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IDENTIFICATION OF GROUNDWATER CHEMISTRY AND HYDROGEOCHEMICAL PROCESSES IN PARTS OF QUILON, SOUTH WEST INDIA

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ABSTRACT

Assessment of spatio-temporal and seasonal variations in the hydrochemical characteristics of groundwater is one of the dynamic fields of research in the present world. Water samples from different parts of Kollam were assessed to identify groundwater chemistry of varying water types and determine their hydrochemical facies. Based on the seasonal variation of 35 samples analyzed for 17 water quality variables the levels of groundwater contamination and spatial distribution of groundwater chemistry are controlled by anthropogenic pollution and existing natural sources. The chemical characteristics of groundwater in Kollam indicate that water samples are of normal alkaline earth origin with chloride as dominating ion besides the prevalence of bicarbonate, indicating mixed water type. The water in the region is predominantly of blended type as it occupies an intermediate position between fresh and brackish water. Piper and Durov diagram was created to compare the results of water types. The observed chemical characteristics may also be attributed to geology and hydromorphology of the region that existed during the Mio-pliocene times.

Key words: water quality, ion chemistry, drinking water, chemical characteristics

INTRODUCTION

Water is one of essential compounds for all forms of life. Due to its specific characteristics, this liquid bears unique properties. It is the most effective dissolving agent, and adsorbs or suspends many different compounds. It is the chemistry of groundwater that determines the quality of drinking water used for various purposes. The quality of water is a vital concern for mankind since it is directly linked with human welfare required to conserve water resources (Jothivenkatachalam, et.al., 2010).

The quality of groundwater varies from place to place with the depth of the water table. The composition of groundwater depends on many natural factors such as the lithology of the aquifer, the quality of recharge waters and the types of interaction between water and aquifer and also on human activities, which can alter these fragile groundwater systems, either by polluting them or by changing the hydrological cycle. The climate, structure and the position of the rock strata and biochemical effects associated with the biota of the environment control the amount of solutes present in the natural water. Water quality affected by the presence of different soluble salts (Sonawane and Khole, 2010) is a major problem with the groundwater as it once contaminated, is difficult to restore the quality. Therefore the knowledge of hydrogeochemical processes that control its chemical composition leads to improved understanding of the hydrochemical systems. This can contribute to effective management and utilization of ground water resource by clarifying relations among many hydrogeological parameters (Rao, N 2008)

In the present study, an attempt has been made to study the interactions between different components of groundwater and their relationships. To establish qualitative effects of natural and human influence factors on the water quality, the classification, modeling and interpretations of monitoring data are important steps in the assessment of water quality (Sharaf and Subyani 2011). Any fall in the quality of the groundwater may result in big reduction in the percentage of the resources and may create serious problems for the water users (Sharaf, et. al 2005). The abundance of various ions can be modeled in terms of weathering of various rock forming minerals (Singh and Hasnian 1999) while the major source of ions can be ascribed to the Quaternary sedimentary aquifers (Soman 1984). The municipal and industrial wastewater discharge constitutes the major polluting source while surface run-off is the seasonal phenomenon contributing to appreciable levels of pollution. Several researchers have investigated the hydrochemical characteristics of ground water in different urban and semi-urban areas (Sarojini et al. 1997; Subramani et al. 2005; Umar et al. 2006; Pandian and Shankar 2007; Raju 2007).

Water chemicals or hydrochemical facies evaluation is extremely useful in providing idea about the complex hydrochemical processes in the subsurface. Determination of hydrochemical facies was extensively used in chemical assessment of groundwater and surface water for several decades. The method is able to provide sufficient information on the chemical quality of water particularly the origin.

