of the area, underlined by Cuddalore sandstone. This formation serves as a good aquifer in many places. The elevation is approximately about 5.75m above the mean sea level. The maximum and minimum temperatures of the study area are 37.2°C and 21.6°C respectively. The precipitation is mainly from the northeast monsoon. The maximum and minimum annual rainfall received is 1400 mm and 1200 mm respectively.

MATERIALS AND METHODS

To comprehend the hydrogeochemistry, 34 bore well samples were collected using standard procedures. The groundwater sample locations are shown in Fig. 2. The analyses were carried out for the major cations Ca^{2+} , Na^+ , Mg^{2+} , K^+ and anions Cl^- , HCO_3^- , SO_4^{2-} . The pH

and electrical conductivity (EC) were also determined and total dissolved solids (TDS), sodium adsorption ratio (SAR), percent sodium (Na %) and residual sodium carbonate (RSC) were calculated. For understanding the groundwater usage, hydrogeo-chemical facies and mechanism of controlling the concentration level, the data have been analysed and interpreted using software WATCLAST (Chidambaram et al. 2004).

RESULTS AND DISCUSSION

pH: The pH of water is an important indication of its quality and provides important piece of information in many types of geochemical equilibrium or solubility calculations (Hem 1985). The pH of the groundwater in the study area varied from 4.47 to 9.46. It indicates that all the samples are within the limits of the water quality standards for drinking specified as 6.5 to 9.1 in WHO (1993).

Electrical conductivity (EC): Electrical conductivity of the groundwater ranged from 500 to 6710 $\mu\text{mho}/\text{cm}$. The conductivity measurement provides an indication of ionic concentrations. It depends upon temperature, concentration and

types of ions present (Hem 1985).

According to the drinking water quality standards of WHO (1993), the desirable and permissible limits of EC is specified as 400 and 2000 $\mu\text{mho}/\text{cm}$ at 25°C respectively. The classification proposed by Wilcox (1955) has shown the suitability of water for its usage. Based on the above classification, all the groundwater samples are within the permissible limit and comes under excellent category (Table 1).

Total dissolved solids (TDS): The principal ions contributing to TDS are bicarbonate, carbonate, chloride, sulphate, nitrate, sodium, potassium, calcium and magnesium (EPA 1976). The water samples have been classified based on the concentration of TDS (USSL 1954) (Table 2). It shows that most of the groundwater samples are within the acceptable limit as useful category, which can be utilized for both domestic and irrigational purposes. Nevertheless, nine samples were in unfit category.

Cations: In the present study, the major cations like Ca^{2+} ,



Fig. 1: Location map of the study area.



Fig. 2: Sample locations.

Table 1: Classification of EC values according to Wilcox (1955).

Classification	Value Range (ppm)	No. of Samples
Excellent	< 250	34
Good	250 - 750	Nil
Permissible	750 - 2250	Nil
Doubtful	2250 - 5000	Nil
Unsuitable	> 5000	Nil

Table 2: Classification of TDS values according to USSL (1954).

Classification	Value Range (ppm)	No. of Samples
Desirable	Less than 200	Nil
Permissible	200 - 500	06
Useful	500 - 1500	18
Unfit	1500 - 3000	09

Table 3: Subdivision and characters of diamond field.

Sl. No.	Subdivision of Diamond field	Characters	No. of samples
1	1	High Ca + Mg & SO ₄ + Cl	13
2	12	Water contaminated with gypsum	21

Table 4: Classification of sodium percentage.

Classification	Value Range (ppm)	No. of Samples
Excellent	< 20	04
Good	20 - 40	15
Permissible	40 - 60	12
Doubtful	60 - 80	02
Unsuitable	> 80	01

Na⁺, Mg²⁺ and K⁺ were analysed. The Ca²⁺ concentration varied from not detectable to 62.2 mg/L. The limit of Ca²⁺ for drinking water is specified as 100 mg/L (WHO 1993). The magnesium concentration varied from 6.3mg/L to 333.90 mg/L. The limit of magnesium for drinking water is 30 mg/L (WHO 1993). Similarly, the sodium concentration varied from 19.4 mg/L to 196.6 mg/L. The limit for drinking water is specified as 175 mg/L (WHO 1993). The potassium concentration ranged from 0.8 mg/L to 167.70 mg/L. The limit of K⁺ for drinking water is specified as 25 mg/L (WHO 1993).

