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GIS BASED HYDROGEOCHEMICAL CHARACTERISTICS OF GROUNDWATER QUALITY IN NAGAPATTINAM DISTRICT, TAMILNADU, INDIA

Gopalakrishnan GNANACHANDRASAMY*, Thirunavukkarsu RAMKUMAR, Senapathi VENKATRAMANAN, Irudhayanathan ANITHAMARY & Sivaprakasam VASUDEVAN

Department of Earth Sciences, Annamalai University, Chidambaram, Tamilnadu, India,

**E-mail: samygnanam@gmail.com. tratrj@gmail.com*

Abstract: In coastal aquifers, saltwater intrusion may cause serious consequence in terms of both environmental and economic impacts**.** An attempt has been made in present study to elucidate the quality of ground water of the study area in terms of the chemical parameter change due to the seasonal variation of water level. The results indicates the over exploitation of groundwater from a shallow aquifers leads to seawater intrusion and severe deterioration of groundwater quality in the study areas. The study adopted GIS based technique to comprehend the groundwater environment. The study was carried out in Nagapattinam district of Tamilnadu. Totally 45 ground water samples collected in postmonsoon and summer season (2010). The physical parameters Hydrogen ion concentration (pH), Electrical conductivity(EC) , Total dissolved solids (TDS) and major cations sodium (Na^+) and anions chlorides (Cl^-) were analyzed. The analytical results of the collected ground water samples exhibits alkaline and sodium (Na^+ 1109.3 mg/l) and chloride (Cl^- 975.2 mg/l) are the dominant cation and anion respectively.

Keywords: Groundwater quality, spatial distribution, GIS, Nagapattinam, sea water incursion

1. INTRODUCTION

Water is essential to people, and the largest available source of fresh water lies under ground. Increased demands for water have stimulated development of underground water resources. Practically all groundwater originates as surface water. Principally sources of natural recharge include precipitation, stream flow, lakes and reservoirs. Other contributions known as artificial recharge occur from excess irrigation, seepage from canals, and water purposely applied to augment ground water supplies (Todd, 1980). The quality of ground water is just as important as its quantity. All ground water contains salts in solution that are derived from the location and past movement of the water**.** Change in groundwater levels with respect to mean sea elevation along the coast largely influences the extent of seawater incursion in the fresh water aquifers. The main use of water in the study area is contributed to agriculture, implementing modern mechanized irrigation techniques accompanied by planting crops with low water demand and high tolerance against salinity may be recommended. Industrial development accompanied by population and consumption growth has imposed heavy pollution loads to natural resources (Mehrdadi et al., 2009).

Groundwater quality mapping in urban groundwater using GIS studied by Bilgehan Nas and Ali Berktay (2010). GIS can be a powerful tool for developing solutions for problems related to water resources, for assessing water quality and managing water resources on a local or regional scale (Tjandra et al., 2003; Anitha et al., 2011). Modern tools such as Geographical Information System (GIS) can be extensively used in ground water investigations and analysis for mapping purposes, based on the compiled database (vector or raster). GIS is used to delineate areas favorable for recharge both in hard rock and sedimentary environs and to recommend suitable recharge structure (Saraff & Choudry 1998). It is also used to analyze the hydro geological data for the assessment of ground water condition of a soft rock terrain in midnapur district, West Bengal, India (Shahid & Nath 2000) in Gurgaon district, Haryana, India (Toleti et al., 2000) in Raniganj area

