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RESEARCH ARTICLE

Assessment of Groundwater Quality in Different Parts of Thiruvallur District of Tamil Nadu, Southern India

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Abstract

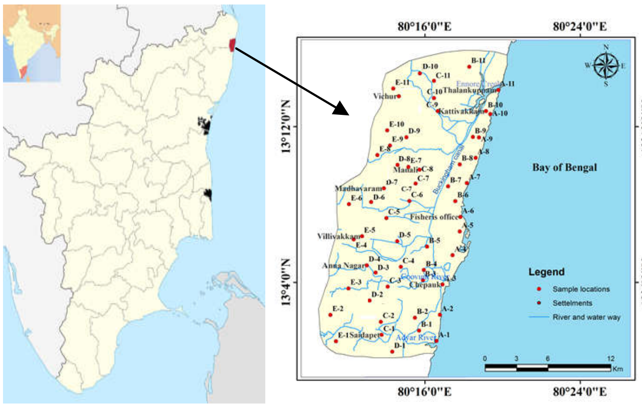
The present study was carried out to assess the physico-chemical characteristics of groundwater in North Chennai of Thiruvallur district. Groundwater samples were collected from 54 locations during pre-monsoon (June) of the year 2016. The samples were analyzed for various parameters like, pH, TDS and EC and major cations and anions to know the geochemistry of the groundwater samples. While comparing BIS (2012), Na, Ca, Mg, K, Cl, NO_3, HCO_3 and SO_4 concentrations it was noted that all were above permissible limit in most of the samples, indicating seawater intrusion along the coastal tract of the study area. Box and whisker plot reveals the order of abundance for major cations and anions. Wilcox diagram and Residual Sodium Carbonate (RSC) indicated the suitability of groundwater for irrigation purpose. Gibb's diagram infers the nature of water and USSL diagram demonstrates the salinity hazard.

Keywords: Groundwater, physico-chemical, geochemical parameters, Gibb's plot, Wilcox diagram.

Introduction

Groundwater is the major source of water for drinking, irrigation and industrial purposes in many arid and semi-arid regions of the world. Groundwater quality has become an important water resources issue due to rapid increase of population, industrialization and urbanization, flow of pollution from upland to lowland and excessive use of fertilizers and pesticides in agriculture (Joarder *et al*., 2008). Groundwater quality in a region is largely determined by the natural processes such as lithology, groundwater velocity and quality of recharge waters/rock-water interaction and interaction with other types of aquifers. Anthropogenic activities like agriculture, industry, urban development, increasing exploitation of water resources and atmospheric input also influence the groundwater quality (Helena *et al*., 2000; Chan, 2001). The poor quality of water adversely affects the plant growth and human health (Todd, 1980; ISI, 1983; WHO, 1984; Hem, 1991). The seawater intrusion is a main cause of high salinity and the groundwater generally demonstrates high concentration not only in total dissolved solids (TDS) but also in major cations and anions (Richter and Kreitler, 1993). Most of the developed countries have already realized that human existence on the earth may be endangered if suitable steps are not taken to discharge agricultural wastes, industrial effluents and urban activities. The quality of groundwater in coastal region is generally affected due to natural processes such as saline water intrusion, evaporation and interaction of groundwater with hard rock formations reported several health hazards among people around the slum areas (Polemio *et al*., 2006; Srinivasamoorthy *et al*., 2011).

Fig. 1. Study area map with sample location.



Hence, keeping the above facts in mind, this study focuses on the groundwater especially in quality aspects in North Chennai, Tamil Nadu. Water samples were analyzed for pre-monsoon (June 2016) for groundwater quality and its contamination and pollutions.

Materials and methods

Study area and geology: The study area is around 250 sq km in North Chennai along the coast and towards inland, Thiruvallur district, North Chennai of Tamil Nadu. It is mainly occupied by industries and factories. The study area falls in the geographical coordinates of 13º00'59.8" to 13º13'53.3" N latitude and 80º16'36" to 80º 19'46.8" E longitude as shown in Fig. 1. It also shows the location of sampling stations.

Table 1. Minimum and maximum concentration of major cations and anions during pre-monsoon season (June 2016).