Anions: The major anions like Cl⁻, SO₄²⁻ and HCO₃⁻ were analysed in the study. The Cl⁻ concentration varied from 38.0 mg/L to 1392.0 mg/L. The limit of chloride concentration for drinking water is 600 mg/L (WHO 1993). The bicarbonate varied from traces to 6.0 mg/L, and sulphate concentration from 5.0 mg/L to 80.0 mg/L. The limit for sulphate in drinking water is specified as 250 mg/L (WHO 1993). The

sample locations are within the limit and some of the samples are above the permissible limit due the exchange of ions in the study area. Apart from the natural rock sources, sulphates could be introduced through the application of sulphatic soil conditioners (Karanth 1987). The NO₃⁻ was found maximum at 1 mg/L in few locations, whereas in other locations it was at much lesser concentration.

Chemical relationship: Among the various Trilinear methods of plotting such as Palmer (1911), Hill (1940) and Piper (1953), Piper's diagram has been extensively used for understanding problems about the geochemical evolution of groundwater (Karanth 1987). The Trilinear diagrams of Piper are very useful in bringing out the chemical relationships among groundwaters in more definite terms (Walton 1970). Hence, the present groundwater samples have been plotted with a modified Piper diagram of diamond field Piper (Fig. 3). The plotted samples were distributed in 1 and 12 of the diamond field. The distribution and characterization of the groundwater samples are given in Table 3.

Sodium adsorption ratio (SAR): The SAR is one of the useful parameters for judging the quality of groundwater for use in agricultural purposes (Todd 1980, Balasubramanian 1986, Sastri & Lawrence 1988). The USSL diagram prepared for the groundwater samples of the study area is shown in the Fig. 4. Richards (1954) classified the waters in relation to irrigation based on the ranges of SAR values. The study area groundwater samples have been observed as C₁S₁ and C₁S₂ category which shows that the water has low salinity and low sodium hazards.

Sodium percentage: Percent sodium in water is a parameter computed to evaluate the suitability for irrigation (Wilcox 1948). Excess sodium combining with carbonate will lead to the formation of alkaline soils while with chloride the saline soils are formed. Either of the soils will not support growth of plants. The groundwater samples of the study area were classified as given in Table 4. This classification indicates that most of the groundwater are suitable for irrigational purpose.

Residual sodium carbonate (RSC): In addition to total dissolved solids, the relative abundance of sodium with respect to alkaline earths and boron and the quantity of bicarbonate and carbonate in excess of alkaline earths also influence the suitability of water for irrigation purposes. This excess is denoted by residual sodium carbonate (RSC) and determined as suggested by Richards (1954). The water with high RSC has high pH and land irrigated by such water becomes infertile owing to deposition of sodium carbonate as known from the black colour of the soil (Eaton 1950). According to U.S. Salinity Laboratory (1954), an RSC of less than 1.25 meq/L is safe for irrigation, values between 1.25 and 2.5 meq/L are

