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Groundwater Quality Assessment of Kurunthancode Block in Kanyakumari District, India

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Abstract: Kurunthancode is located in Kanyakumari district, the Southern end of India. The region covers about 106 Km^2 area situated 695 Km from Chennai and 65 km from Thiruvananthapuram. This area depends on Valliyar river and groundwater resources for their domestic and agricultural purposes. Groundwater samples were collected from 25 wells in open and tube wells at various locations in the study area during January 2014. The collected samples were analyzed for major and minor ions and the analytical data were interpreted according to published guide lines. The physico-chemical parameters such as pH, EC, Na^+,Ca^{2+},Mg^{2+},K^+ , Cl^- ,HCO_3^- -,SO_4^{2-} ,NO_3^- and F^- were analyzed to know the present status of groundwater quality. The spatial maps show that the concentration of the chemical constituent in ground water varies spatially. Gibbs diagram revealed that the overall hydro-geochemical environment of the study area is controlled by rock-water interaction. A comparison of groundwater quality in relation to dinking water quality standards proves that most of samples suitable and few samples exceed the permissible limit for drinking. Wilcox diagram USSL classification and RSC were found to be in consonance with its irrigation suitability.
Keywords: Groundwater, Physicochemical characteristics, Irrigation water quality.

Introduction

Water is one of the most indispensable resources and is the elixir of life. Water constitutes about 70% of the body weight of almost all living organisms. About 97.2% of water on earth is salty and only 2.8% is present as fresh water from which about 20% of the world resources of fresh water widely used by industries, irrigation and domestic purposes[1]. Water plays an important role in the wealth of a nation particularly like India which is predominantly an agriculture dependent economy. The importance of water for the existence of life need not be over emphasized. Ground water is the major source for drinking and domestic purposes in both rural and urban areas. Besides, it is an important source for agriculture and industrial sectors. In rural areas where the water sources like dam, canal or river is not available groundwater is explored for domestic and agricultural purposes. As per current analysis, this is observed that the groundwater get polluted drastically because of increased human activities because of which, water borne diseases has been seen which a cause of health problems a lot. The above situation is changing very rapidly and at a very alarming ate due to pollutants from various sources. Moreover the groundwater quality is mostly affected by either natural geochemical such as mineral weathering dissolution/precipitation reactions, ion exchange etc the quality of groundwater may vary from place to place. In addition to above rapid population growth increasing living standards, untreated municipal and industrial waste-water fertilizers application of pesticides sewers and landfill areas are the potential sources of groundwater pollution. Water pollution is considered with great concern, since the quality of water is of vital importance for mankind and it is associated with human welfare. Therefore basic concentration is needed to monitor the quality of water as well as to find out various sources which increased groundwater pollution. The present study was carried to evaluate the groundwater quality and its suitability for domestic and agricultural activities in Kurunthancode bock of Kanyakumari district.