Characteristics	Min	Max	BIS (2012)	
			Acceptable limit	Permissible limit
pH	7.1	8.2	6.5-8.5	No relaxation
EC (µS/cm)	625	10313	-	-
Total dissolved solids (TDS)	400	6600	500	2000
Total alkalinity mg/L (HCO_3)	42	640	200	600
Sodium mg/L (Na)	112	1368	-	200
Calcium mg/L (Ca)	12	460	75	200
Potassium mg/L (K)	17	118	-	42
Magnesium mg/L (Mg)	19	380	30	100
Chloride mg/L (Cl)	98	2170	250	1000
Nitrate mg/L (NO_3)	10	238	45	No relaxation
Sulphate mg/L (SO_4)	50	541	200	400

It is a coastal region that consists of alluvium, which helps in easy infiltration of the surface water. The district receives rain under the influence of Southwest (Jun-Aug) monsoon and Northeast monsoon (Sep-Nov) seasons, that decreases the concentration of contamination of groundwater. The basement is composed of Precambrian Charnockite and outcrops of which are seen in the western and southwestern regions of the study area. The alluvial flood plains are of sandy-clay that overlies the basement rock. The weathered/fractured Charnockite and alluvium forms the major aquifer system, major source of groundwater recharge is precipitation only. The rock mass consists of quartz, feldspar, biotite and pyroxene. The borehole lithology and rock quality designation, the charnockite rock mass, to a great extent, is classified as 'excellent' and 'good' (Arumugam, 1994). The main source of coastal pollution in Chennai arises from Cooum and Adyar rivers. Ennore creek outlets and industrial effluent discharge at various places along the coastal region (especially, in the North Chennai region). The Chennai city is the fourth largest Metropolis in India and the coastal region of this city is a typical example for uncontrolled disposal of wastewater and serious pollution level.

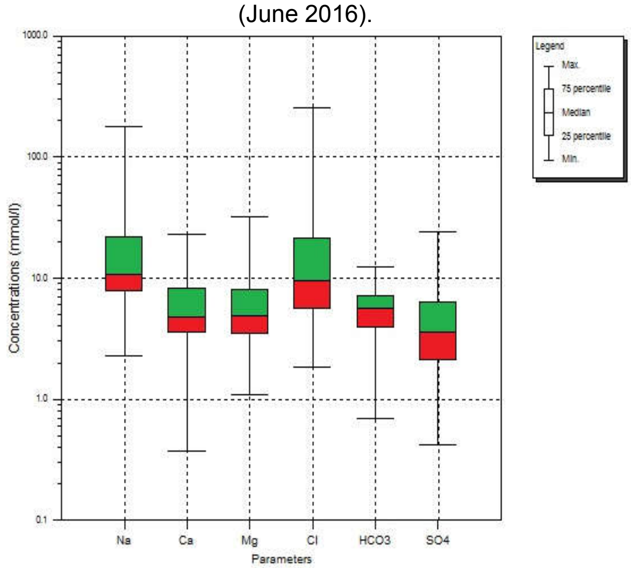
Sample collection: One liter of water sample was collected in polyethylene bottles from various wells during the month of June 2016 representing pre-monsoon season. Fifty four groundwater samples were collected for the season mentioned, for analysis of various physical and chemical parameters. The pH, temperature, electrical conductance (EC) and total dissolved solids (TDS) were measured *in situ* using portable kit in a field. The samples collected were analyzed in the laboratory for concentration of major ions like, calcium, magnesium, potassium and sodium for cations and sulphate, nitrate and chloride for anions were analyzed by Ion Chromatography. Bicarbonate was analyzed by titration method. The analytical procedures followed are as per the American Public Health Association (APHA, 1998). The base map of the study area was prepared using the Survey of India toposheets 66 D/1 and 66 D/5 and was digitized using ARC GIS 9.3 software.

Results and discussion

Minimum and maximum concentration of major cations and anions of groundwater for the study area are presented in Table 1. Groundwater in the study area is generally alkaline in nature with pH ranging from 7.1 to 8.2 during pre-monsoon. In the study area, EC ranges from 625 to 10313 µS/cm during pre-monsoon season. TDS varies from 400 to 6600 mg/L according to BIS (2012).

Box and Whisker plot: Box plots can be used to compare ground water quality data (generally for the same parameter) between wells. The plots are constructed using the median value and the interquartile range (25 and 75 cumulative frequencies are measured as central tendency and variability) (U.S. EPA, 1992). They are a quick and convenient way to visualize the spread of data. Complicated evaluations may dictate use of a series of box plots. The chemical composition of the groundwater samples is shown in Fig. 2. The diagram reveals that the abundance of the major cations is in the order of Na>Mg>Ca and the abundance of the major anions is in the order of Cl>HCO_3>SO_4 during the pre-monsoon season.