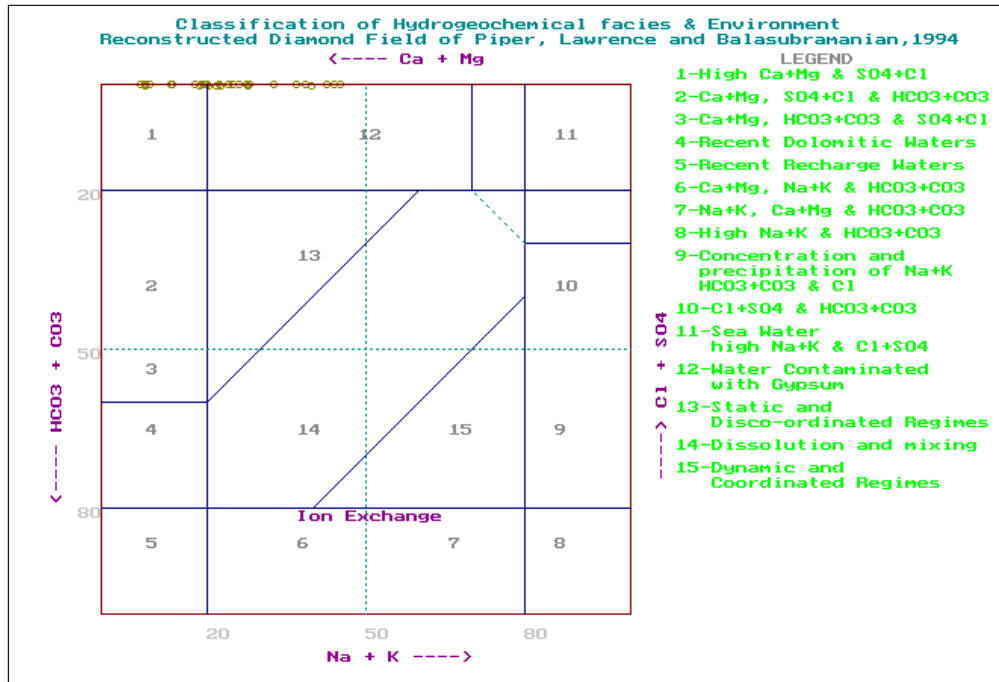


Fig. 3: Modified diamond field of Piper.

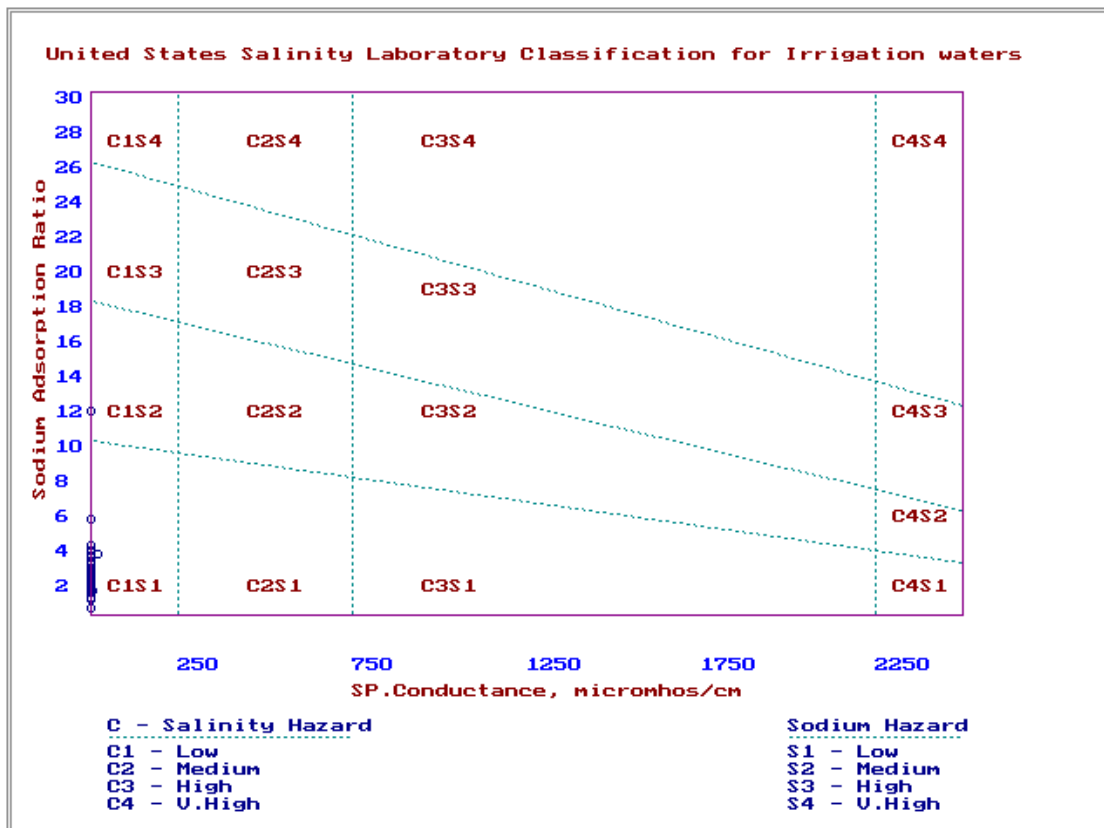


Fig. 4: USSS diagram.