Study Area

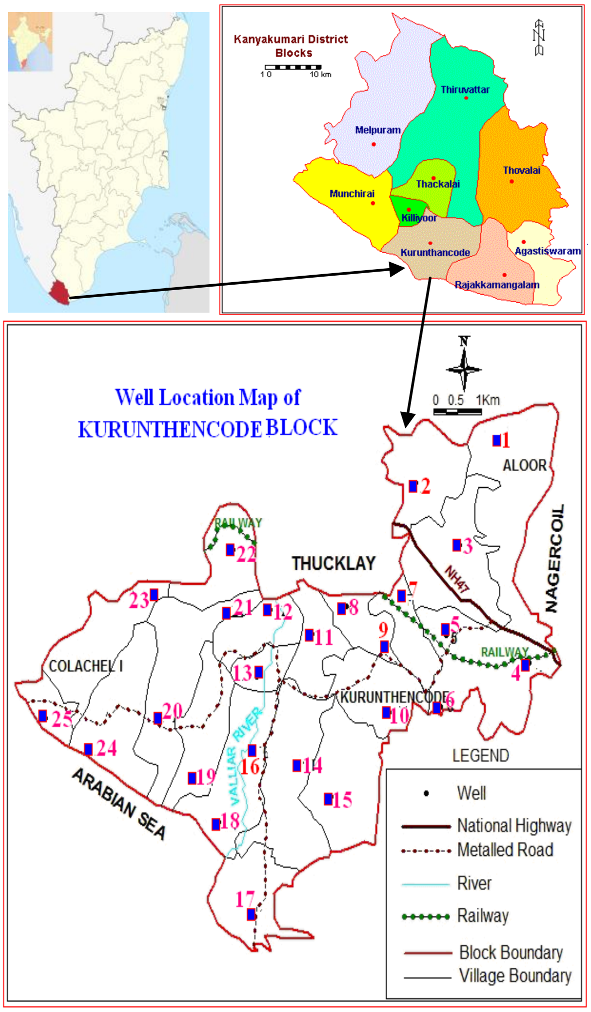

Fig.1: Location of the study area with

The study area chosen for this study is Kurunthancode block located in Kanyakumari district of Tamil Nadu in southernmost tip of India (Fig. 1). The National Geographic has suggested that Kanyakumari district is one of Indian’s Six Hidden Gems. The area covers about 106 Km^2 situated 695 Km from Chennai and 75 km from Thiruvananthapuram. It lies between the longitudes 77 ^{0}14’ 40 ’’ E to 77^{0} 21’ 10’’ E and 8^{0}10’37’’N to 8^{0}14’02’’N to latitudes. The block is situated closed to the tip of the peninsular India is the southernmost part in the Indian main land. The area is sandwiched between the Arabian Sea and the Western Ghats, the area is surrounded by hills, lush green paddy field, and sandy beaches on western sides. This area forms a part of the Survey of India toposheet no. C43/8. The southwest monsoon chiefly contributes to the rainfall in the district. The normal annual rainfall over the block varies from about 826 to 1456 mm and the temperature varying from 23.78^{0}C and 33.95^{0}C respectively. The area is underlain by Kondalite and Migmatite complex rocks. Soil types within the area are classified into red loams, red lateritic soil, and pale reddish in colour. They are derived from laterisation of gneisses and mostly brownish colour. The coastal sand occurs in the western side of the area. The groundwater condition may discontinuous, unconfined to semi-confined aquifers, restricted to weathered residuum and fractures. Normally yield prospects of these aquifers are 150 to 200 cumec/day. The main surface water resources is Valliyar river which originating from Vallimalai hills. This area depends on Valliyar river and Thirparappu falls for its drinking water supply. In addition to this, people in this region also depend on the groundwater resources for their domestic and agricultural needs. Urbanization and improper disposal are causing pollution, especially groundwater contamination in the area of concern. The chief irrigation sources in the area are the Canals, tanks, wells and tube/bore wells and other sources The principal crops are paddy, banana and coconut be cultivated by surface and sub surface irrigation sources. Textile dyeing and agriculture are the activities in this area. Kurunthancode is accessible by road from any parts of Nagercoil and Thucklay towns.

Materials and Methods

Table 1: Showing Sampling Locations

Sample ID	Location	Source	Sample ID	Location	Source
1	Villukury I	Open Well	14	Seramangalam	Bore Well
2	Villukury II	Bore Well	15	Manavalakurichi	Bore Well
3	Karavilai	Bore Well	16	Kannamangalam	Bore Well
4	Aloor	Open Well	17	Muttom	Bore Well
5	Kaddimancode	Bore Well	18	Mondaikadu	Bore Well
6	Nanganvilai	Bore Well	19	Vivekananda School	Bore Well
7	Cheruppancode	Open Well	20	Lekshmipuram	Bore Well
8	Nettancode north	Bore Well	21	West Kallukottam	Bore Well
9	Nettancode south	Open Well	22	Kallukottam	Bore Well
10	Kurunthancode	Bore Well	23	Colachel I	Bore Well
11	Gnarode	Bore Well	24	Colachel II	Bore Well
12	Attuvarambu	Open Well	25	Kalimar	Bore Well
13	Thalakulam	Bore Well			