(Sikdar et al., 2004). Phukon et al., (2004) applied multicriteria evaluation technique in GIS environment for ground water resources mapping in Guwahati city areas. Groundwater quality suitable zones identification applications of GIS, Chittoor area, Andhrapradesh, India (Srinivasarao Yammani, 2007). GIS has been found to be one of the powerful techniques in locating the groundwater potential zones. (Claure, 1994, Burrough, 1986, Hendrix & Price, 1986 Hiroshi, 1988, Zuviria et al., 1994). Vulnerability assessment of seawater intrusion and effect of artificial recharge in pondicherry coastal region using GIS (Lenin Kalyana sundaram et al., 2008). Thus this research has been carried out with the aim of testing the performance of spatial interpolation techniques for mapping Groundwater quality. GIS is an effective tool for storing large volumes of data that can be correlated spatially and retrieved for the spatial analysis and is able to take temporal changes into account and to provide the final more reliable and current version of outputs (Hrkal, 2001). The use of maps is common practice in earth related sciences in order to evaluate the evolution of physical phenomena and predict natural variables as well as assess the risk regarding surface and groundwater contamination in waste disposal industrial and other sites (Xenidis et al., 2003). This work is significant and presents novelty as this is the comprehensive study in the area to describe the impact of seawater incursion. The aim of this study is to analyze the hydro chemical quality of groundwater in coastal areas of in and around Nagapattinam district, Tamilnadu.

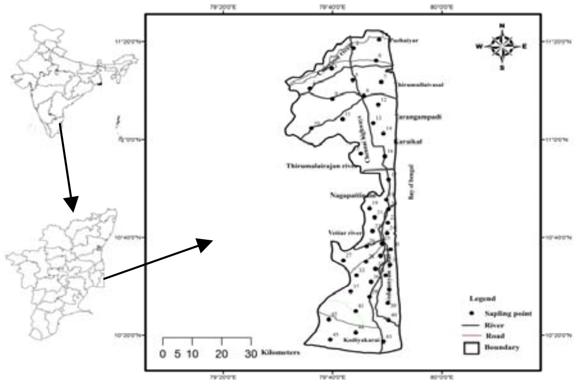


Figure 1.Study area map

2. STUDY AREA

Nagapattinam district (Fig. 1) located between 10° 15’ to 11° 30’N and 79° 30’ to 79° 55’ E, it stretches from River Coleroon in the north to Pointcalimer in the south. The district has a coastline stretching to 190 km. Ground water occurs in these formations and is extracted by filter point wells, tube wells, shallow bore wells and infiltration wells, especially from the sandy aquifers. The Pliocene and Quaternary shallow aquifers are represented by sand, gravel and clay. The aquifer is more clayey towards east and south eastern part of the district except the coastal stretch where the beach sands occur. The depth of the aquifers varies between 3m and 35m and deep aquifers to an extent of 80m to 100m.

3. METHODOLOGY

During the study period, forty five ground water samples were collected using acid cleaned 500ml polyethylene bottles for the year of 2010. The physical parameters pH, Electrical conductivity (EC), Total dissolved solids (TDS) and major cations sodium (Na^+) and major anions chlorides (Cl^-) were identified by various methods. pH was measured using a pH prop meter. The Electrical conductivity (EC) and Total dissolved solids (TDS) of represented ground water samples were measured in situ. The concentrations of major anions (Cl^-) were analyzed in the laboratory according to the methods given in the standard methods (American Public Health Association (APHA), 1985).The major cations of Na^+ concentration was determined by flame photometer. Analytical results of the groundwater sample interpreted in the software Arc GIS9.3 and the spatial distribution map was prepared. The results of the physiochemical analysis are presented in table 1

4. RESULTS AND DISCUSSIONS

4.1.1 Physical parameters: pH

The pH level in the ground water samples during study period ranged from 6.2 to 8.3. The maximum level of pH was observed during summer season at sample no 14 and pH was observed in 8.3. During post monsoon season pH value ranged from 7.1 to 8.1 (Sample No: 20& 16). Generally pH value of ground water is controlled by the amount of dissolved carbon dioxide gas and the dissolved carbonates and bicarbonates from mineral salts. This is perhaps due to dissolved atmospheric carbon dioxide which will release sodium, calcium with turn progressively increase the pH and alkalinity of the water. This kind of result was observed by Frengsted et al., (2001). Although pH usually has no direct impact on consumers, it is one of the most important operational water quality parameters (World Helath Organisation 2004, WHO). Spatial distribution of pH during the study period is shown in figures 2 A and B.