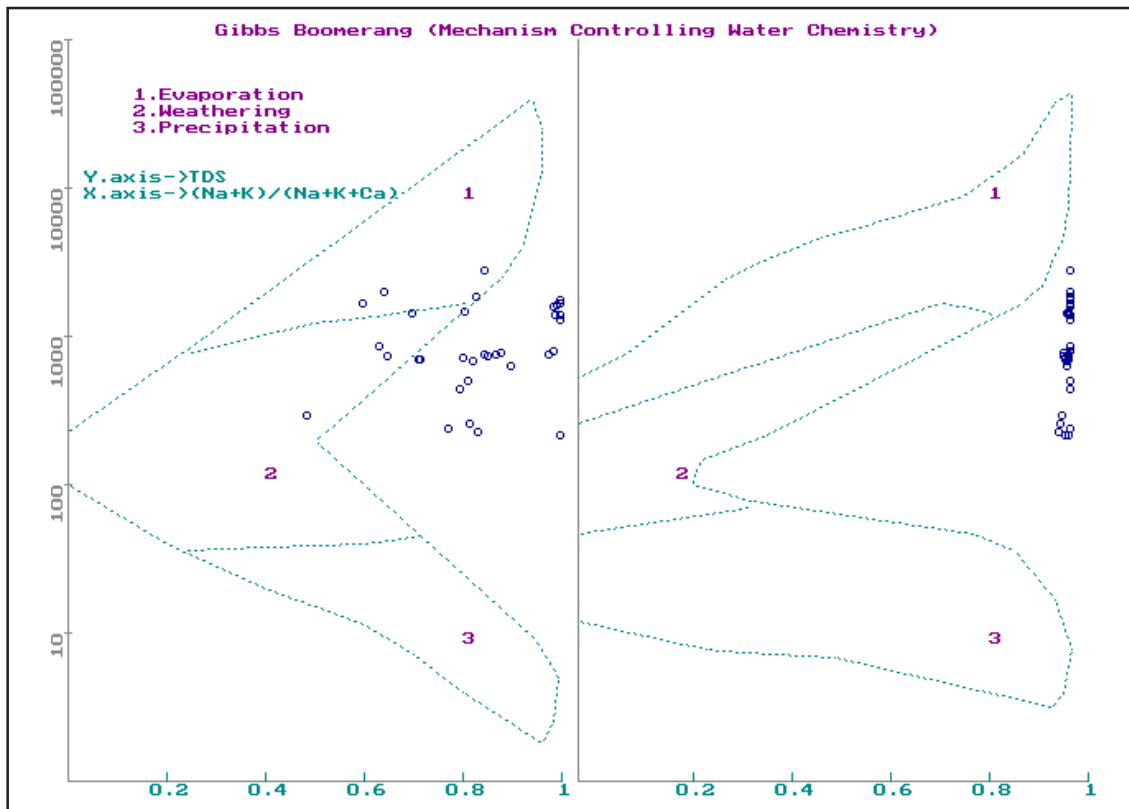


Fig. 5: Gibb's plot.

of marginal quality and values of more than 2.5 meq/L are unsuitable for irrigation. In the study area, all the water samples were with less than 1.25 meq/L RSC, which indicates that they are suitable for irrigational purposes.

