Hydrogeochemical Characteristics and Evolution of Coastal Groundwater at Cuddalore Area, Tamilnadu, India

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ABSTRACT - The hydrogeochemical data of groundwater's of the different aquifers of the Cuddalore coastal area, Tamilnadu were examined to determine the main factors controlling the groundwater chemistry and salinity as well as its hydrogeochemical evolution. The geology of the area plays a significant role in the determination of the groundwater potential of the region. The area underline by the various geological formations ranging in age from the oldest Archaean rocks to recent sediments. Groundwater of the coastal alluvial aquifer has the highest conductivity values in the study area due to the impact of seawater and agricultural activities. Piper diagram showed that Cl and SO4 are the dominant anions, whereas Na is the most dominant cation, where it is sometimes replaced by Ca and/or Mg in the hydrochemical facies of the ground waters. The paper revealed that the groundwater has been evolved from Ca-HCO3 recharge water through mixing with the pre-existing groundwater to give mixed water of Mg- SO4 and Mg-Cl types that eventually reached a final stage of evolution represented by a Na-Cl water type. Different ionic ratios revealed the impact of seawater and marine aerosols on the hydrochemical composition of groundwater of the Quaternary aquifer. Dissolution of carbonate and sulfate minerals in the aquifer matrices and recharge areas as well as cation exchange are shown to modify the concentration of ions in groundwater. Groundwater-mineral equilibrium showed the prevailing dissolution-precipitation reactions in the groundwater.

Keywords: Hydrogeochemistry, Groundwater, water facies, saline water,

INTRODUCTION

Groundwater often serves as drinking water in rural areas located along the Cuddalore coast of Tamilnadu, India. Many problems normally arise due to indiscriminate use of ground water over long periods. This includes problems such as water logging, sea water intrusion in coastal aquifer, critical lowering of water table, land subsidence and water quality deterioration, and are often attributed to an inadequate analysis of the response of various aquifer stresses on the ground water behavior. Groundwater in an alluvial aquifer, probably the dominant type of aquifer in the coastal area, is relatively vulnerable to the contamination by seawater intrusion, which

makes groundwater unsuitable for drinking. As a result of chemical and biochemical interaction between groundwater and contaminants from urban, industrial and agricultural activities along with geological materials through which it flows, it contains a wide variety of dissolved inorganic chemical constituents in various concentrations. When seawater intrusion is the only cause for the salinity of groundwater in an aquifer system, the groundwater does not only exhibit high total dissolved solids (TDS) but also shows high concentrations of most major cations and anions (Richter and Kreitler, 1993).   Hydrogeochemical data helps in estimating the extended of mixing, the circulating pathways and residence time of groundwater (Edmunds, 1994). The type and concentration of salts in depend on the geological environment and movement of groundwater (Ragunath, 1987). The purposes of this study are to examine spatial and temporal variations of groundwater chemistry in a coastal aquifer system, which is located in Cuddalore coastal area, and to interpret reasonable processes that control the groundwater chemistry. Chemical compositions of groundwater and Chemical aspects were used to determine factors affecting the hydrogeochemistry of groundwater in the study area.