Groundwater samples were collected from 25 wells spread throughout the study area (Table 1) for a period January 2014 (winter season) from open wells and tube wells. The collected groundwater samples were transferred into precleaned polythene container for analysis of chemical characters. Electrical Condutivity (µS/cm) and hydrogen-ion activity (pH) of water samples were measured in the field by using portable kits. The collected groundwater samples were carried to the laboratory for the analysis of major ions such as Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, CO_3^{2-}, HCO_3^{-}, Cl^{-}, SO_4^{2-} and trace ions NO_3^{-}, F^{-}. The water quality variables analysis was done as per the standard procedure of APHA[2].

Results and Discussion

Physico-Chemical Analysis of Groundwater:

The water quality analysis of different groundwater samples have been carried out for pH, EC, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, CO_3^{2-}, HCO_3^{-}, Cl^{-}, SO_4^{2-} ,NO_3^{-}, F^{-}. The data were used for understanding the spatial distribution of ions, suitability for domestic and irrigation purposes in Kurunthancode block.

pH and Electrical Conductivity (EC) :

The pH in natural water is the carbonate which comprises CO_2, and HCO_3^{-}[7]. It is depending on the composition of the rocks and sediments that surround the travel pathway of the recharge water infiltrating to the ground water. The pH is a measure of the intensity of acidity or alkalinity. The pH value of water samples varied between 1.92 to 7.79 with an average value of 7.80, and were found within the limit prescribed by WHO (6.5-8.5). All the samples shows slightly alkaline values, one of the sample was acidic in nature i.e. tube well from Colachel (1.92) is due to local pollution. There is no abnormal change of pH in the groundwater samples.

Electrical conductivity (EC) is a measure of water capacity to convey electric current[3]. Conductivity becomes an indicator of dissolved salts present in any water sample, which is measure of salinity that affects the taste of potable water. All the samples were within the permissible limits of standards for dinking water except few samples exceed the limit. About 84% of samples have TDS less than 1000 mg/l; hence suitable for drinking. EC values ranges from 60 to 8574µs/cm with an average value of 1052.92µS/cm, indicating low mineralization in this region except in Nettancode and Colachel-I were higher than permissible limit. The higher conductivity might be due to domestic wastes, agricultural practices and geological formation. The spatial distribution of pH and EC in groundwater is given in Fig. 2. Thus it indicates that the groundwater samples are fit for domestic purposes.

Calcium (Ca^{2+}) and Magnesium (Mg^{2+}): Calcium and magnesium are directly related to hardness[4]. Most of the aquifer are composed of calcium in groundwater, the calcium content generally exceeds the magnesium content[5]. Calcium content is very common in groundwater, because they are available in most of the rocks abundantly and has its higher solubility. But calcium is an essential nutritional element for human being and aids in the maintaining the structure of plant cells and soils[6]. In drinking water, the desirable limit of calcium is 75 mg/l and permissible limit in the absence of alternative source of water is 200 mg/l as per BIS[7]. Calcium concentration in groundwater of the area ranges from 5 to 200 mg/l with an average value of 48.26 mg/l; whereas high concentrations are found in 5 locations exceed the desirable limit, conditionally unfit for dinking purposes in case there is no alternative source of water supply.

Magnesium (Mg^{2+}) generally occurs in lesser concentration than calcium because of dissolution of magnesium rich minerals is slow process and calcium is more abundant in earth crust[8]. Magnesium contents ranges from range from 1 to 504 mg/l with the average value of 36.36 mg/l. The desirable limit of magnesium is 30 mg/l and the maximum permissible limit for magnesium is 100 mg/l in drinking water supplies. It is observed that 52% of groundwater samples exceed the desirable limit. The spatial distribution of calcium and magnesium in groundwater is shown in Fig. 2.