Gibb's diagram: Gibbs (1970) proposed a diagram to understand the relationship of the chemical components of water from their respective aquifer lithology. The Gibb's ratio-I, $Cl/(Cl + HCO_3)$ for anions and ratio-II, $Na + K/(Na + K + Ca)$ for cations of the samples are plotted separately against respective values of the total dissolved solids (Fig. 5). From these interpretations, it could be confirmed that the chief mechanism controlling the chemistry of groundwaters of the study area are dominated by rock water interaction but some of the locations fell in evaporation dominance zone.

CONCLUSION

The present study area groundwater quality has not exceeded the maximum permissible limit of the standards prescribed by WHO, but in many sample locations the waters were identified with high concentration of major cations such as Ca and Mg. In the anions part, the chloride is the dominating ion, which was observed in all the sample locations of the study area. Major ionic relationships indicate that weathering

reactions have insignificant role in the hydrochemical processes of the shallow groundwater system. Dissolution of carbonate minerals adds significant amount of Ca^{2+} and Mg^{2+} to the groundwater. The modified Piper and Gibb's diagrams too have shown the indications of ionic source from the host rock and rock water interaction respectively. Besides, releasing of elements, infiltration rate and groundwater discharge nature of the study area could have considerable contribution. Though, the study is a preliminary attempt, it helped to characterize the hydrogeological parameters role in groundwater chemistry and quality.

REFERENCES

- Balasubramanian, A. 1986. Hydrogeological investigations in the Tambaraparani River basin, Tamilnadu. Unpublished Ph.D. Thesis, University of Mysore.
- Chidambaram, S., Ramanathan, A.L., Srinivasamoorthy, K. and Ananthan, P. 2004. WATCLAST-A computer program for hydrogeochemical studies. Recent Trends in Hydrogeochemistry (Case Studies from Surface and Subsurface Waters of Selected Countries). Published by Capital Publishing Company, New Delhi, pp. 203-207.
- EPA 1976. Quality Criteria for Water, Environmental Protection Agency, Washington DC., USA.
- Eaton, F.M. 1950. Significance of carbonates in irrigated waters. Soil. Sci., 69: 127-128.

- Gibbs, R.J. 1970. Mechanism of controlling world's water chemistry. *Science*, 170: 1088-1090.
- Hem, J. D. 1985. Study and interpretation of the chemical characteristics of natural water. U.S. Geol. Survey, Water Supply paper-2254, 264 p.
- Johnson, C.C. 1979. Land application of waste - An accident waiting to happen. *Groundwater*, 17(1): 69-72.
- Karanth, K.R. 1987. *Groundwater Assessment Development and Management*. Tata McGraw -Hill Company Limited, New Delhi, 720 p.
- Llamas Ramon 1993. All of US, Environmental education dossiers, Centre UNESCO de Catalunya, Mallorca, 4: 285.
- Palmer, C. 1911. The geochemical interpretation of water analysis. *USGS Bull. No. 479*, 31 p.
- Piper, A.M. 1944. A Graphical procedure in the chemical interpretation of groundwater analyses. *Trans. Amer. Geophy. Union*, 25: 914-923.
- Pojasek, R.B. 1977. *Drinking Water Quality Enhancement Through Protection*. Ann Arbor Science Publishers Inc., Ann Arbor, Michigan, 614p.
- Raghunath, H.M. 1983. *Groundwater*. Wiley Eastern, New Delhi, p. 459.
- Richards, L.A. 1954. *Diagnosis and improvement of saline and alkali soils*. USDA, Handbook, No. 60, p. 160.
- Todd, D.K. 1980. *Groundwater Hydrology*, 2nd Edn. John Wiley and Sons, New York, pp. 535.
- U. S. Salinity Laboratory 1954. *Diagnosis and Improvement of Saline and Alkali Soils*. U.S. Deptt. Agriculture, Hand book-60, Washington DC., 160 p.
- Walton, W.C. 1970. *Groundwater Resource Evaluation*. McGraw Hill Book Co., New York, 664 p.
- Wilcox, L.V. 1955. *Classification and use of irrigation water*. U.S. Deptt. of Agriculture, Circular 969.
- WHO 1993. *Guidelines for Drinking Water Quality, Recommendations*. World Health Organization, Geneva.