Fig. 2. Box and Whisker plot during pre-monsoon season (June 2016).



Wilcox diagram: Sodium concentration is important in classifying the water for irrigation purposes because sodium concentration can reduce the soil permeability and soil structure (Todd, 1980; Domenico and Schwartz, 1990). The concentrations of ions are expressed in milli equivalents per liter in Wilcox diagram (Wilcox, 1955). The water is classified based on the Na% with respect to other cations that are present in water. Values of pre-monsoon groundwater samples of the area are plotted in the Wilcox diagram and are shown in Fig. 3. In the study area, 20% of samples fall in “Doubtful”, 25% of samples fall in “Unsuitable”. It is observed that 16% samples fall in “good to permissible” and 7% samples are in “very good to good” and 32% are “doubtful to unsuitable”. The locations of samples that record “Doubtful to Unsuitable” are of agricultural lands where fertilizers cause the degradation of quality of groundwater. The factories and industries that have been located in and around Ennore, northern region of the study area, also causes the degradation of quality of groundwater and samples collected from this region is also falling under “unsuitable” category. It is observed from Table 2 that most of the samples fall in “Doubtful to unsuitable” and “Unsuitable” categories for irrigation purpose during pre-monsoon season of the study area.

Fig. 3. Wilcox diagram for pre-monsoon season (June 2016).

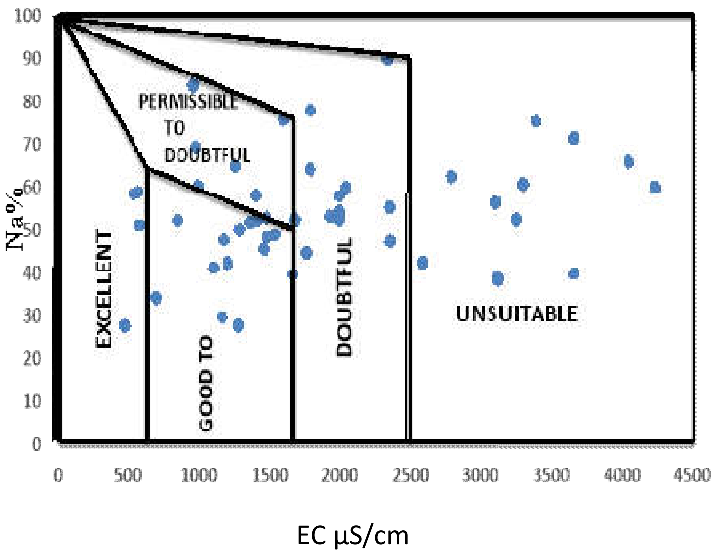


Table 2. Wilcox percentage for pre-monsoon season (June 2016).

Category	Pre-monsoon
Very good to good	7%
Good to permissible	16%
Permissible to doubtful	20%
Doubtful to unsuitable	32%
Unsuitable	25%

Table 3. Residual sodium carbonate percentage for pre-monsoon season (June 2016).

Category	Range	Pre-monsoon sample
Good	<1.5	16%
Doubtful	1.5-2.5	12%
Unsuitable	>2.5	72%

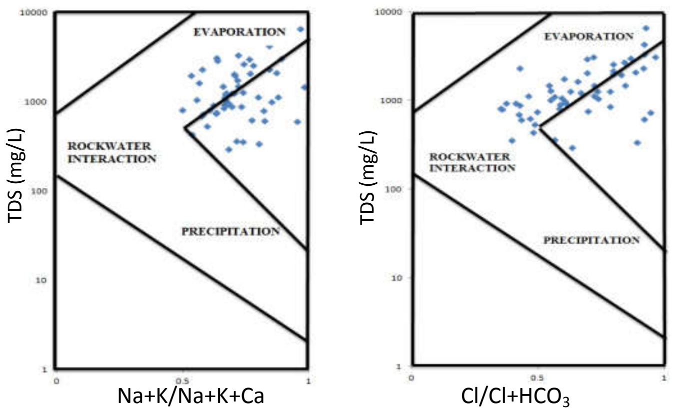
Residual Sodium Carbonate (RSC): Residual Sodium Carbonate is another parameter used to classify groundwater for irrigation purposes. The RSC in groundwater is mainly due to the water that has higher concentration of bicarbonate ions, which precipitates Ca and Mg ions as their carbonates and increases the Na ions which increases the sodium carbonate in the groundwater (Srinivasamoorthy *et al.,* 2013). The RSC was calculated by the following equation (Eaton, 1950).