The major ion data were used to characterize Kollam groundwater. The data is presented on box plots, Tri-linear diagram, Durov diagram and Wilcox diagram. Piper diagram is one of the most widely used graphical form in which the hydrochemical concepts can help to elucidate the mechanisms of flow and transport in the groundwater systems. It is an effective tool in segregating analysis data with respect to sources of the dissolved constituents in groundwater, modifications in the character of groundwater as it passes through an area and related geochemical problems (Piper, A.M 1944). The data illustrate the variability of Kollam groundwater, reflecting the diverse geology and local environmental conditions.

MATERIALS AND METHODS

Geological Setting

Kollam the coastal city in South west of India with an overall area (57 km^2) in Kerala lies between North latitudes 8˚ 50’ 15” and 80 56’ 35” and East longitudes 76˚ 32’17” and 76˚ 39’00. The study area is underlain by crystalline rocks of Archean age above which sedimentary formation of Miocene to recent ages is seen. The major rock type of Archeans consists of Garnet- Biotite gneiss and its variants. The next geological unit exposed belongs to tertiary succession of Kerala known as Warkalli and Quilon formations of Neogene (Mio-pliocene) age (Padmalal et.al., 1998).). The study area is characterized by tropical humid climate with an oppressive summer, plentiful rainfall and temperature without wide variations during different seasons.

Chemical analyses

The samples (N=35) were analysed for various physico - chemical parameters *viz.*, temperature, pH, electrical conductivity (EC), total alkalinity (TA), salinity, total dissolved solids (TDS), total hardness (TH), nitrate (NO_3^-), phosphate (PO_4^{3-}), for cations (Ca^{2+}, Mg^{2+}, Na^+, K^+) and anions (HCO_3^-, CO_3^{2-}, SO_4^{3-}, Cl^-). Physico-chemical analyses were performed following standard methods Trivedy and Goel (1984) and APHA (1992). The study area depicting the sampling stations is illustrated in Figure 1.