LOCATION OF THE AREA

Area chosen for study is Cuddalore region, which is located in southern part of Cuddalore district in the east coast of India (Figure 1). It lies in between $79^o 29"E$ to $79^o 54"E$ longitude and $11^o 20"N$ to $11^o 45"N$ latitudes (Fig 1). Long term average rainfall of the district is 1160.36mm. Groundwater in this area is overexploited for agriculture and industrial purposes are predominant land use in this area, which induces salinity in the coastal aquifers, and coastal stretch of Cuddalore district is about 10km. The geology of the area plays a significant role in the determination of the groundwater potential of the region. The area lies between the various geological formations ranging in age from the oldest Archaean rocks to recent sediments. The most common outcrops in the area are limestone, sandstone and clays. These are covered in places by lateritic, kankar and alluvium. The tertiary formation having good potential groundwater covered by sandstone argillaceous and pebble bearing grits, clays (variegated) with lignite seams and pebble beds.
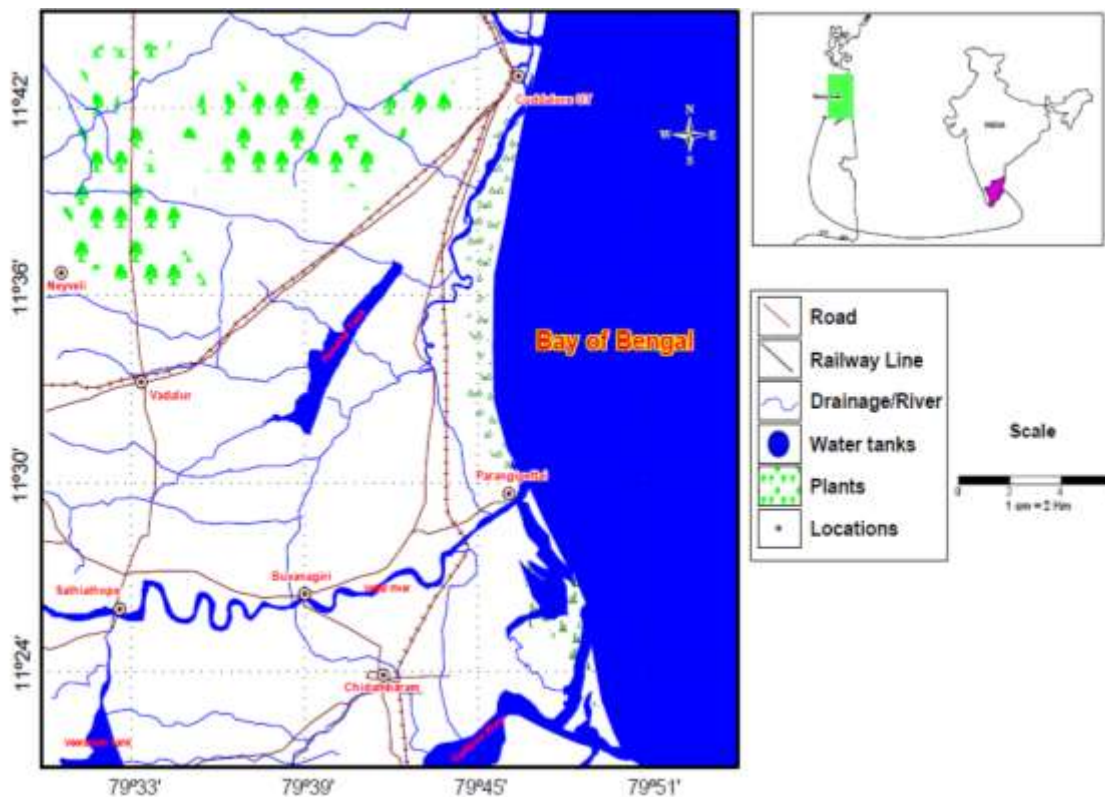
Fig 1: Location map of the study area.

MATERIAL AND METHODS

Totally fifty four groundwater samples were collected during post monsoon (POM) and pre monsoon (PRM) in year 2007 mostly covered by the shallow aquifers in this region. The samples collected after 10 minutes pumping and stored in polyethylene bottles. pH, electrical conductivity (EC) and total dissolved solids (TDS) were measured by handheld pH, EC and TDS meter in the field. The collected samples were analyzed for major cations, like Ca^+ and Mg^+ by Titrimetry, Na^+ and K^+ by flame photometry (AIMIL); anions, like Cl^- and HCO_3^- by Titrimetry, SO_4^-, PO_4^-, NO_3^- and H_4SiO_4 by Spectrophotometer (JENWAY 6505). The analyses (APHA 1998) were done by adopting standard procedures.

RESULT AND DISCUSSION

Groundwater samples were collated in space and time and analyzed for major and minor dissolved ions using standard procedures. The results of the physical – chemical analysis of the ground waters of Cuddalore coastal aquifers for two seasons are given in table 1 the maximum minimum and average of the samples. In general pH of the waters is alkaline in nature. The pH is controlled by total alkalinity of the ground water and partially by sea water mixing. pH in the study area varies from 6.6 to 8.1 with an average of 7.4 in post monsoon and in pre monsoon it ranges from 6.4 to 7.8 with an average of 7.17. EC varies from 354 to 1596 $\mu s/cm$ with an average of 827 $\mu s/cm^2$ in post monsoon and 258 to 2630 $\mu s/cm$ with an average of 827.32$\mu s/cm$ in pre monsoon. Total