Table 1. Physico-chemical Parameter

Samples No	Water quality parameter in mg/1	WHO standard mg/1 (1983)	Concentration in study area mg/l	
			Postmonsoon	Summer
			Min – Max	Min –Max
1	pH	6.5 to 8.5	7.1 to 8.1	6.2 to 8.3
2	Electrical conductivity (µS/cm)	500 to 1500	1562.4 to 3711.3	1558.2 to 4498.3
3	Total dissolved solids (TDS)	500	999.9 to 2375.2	997.2 to 2878.9
4	Sodium (Na)	200	100.6 to 750.6	118.2 to 1109.3
5	Chloride (CI)	250 to 600	186.2 to 964.2	195 to 975.2

During post monsoon season a higher concentration of pH was observed in Northeastern and southern part of the study area. During summer season higher level of pH was distributed in northeastern and middle and southern part of the study area. A reason for increasing pH concentration in coastal region related to the chloride in seawater or from marine clay which have increased the pH concentration. Hence the groundwater in the study area is not suitable drinking but can be used for irrigation, industrial and domestic purposes.

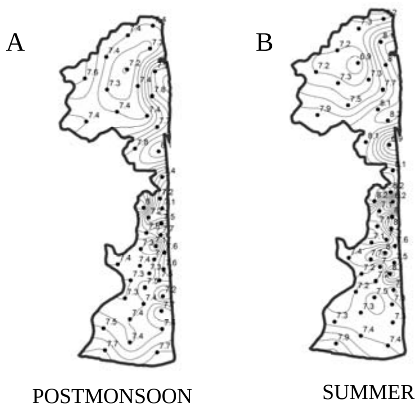


Figure 2.Spatial distribution of pH

4.1.2. Electrical Conductivity (EC)

Generally, the electrical conductivity is a measure of the ability of water to pass on electrical current and is affected by the presence of dissolved solids. As the level of total dissolved solids (TDS) raises, the conductivity will also increases. The electrical conductivity values of the ground water samples observed during the study period ranged from 1558.2 to 4498.3µs/cm in the sample no 3 & 17. The maximum value of electrical conductivity was observed during summer season. Whereas the electrical conductivity of the post monsoon season ranged from 1562.4 to 3711.3 µs/cm (sample no 2 & 17). The high electrical conductivity value observed during summer season (4498.3µs/cm) was due to big amount of total dissolved salts in ground water. Total dissolved solids and electrical conductivity is directly related. The high level of electrical conductivity in ground water is related to the input of sewage water, agricultural activities and seawater incursion in some coastal aquifers. This is similar to the observation of Tutmet et al., (2006) have modeling studies on electrical conductivity of groundwater. Electrical conductivity was low when the freshwater recharge during pre monsoon and post monsoon and progressively increases during summer along the coastline studied by Anithamary et al., 2010; Senapathi Venkatramanan et al., 2012.

The spatial distribution of electrical conductivity during post monsoon season indicates that the higher concentration was observed Northeastern part of the study area. In the summer season the higher concentration of electrical conductivity values were associated with east and southern part of the study area. A reason for higher electrical conductivity value in groundwater during postmonsoon season was related to the enrichment salt due to evaporation effect in the previous summer season.

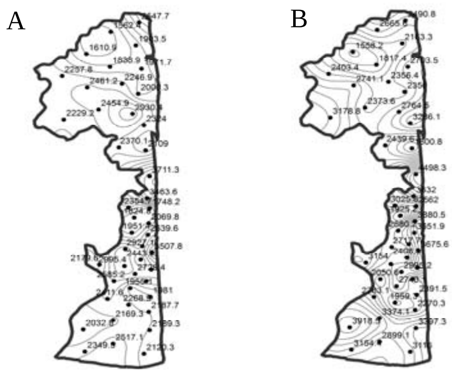


Figure 3.Spatial distribution of EC

This is similar to observation of Manish Kumar et al., (2007) have valuated the groundwater suitability for irrigation and drinking purpose in the intensively cultivated district of Punjab, India. The higher electrical conductivity observed in the study area was due to the reason as these region lies close to the sea, where mixing of sea water with fresh water aquifer is possible as increases the conductivity. The figures 3 A and B show the spatial distribution of EC.