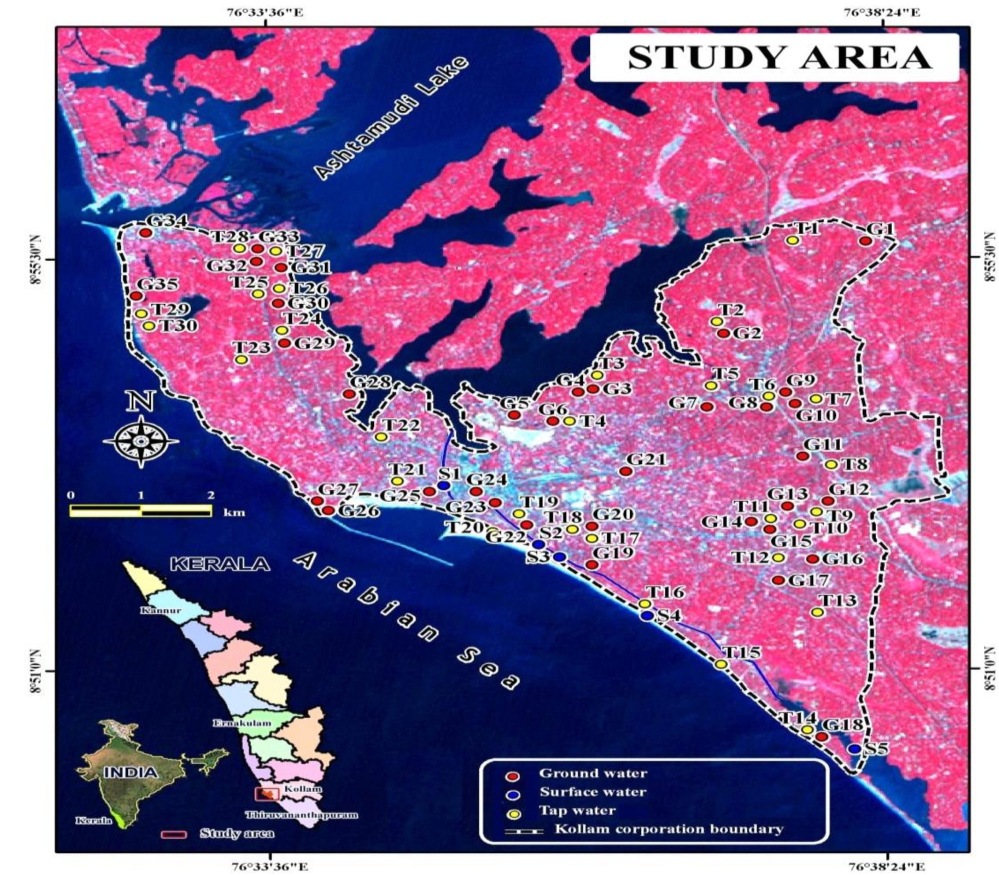

Figure 1 showing the water sampling points in Kollam

RESULTS AND DICUSSION

The distribution of major ions (Na^+, K^+, Ca^{2+}, Mg^{2+}, HCO_3^-, SO_4^{3-}, Cl^-, NO_3^-) in the groundwater samples are depicted as box plots (Figure 2). Exploratory data analysis was carried in box plots for the elements nitrate, phosphate; cations *viz.*, Na^+, K^+, Ca^{2+}, and Mg^{2+}, and anions *viz.*, HCO_3^-, CO_3^{2-}, SO_4^{3-}, and Cl^-. In the diagram, the box represents interquartile range and line on either end of the box indicates the minimum and maximum values. From the box plot diagrams, the general pattern of ionic ordering in groundwater samples in the study area during monsoon and non-monsoon period is represented below:

MON ’08 : Cl^{-}> HCO_3^{-}>Ca^{2}+>Mg^{2+}>SO_4^{3-}>K^{+}>Na^{+}> NO_3^{-}

MON ’09 : Cl^{-}>Ca^{2}+> HCO_3^{-}>Mg^{2+}> Na^{+}>SO_4^{3-}> K^{+}>NO_3^{-}

NMON ’08 : HCO_3^{-}>Cl^{-}>Ca^{2}+>Mg^{2+}>SO_4^{3-}> K+ > Na^{+}>NO_3^{-}

NMON ’09 : Ca^{2}+> HCO_3^{-}>Cl^{-}> Mg^{2+}>SO_4^{3-}>K^{+}>Na^{+}> NO_3

Among the major ions, chloride is the dominating ion during monsoon season and HCO_3^{-} during non-monsoon season during the study period.

Table 1. Chemical classification of groundwater of Kollam

Water	**Season**	**Dominant groups of water types**	**Samples**
Groundwater	monsoon '08	Ca - Mg - HCO3 - Cl	4, 5, 6, 11, 13, 18
	non-monsoon '08	Ca - HCO3 - Cl	3,4,7,8,11,25
	monsoon '09	Ca - Mg - Cl	5,11,12,13,14,15,21,22,31
	non-monsoon '09	Mg- Ca - Cl	1,3,6,11,12,15,17,21,29,34