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

The classification of groundwater was based on the values presented in Table 3. According to this classification, 72% of samples fall in “unsuitable” category for irrigation purpose and these samples are nearer to the coast.

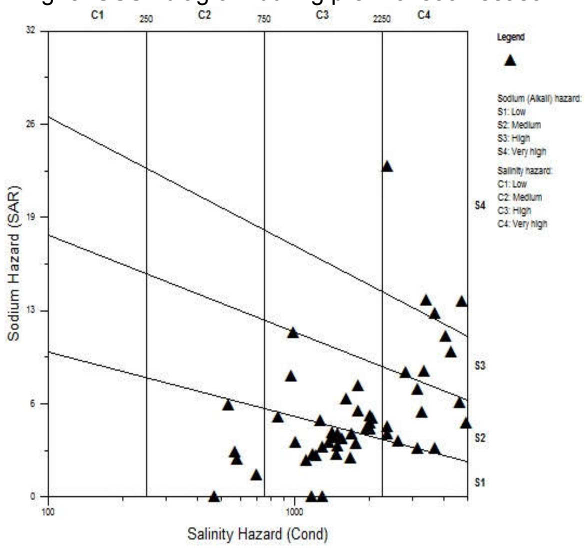
Gibb’s diagram: Chemical relationships of groundwater is based on aquifer lithology (Gibb’s 1970) where there are three kinds of fields that are recognized in the Gibb’s diagram, namely, precipitation dominant, evaporation-crystallization dominant, and rock-water interaction dominant. Gibb’s present two plots, TDS versus (Na+K/Na+K+Ca) and TDS versus ($Cl/Cl+HCO_3$). Gibb’s plot for pre-monsoon (Fig. 4) using the groundwater quality data have been plotted. The majority of the samples fall in “Evaporation” field. Groundwater samples of fresh and saline waters were individually scattered in the evaporation dominance fields for the season that indicates higher concentration of salts in the respective locations. According to Gibb’s plot, evaporation and anthropogenic activity in the study area are responsible for the chemical composition of the groundwater during pre-monsoon season.

Fig. 4. Gibb’s diagram for pre-monsoon season (June 2016).



USSL diagram: This diagram is used in interpreting the analysis for irrigation and the water can be grouped into 16 classes. It uses Sodium Absorption Ratio (SAR) in vertical axis and conductance along horizontal axis (Fig. 5). All concentration values are expressed in equivalents per million. Salinity, sodicity and toxicity generally, need to be considered for evaluation of the suitability of groundwater for irrigation (Todd, 1980, Shainberg and oster, 1976). Sodium absorption ratio is also used to determine the suitability of groundwater for irrigation as it gives a measure of alkali/sodium hazard to crops. If calcium and magnesium are dominant, the hazard is low. In the USSL diagram, S1, S2, S3, S4 types indicate sodium hazards and C1, C2, C3, C4 types indicate the salinity hazards. Based on this classification, the majority of the samples belongs to C3S1 (High salinity, Low sodium) and C3S2 (High salinity and Medium sodium) during pre-monsoon season of the study area.

Fig. 5. USSL diagram during pre-monsoon season.



Conclusion

The concentration of cations and anions were above the permissible limit in some locations are due to continuous discharge of industrial effluents as well as seawater intrusion. The Box and Whisker plot reveal the abundance of major Cation as Na> Mg>Ca and major Anion as Cl> HCO_3> SO_4> NO_3. Wilcox diagram reveals that the samples collected nearer to the coast are "Unsuitable" and samples collected nearer to the factories and industries are "Doubtful to unsuitable" for irrigations. The RSC percentage in most of the samples shows "unsuitable" category for irrigation purposes. From the Gibb's diagram, it is inferred that majority of the samples fall in "evaporation" field which facilitate the increase in concentration of salts in the respective locations. USSL diagram demonstrate that the samples fall in C3S1 and C3S2 indicate the salinity hazard, unsuitable for irrigation due to addition of agricultural waste, industrial effluents, and urban activities apart from seawater intrusion.

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