4.1.3 Total Dissolved Solids (TDS)

Generally TDS is defined as the quality of dissolved material in water, and depends mainly on the solubility of rocks and soils the water is in contact. The total dissolved solids in the water samples during the study period ranged from 997.2 to 2878.9 mg/l sample no (3 & 17). The maximum level of TDS observed from summer season. The TDS level during post monsoon season ranged from 999.9 to 2375.2 (mg/l) sample no (2 & 17). The reason for increased total dissolved solids is from dissolution or weathering of the rock and solids and dissolving nature of lime, gypsum and other salts, when the source water passed over or percolates through them (Chebotarev,1985 and TaghizadehMehrjardi et al., (2008). Concentrations of TDS in water vary considerably in different geological regions owing to differences in the solubility of minerals (WHO, 2004). Low concentration of total dissolved solid in the study area was related to the addition of fresh water with low TDS and decrease in temperature that consequently reduced the evaporation rate. This was similar to the observation made by Suman Mor et al., (2006) in their study on the assessment of groundwater quality near municipal solid waste land fill site. Spatial distribution of total dissolved solids during the study period is shown in figures 4 A and B.

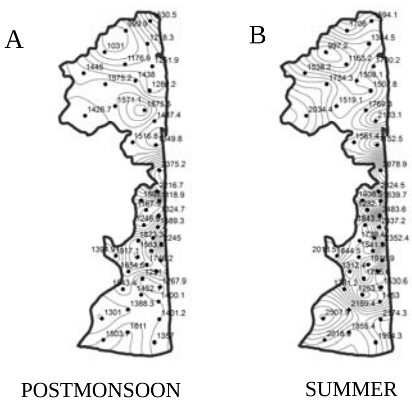


Figure 4.Spatial distribution of TDS

During summer season a higher concentration of total dissolved solids were distributed in the eastern and southern part of the study area. In the post monsoon season total dissolved solids was observed in north and central part of the study area. The spatial distribution indicates that TDS where higher in eastern part of the study area indicating influence of sea water incursion. In the coastal tract the reason for increased level for total dissolved solids is not only saline water intrusion in to the coastal aquifers, sometimes deep water condition dissolution of rock in ion particle mixed with fresh water mixed with fresh water so increase total dissolved solids in groundwater. This was observed by Freeze and Cherry (1979).

4.2. Chemical Parameters

4.2.1. Sodium

In general, the source of sodium is derived geologically from leaching of surface and underground deposits of salt and decomposition of various minerals. Weathering of plagioclase feldspar (albite), in area with evaporates deposits and the solution of halite is also an important source of sodium ions in the groundwater. The higher concentration of sodium was observed in summer season. It's ranged from 118.2 to 1109.3 mg/l at sample no 36 & 17. Where post monsoon season it's ranged from 100.6 to 750.6 mg/l at sample no 2 & 16. A higher concentration of sodium (1109.3mg/l) was observed during summer season may be due to the ion exchange. The agricultural water can also contribute to the increase of sodium ion. This behavior was observed by Guo & Wang (2004). The lower concentration of sodium was observed during postmonsoon season (100.6 mg/l). The concentration of sodium in majority of the samples was above the desired limit of 200mg/l in summer season than postmonsoon. Low concentration of sodium in the study area which may probably by the dilution of groundwater by rainwater.