dissolved solids (TDS) ranges vary from 247.8 to 1117 mg/l with an average of 579.41 mg/l in post monsoon and 208.60 to 1809 mg/l with an average of 581.82 mg/l in pre monsoons. The water samples of the study area are classified as fresh to brackish in nature. Bicarbonate is the dominant anion followed by chloride, sulphate, nitrate and phosphate in post monsoon season and in pre monsoon bicarbonate is the dominant anion followed by chloride, sulphate and phosphate. The dominant cations are as follows: calcium followed by sodium, potassium and magnesium during post monsoon and calcium followed by magnesium, sodium and potassium in pre monsoon. The spatial distribution of EC of samples was carried out for all five major seasons (figure 2). In general, EC found to be higher near the coastal areas. The Neyveli mine area shows high concentration in pre monsoon which indicate the over exploration of groundwater. The EC spatial diagram mainly shows variation of the concentration in area wise. Majority of the coastal regions of the study area affected by the salt water intrusion due to the over exploration of groundwater by Veeranam metro project, Neyveli Lignite mines, agriculture and domestic purposes (Prasanna et al, 2010).

Table 1: Comparison of chemical composition of water with WHO (2004) and ISI (1995) in mg/l (except EC in μs/cm and pH)

| Parameters	POM 07		PRM 07		WHO (2004)	Highest desirable	ISI (1995)
	Min	Max	Min	Max			
pH	6.60	8.10	6.40	7.80	6.5-8.5	7-8.5	6.5-9.2
EC	578.90	3104.15	495.99	2833.56	1400.00	-	-
TDS	320.50	2152.00	331.27	1973.05	1000.00	500.00	1500.0
Ca	26.90	125.36	20.85	101.48	500.00	75.00	200.0
Mg	12.20	66.60	7.47	81.67	-	30.00	100.0
Na	22.50	421.25	16.60	504.10	200.00	-	-
K	15.70	76.00	7.18	57.89	-	-	-
Cl	74.50	856.24	68.36	984.25	250.00	250.00	1000.0
HCO$_3$	81.70	394.20	75.24	331.72	-	300.00	600.0
SO$_4$	1.40	27.36	2.86	41.20	400.00	150.00	400.0
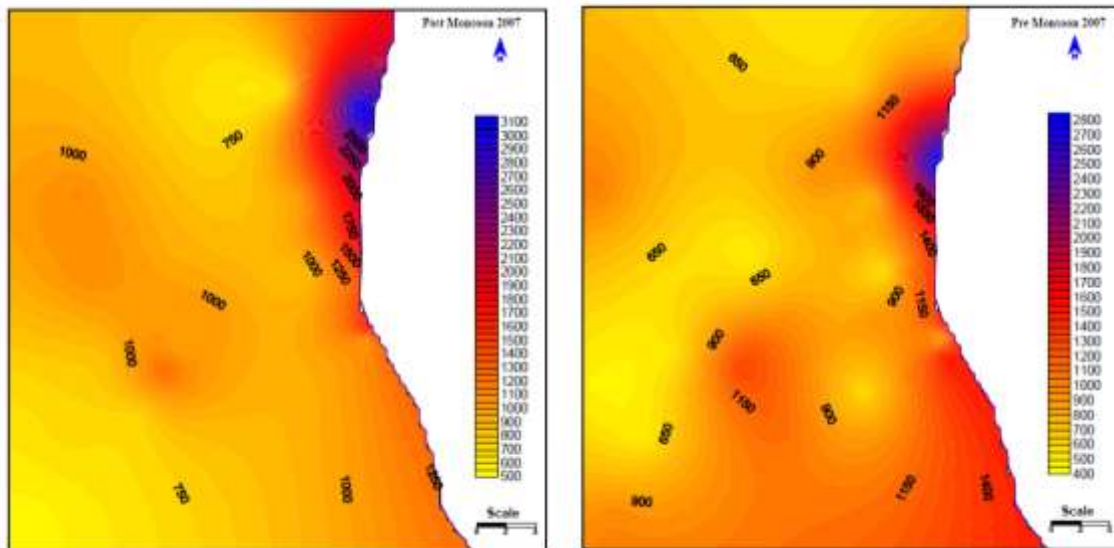
Figure 2: Spatial distribution of EC (µs/cm) in groundwater during the year 2007