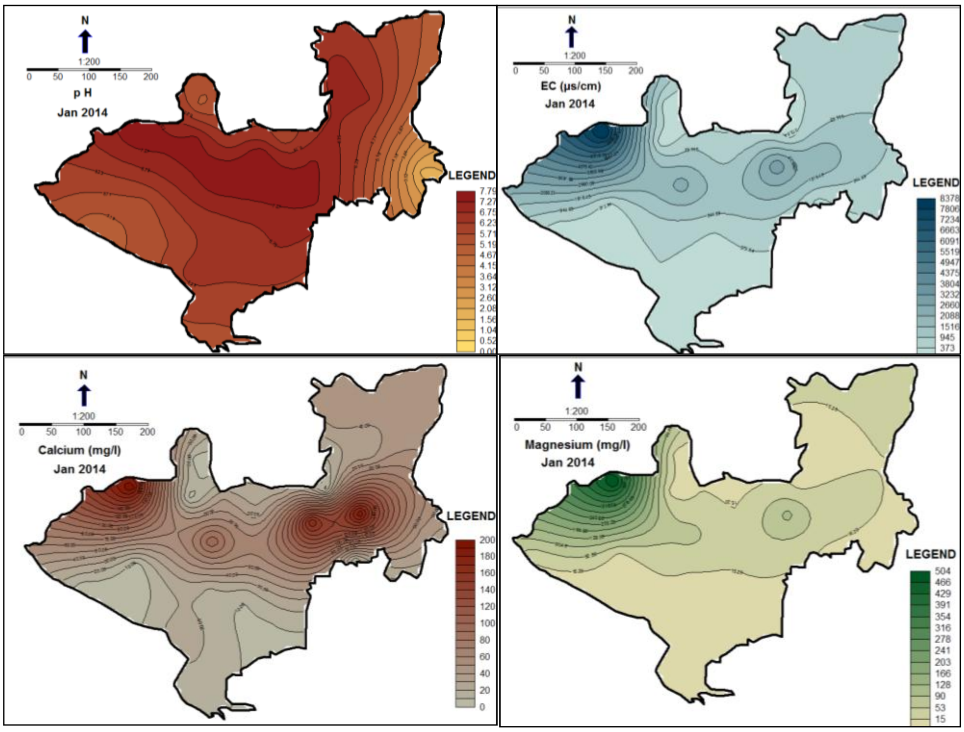

Fig. 2: Spatial Distributions of pH, EC, Ca and Mg in

Sodium (Na^{+}) and Chloride (Cl^{-}):

Sodium unlike calcium, magnesium and silica is not found as an essential constituent of many of the common rock-forming minerals. The sodium concentration more than 50 mg/l makes the water unsuitable for domestic use because it causes severe health problems like hypertension. Sodium concentration of groundwater samples in this area varies from 7 to 640 mg/l with an average value of 4.35 mg/l. All the samples are within the permissible limit except 3 samples which exceeds the permissible limit. High concentration of sodium ion in drinking water may cause heart problems and high sodium ion in irrigation water may cause salinity problems[9].

Chloride is a major anion in potable and industrial water has no adverse effect on health, but imparts bad taste to drinking water. The chloride concentration serves as an indicator of pollution by sewage. Chloride salts in excess of 100 mg/l give salty taste to water. People accustomed to higher chloride in water are subjected to laxative effects[10]. Increase of chlorine level in water is injurious to people suffering due to heart and kidney diseases. The chloride concentration of groundwater samples in this area ranges from 10 to 2650 mg/l with an average value of 271.6 mg/l. Excessive chloride (>250 mg/l) imparts a salty taste to water in 5 locations and other area concentration is less as per limit. The spatial distribution of sodium and chloride in groundwater is shown in Fig. 3.