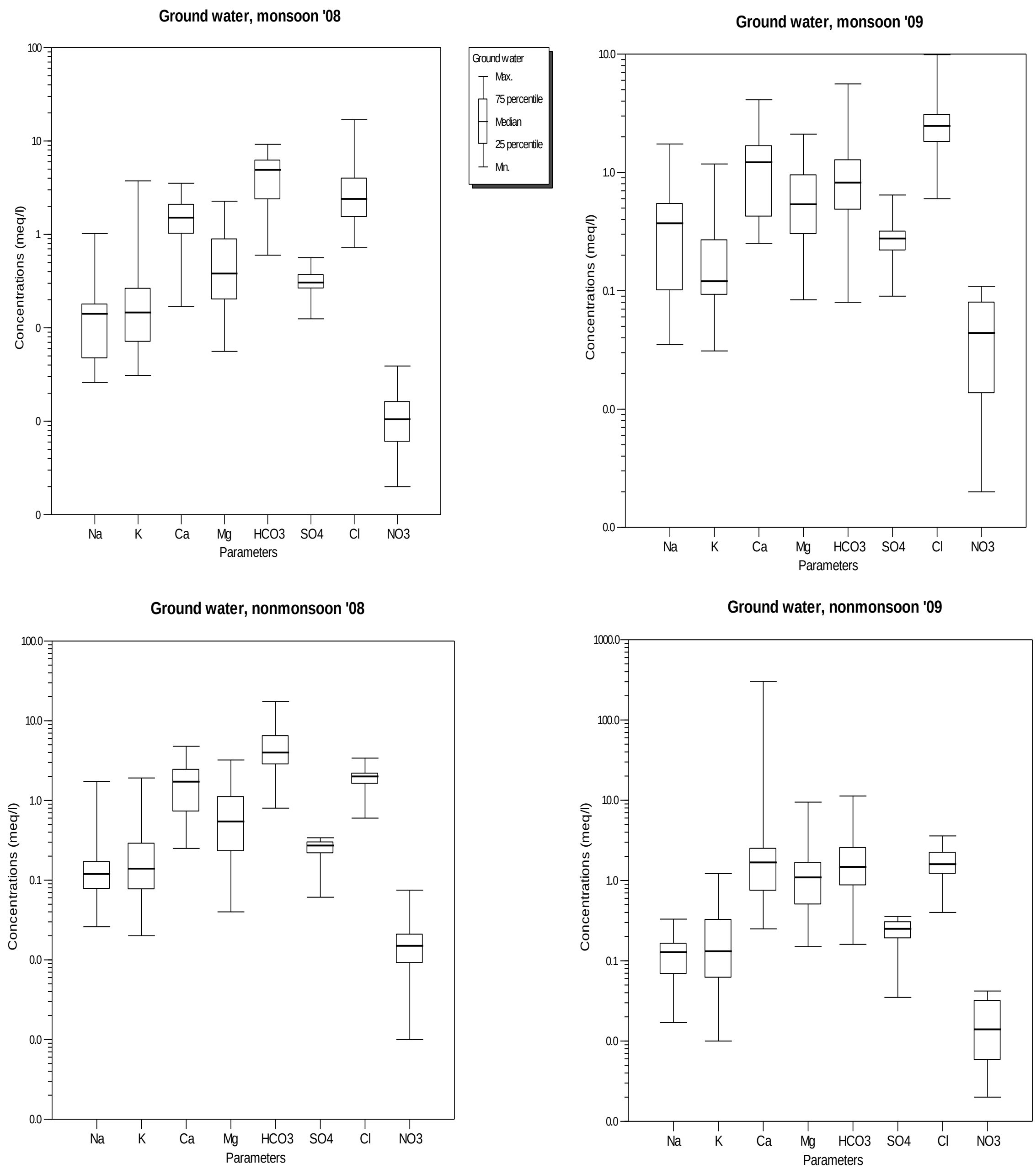

Figure 2 showing boxplots of groundwater samples

The ionic concentration of major cations and anions found in groundwater of the study area are plotted in Piper's trilinear diagram (Fig. 3) by the geochemical software AquaChem. The chemical characteristics of groundwater in Kollam indicate that water samples are of normal alkaline earth origin with chloride as dominating ion. Among the dominant water types, Ca-Mg-HCO_3-Cl; Mg-Ca-HCO_3-Cl are termed as blended water with dominance of chloride. The blended water is inferior in quality compared to the fresh water type (Sahu and Sikdar 2008). Apart from the monsoon rain which adds high chloride to the shallow ground water from organic pollution, the formation of marine transgression in the study area, during late quaternary period needs to be taken into consideration. Therefore the high chloride content of the groundwater of this area possibly represents the remnant of ocean water entrapped in the sediments (Babu et al. 2006). The relatively high saline groundwater with Cl content *viz.*, Ca- Mg-Cl; Mg-Ca-Cl and Ca-Mg-Cl-HCO_3 water types may be attributed to the reasons of high saturation with dolomite and relative saturation with calcite which reflects the water mixture of sub-modern and recent recharge of ground water (Clark and Fritz 1997). A few of the groundwater collected from the dug wells showed mixing of fresh and saline water during monsoon. The data collected over the monitoring period state that the main processes controlling the hydrochemistry are mixing and simple dissolution reactions respectively.