The trilinear piper diagram is one way of comparing quality of water. It is the first step of determining the water facies for the purposes of studying the evolution of groundwater (Vajrappa et al, 2007). studied Irrigation effects on the salinity of the Arba and Riguel Rivers (Spain), they evolved from a Calcium Bi Carbonate composition by using the Piper Classification. Geological hydro geochemical investigation of the Uranium potential of an area between Orange and Kuruman River (Levin, 1980) has discussed the salinity of groundwater with the Piper diagram. The geochemical evolution of groundwater can be understood by plotting the concentration of major cations and anions in the Piper (1994) trilinear diagram. It consists of two lower triangular fields and a central diamond shaped fields. All the three fields have incorporation of major ions only.
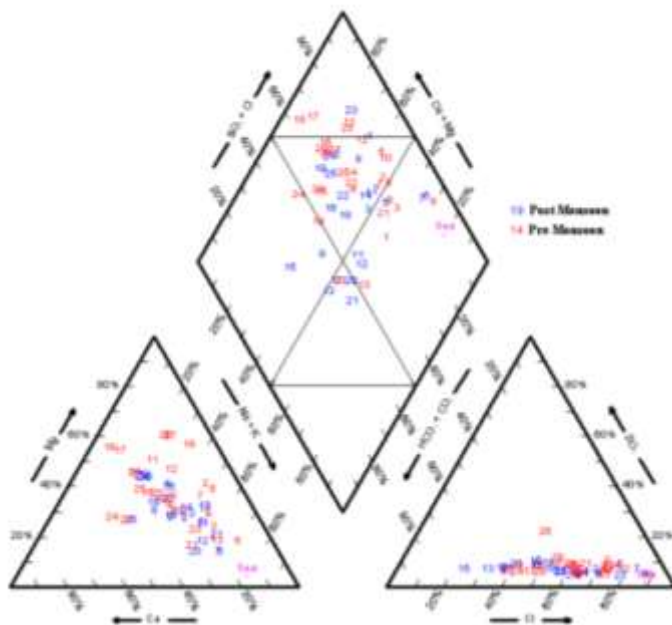

Figure 3: Hill Piper Plot for the groundwater in 2007 (after Hill Piper, 1944)

The Triangular fields are plotted separately with epm values of cations Ca,Mg alkali earth, (Na+ K) alkali, HCO3 weak acid SO4 and Cl strong acid. Water facies can be identified by projection of plots in the central diamond shaped field (Chidambaram 2000 and Pandian and Sankar 2007). Hydro geochemical facies interpretation is a useful tool for determining the flow pattern, origin of chemical histories of groundwater masses. The plot (Figure 3) of POM samples fall in the Na-Cl (40%) type of water, followed by Mg-Cl (28%), Na-HCO3 (16%), Ca-Cl (8%) and Ca-HCO3 (8%) type of water. In PRM (41%) sample fall in Na-Cl type of water, followed by Mg-Cl (31%), Ca-Cl (14%), Na-HCO3 (8%), Ca-HCO3 (3%) and Mg-HCO3 (3%). The concept of Hydrogeochemical facies offers a mass regional relation between chemical character, lithology and regional flow pattern. For all 2 seasons there exists a continuous mixing of Na, Cl and Mg with few representations of HCO_3 and Ca. Thus, the ground water chemistry of the area is mainly controlled by chemical weathering followed by infiltration, leaching, evaporation, sea water intrusion and anthropogenic activities. The POM and PRM seasons Na-Cl type of water dominated in coastal areas indicating sea water intrusion and the representation of other samples indicate rock weathering, evaporation and leaching

The SAR (alkali hazard) and specific conductance (Salinity hazard) is plotted in USSL diagram (Figure 43), classification of water for irrigation purpose can be determined. In year 2007, POM samples fall in C3S2 range and one sample fall in C3S2 area, comparatively POM POM 07 data shows that the salinity concentration increases from medium to high conductivity due to saline water intrusion. Soils in this terrain are to be preferablly salt tolerance plants (Karanth 1989). In PRM sample fall C2S2 (40%) and C3S1 (60%) it indicates the high salinity and medium sodium hazard. applications of gypsum, make water feasible and also increases soil permeability (Goyal and Jain 1982).
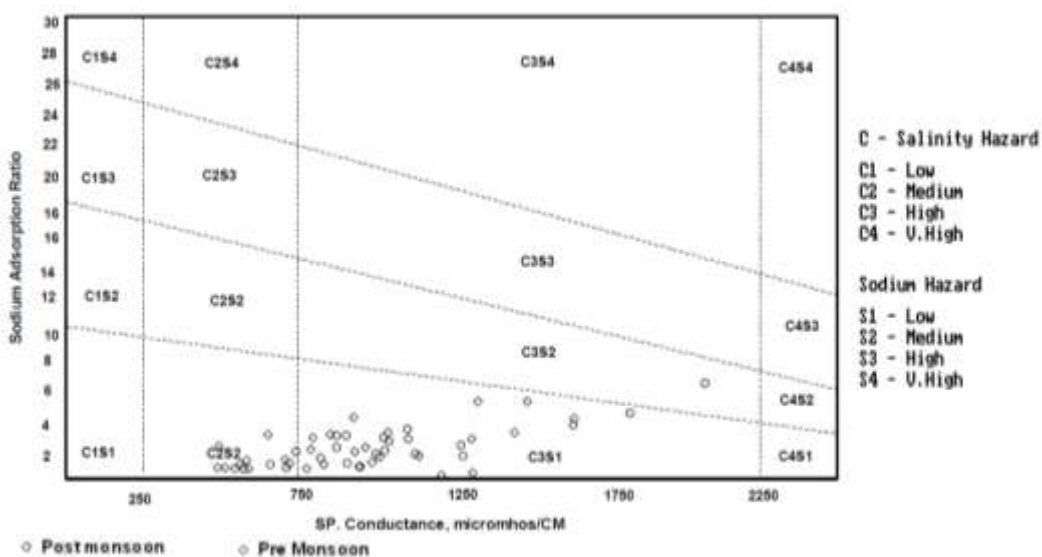