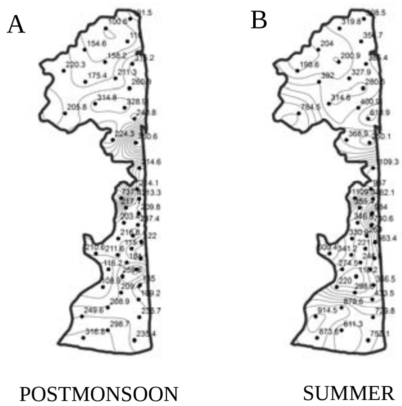


Figure 5.Spatial distribution of Na

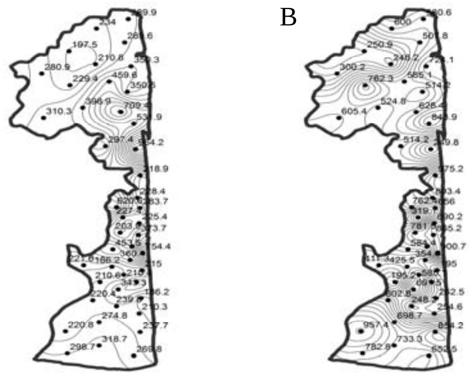
Spatial distribution of sodium during post monsoon season a higher concentration was observed Middle Eastern and southern part of the study area. Whereas summer season the higher concentration extends from eastern to southern part of the study area. The higher concentration of sodium was observed in summer season. The spatial distribution of Sodium shows in figures 5 A and B.

4.2.2. Chloride

The chloride concentration in the ground water samples during post monsoon season ranged from 186.2

to 964.2 mg/l (sample no 28 & 16). During summer season it's varied from 195 to 975.2 mg/l (sample no 31 & 17). The maximum concentration was observed from summer season. In water, chlorides are usually present as sodium chloride, magnesium chloride and calcium chloride. It occurs naturally in all waters. Rain water carries small amount of chloride derived from the ocean. Generally, high chloride content is attributed to the region where in high evaporation, enriched irrigation return flow and intensive irrigational activities. Leaching of salt by water can also leads to higher concentration of chloride in groundwater as documented by Guo et al., (2003). The higher concentration of chlorides can be attributed to the close proximity of these locations near to the sea. The spatial distribution of chloride shown in figures 5 A and B during post monsoon season most of chloride concentration was distributed in eastern part of the study area. Whereas summer season the concentration of chloride was observed in north eastern and southern part of the study area. The high chloride concentration in study area indicates sea water as a source of contamination.

A B



POSTMONSOON SUMMER

Figure 6.Spatial distribution of Cl

5. CONCLUSIONS

In this research, physical and chemical analyses of the ground water samples collected from the coastal areas of Nagapattinam district in Tamilnadu have been studied to investigate to hydrochemistry of the coastal aquifer in order to explain the impact of sea water incursion on the groundwater characteristics. The study area showed generally similar hydrochemical charactersitcs slightly higher level of Cl^-, Na^+ and EC was observed. Based on the Cl^-, Na^+ and EC data, the ground water falls within high salinity. Thus, the use of groundwater in some areas which are very close to the Bay of Bengal. Spatial distribution of ground water quality parameters were carried out through GIS spatial interpolation techniques shows that the quality of ground water based on Na^+, Cl^- and EC parameters. These techniques have successfully identified in groundwater quality mapping of Nagapattinam district. There are two ground water types identified they are desirable and undesirable category.

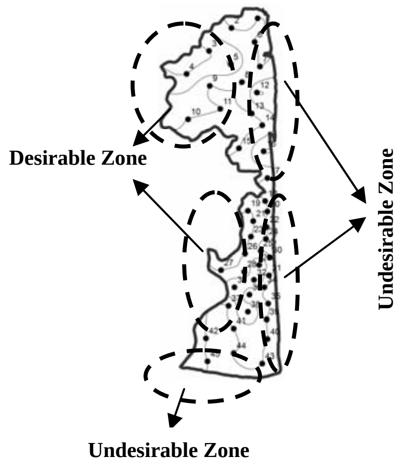


Figure. 7 Groundwater quality map

The figure 7 shows the Ground water quality map. In order to mitigate the environmental effects due to groundwater exploitation for irrigation, a legal restriction on groundwater and the conversion to surface water from groundwater should be implemented in areas where pumping has been intensive. There are several remedial measures including freshwater injection, extraction of saline and brackish waters, modifying pumping practices; land reclamation; increase of the upland recharge areas. So it is essential to the planning and implementation of a long term program for the monitoring and improvement of groundwater quality.

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