Hydrochemical concepts can help to elucidate the mechanisms of flow and transport in groundwater systems, and unlock an archive of paleoenvironmental information (Pierre D et. al., 2005). Durov’s diagram (Figure 4) depicts that most of the groundwater samples in Kollam fall in the fields 4 and 5 which indicate mixed water or groundwater exhibiting simple dissolution and mixing. The fields 7 and 8 denote Cl dominant anions which indicate reverse ion exchange of Na-Cl in groundwater. The analytical results of the chemical data from the durov diagram could be attributed to the fact that the aquifer units behaved independently due to the subsurface structural setting. The existence of different hydrochemical facies corresponds to the variations in the lithology, groundwater recharge rates, temperature gradients and residence time of groundwater in the aquifer roughs. The ground water samples of the study area indicate mixed water or simple dissolution and mixing

Table: 2 Statistical summary of major-ion chemistry of groundwater samples

Parameters	MON '08	NMON '08	MON'09	NMON'09
Cl	126.9 ± 117	67.7 ± 22.95	102.8 ± 66.6	64.8 ± 25.7
SO_4	30.71 ± 9.9	24.2 ± 6.9	27.2 ± 9.9	23.7 ± 7.6
NO_3	0.86 ± 0.6	1.3 ± 1.1	2.9 ± 2.0	1.1 ± 0.86
PO_4	0.14 ± 0.1	0.06 ± 0.06	0.27 ± 0.83	0.12 ± 0.13
Ca	31.43 ± 17.1	34.8 ± 21.8	25.8 ± 17.85	207.9 ± 1017.6
Mg	4.63 ± 5.9	9.4 ± 9.1	7.96 ± 5.27	18.8 ± 20.6
Na	3.40 ± 5.6	5.4 ± 8.8	9.7 ± 7.9	3.2 ± 1.9
K	6.20 ± 24.8	10.96 ± 14.4	9.73 ± 10.1	11.4 ± 13.4

(All units are expressed in mg/L except pH, EC (µS/cm);TH-Total Hardness asCaCO3; TA-Total Alkalinity; TDS-Total Dissolved Solids).MON- monsoon; NMON- non-monsoon