Figure 4: USSL classification for the groundwater in 2007 (after USSL, 1954)

The Piper diagram (Johnson 1975) in year 2007 (Figure 5), POM (48%) and PRM (42%) samples fall in zone contaminated with gypsum and also with few representations in static and disco-ordinate regimes indicating weathering of bed rocks and intensive ion exchange process in this region. During PRM season most of the samples (38%) fall in Ca+Mg and SO4+Cl category. The PRM seasons in 2007 have higher secondary salts precipitation, with fewer representations in Ca+Mg and SO4+Cl and Ca+Mg, SO4+Cl and HCO3+CO3 indicating the secondary precipitation of salts in all seasons.
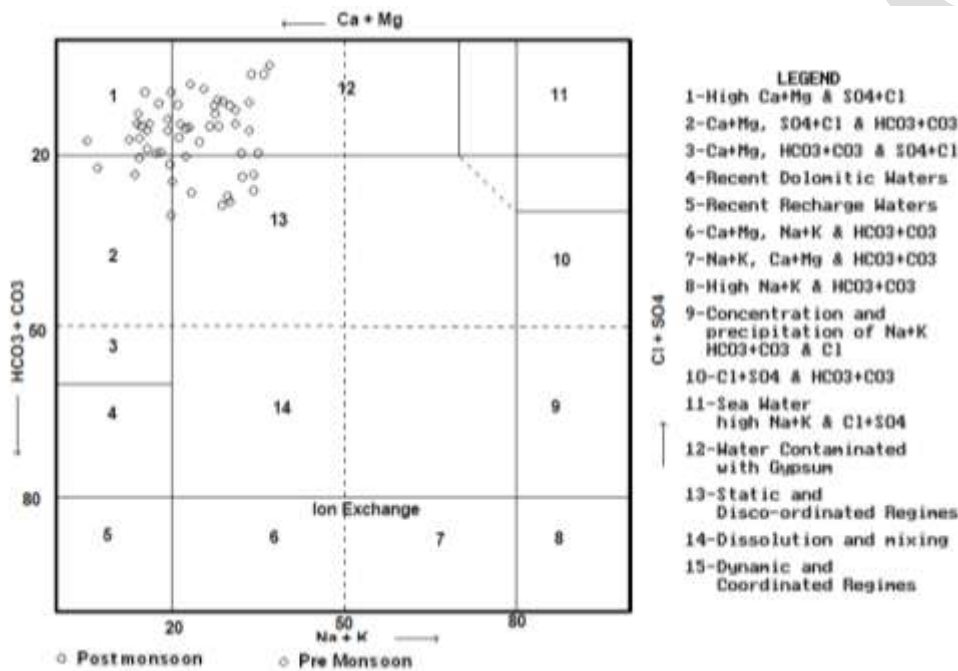

Figure 5: Reconstructed Diamond field of Piper for the groundwater in 2007 (After Johnson, 1975)

The Na+/Cl− couple: In natural waters these two chemical elements are often connected to halite (NaCl) dissolution. The evolution of Na+ is studied according to the chlorides contents, because this is considered as a steady tracer and conservative of the very soluble evaporates; rarely incoming in saline precipitation, and not intervening in the oxidation-reduction phenomena, and little influenced by the bacteria intervention (Seghir ,2008). For the strong concentrations of chlorides, one observes a direct relation between Na and Cl, indicating that a common origin of these two chemical elements For the weak concentrations of chlorides, one observes a constant excess of sodium contents, it explains itself by another origin of the ion of soda that made increase the concentration of sodium This contribution supplementary could come from the alteration of soda silicates (Clays). But since, this

excess of Na is derived due to the deficit of Ca in relation to HCO3 - and SO4 (Figure 6), the increase of Na contents cannot explain

itself that by the process of base exchange related to the clayey minerals. This process fixes an ion of Ca after liberation of two ions of