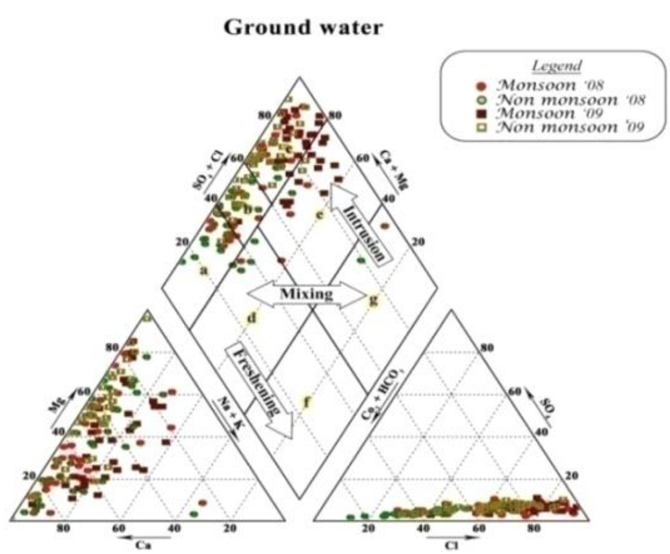

Figure 3 showing Piper trilinear diagram of groundwater samples

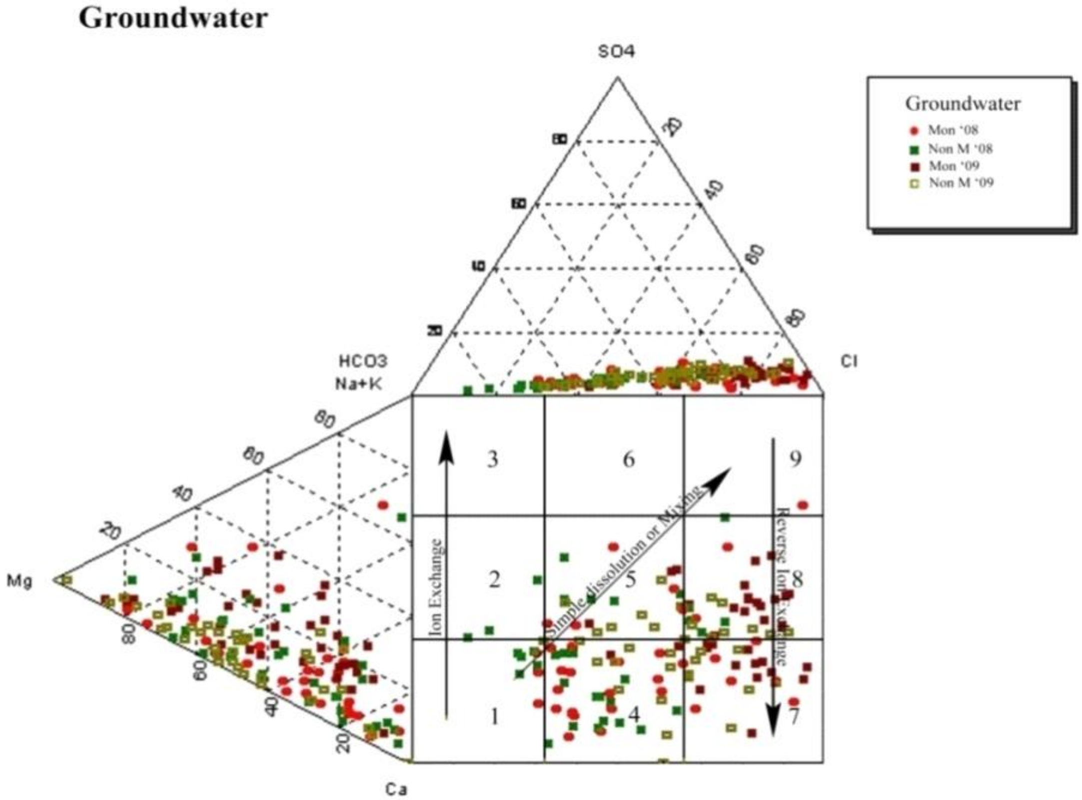

Figure 4 showing Durov diagram of groundwater samples

Groundwater in Kollam is dominated by Ca-HCO_3 waters, but with a significant number of Ca-Mg-HCO_3-Cl; Mg-Ca-HCO_3-Cl and Ca-HCO_3-Cl. Ca-Mg-HCO_3- and weakly mineralized Na-Cl waters. The concentrations of most of the major ions, particularly Ca and HCO_3, but also SO_4, Mg and K, indicate water-rock interaction.

CONCLUSION

Typically, the ground water in the study area is brackish in nature indicating saline influence on the ground water realm. The dominant percentage of groundwater samples of Kollam region is normal earth alkaline origin which belongs to Ca-Mg-HCO_3-Cl; Mg-Ca-HCO_3-Cl and Ca-HCO_3-Cl. The adverse effects on groundwater quality in Kollam are not intentionally by agriculture but the results of man's activity at ground surface by domestic and industrial effluents, unexpectedly by sub-surface or surface disposal of sewage and industrial wastes. Solid waste dumped near the surface water bodies, is subjected to reaction with percolating rain water and reaches the groundwater level. Also, it is evident that much of the samples have acquired their chemistry through rock-water/sediment interactions and dissolution mechanisms.

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