Na+. The Ca/(HCO3 + SO4)- Na/Cl diagram (Seghir 2008) in 2007 almost all the samples fall in the natural state and the samples of

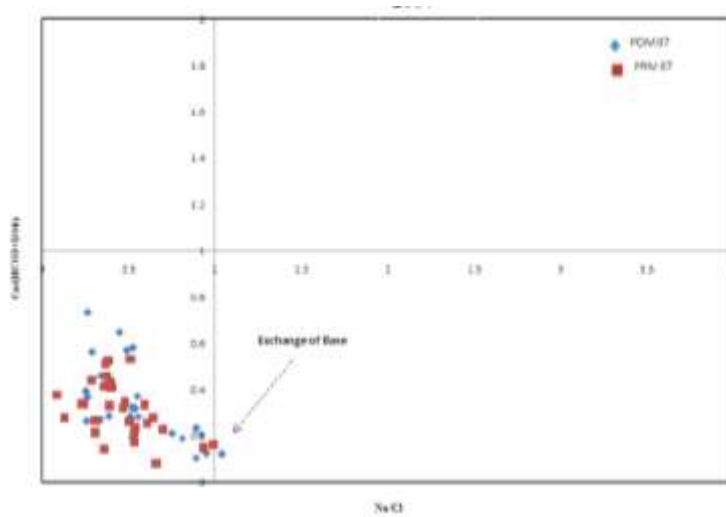PRM fall near to the base exchange zone.

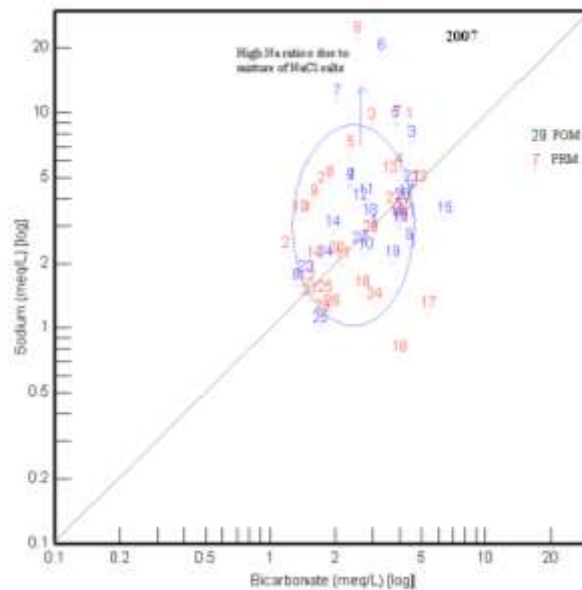Figure 6: Basis Exchange of groundwater in 2007

Figure 7: Relationship between Na and Cl compared against a 1:1

The ionic relationship between Na and Cl is observed to determine their magnitude on the total salinity of groundwater in the coastal area. This is true for most groundwater samples in the year 2007 (Figure 7) except at lower concentrations, where the ratio tends to be greater than 1 indicating cation exchange reactions where Ca or Mg is exchanged for Na in groundwater or Na is derived from another source such as localized mineral hydrolysis. Na is derived from another source such as localized mineral hydrolysis.

CONCLUSIONS

In the study area, hydrogeochemical characteristics of groundwater of Cuddalore area have been studied and the groundwater quality is mainly controlled by weathering, precipitation, mixing of seawater, ion-exchange reactions, and anthropogenic inputs. The dominant water facies is Mg^+- Cl^- ,Ca^+- Cl^- , Na^+-Cl^- in post monsoon Mg^+ – Cl^- , Ca^+- Cl^- , Na^+- HCO_3^- in pre monsoon season. SAR ratio for POM and PRM seasons, most of the samples fall in Class II and Class III indicating the salinity concentration increases from medium to high conductivity due to saline water intrusion.. In general, EC found to be higher near the coastal areas. Majority of the coastal regions of the study area affected by the salt water intrusion due to the infiltration of contaminant water from industry and over exploration of groundwater for agriculture and domestic purposes.

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