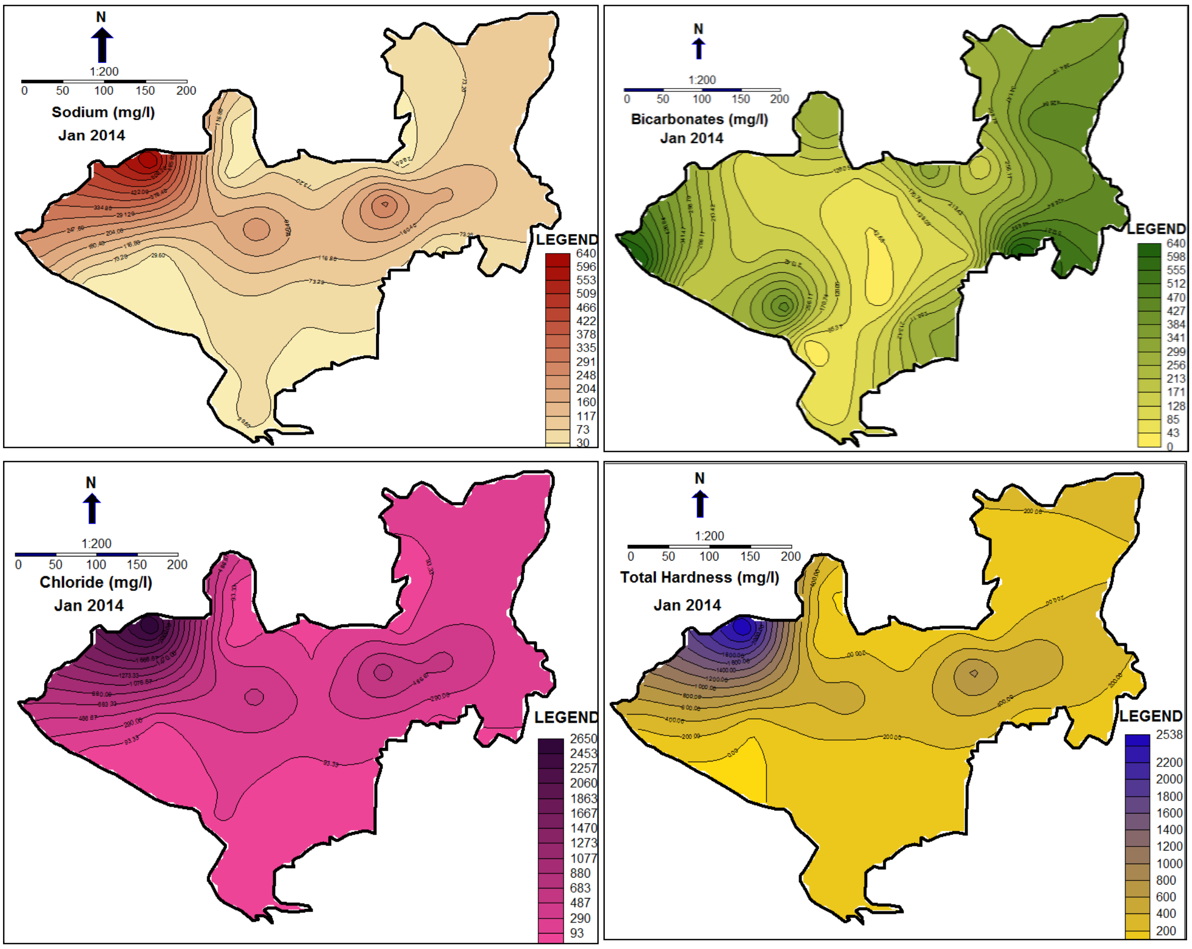

Fig. 3: Spatial Distributions of Na, HCO3, Cl and TH

Bicarbonate (HCO_3^-) and Total Hardness (TH):

The primary source of HCO_3^- ions in groundwater is the dissolved CO_2 in rainwater that on entering in the soil dissolves more CO_2. An increase in temperature or decrease in pressure causes reduction in the solubility of CO_2 in water, decay of organic matter and SO_4^{2-} reducing bacteria may also release CO_2 for dissolution. Water changed with CO_2 dissolved carbonate minerals, passes through the soil and rocks, to give HCO3-. Weathering of silicate minerals also has the possibility of HCO_3^- liberation. Bicarbonate concentration of groundwater samples in this area varies from 24.4 to 652.7 mg/l with an average value of 417 mg/l. Nearly 44% of the groundwater samples exceed the permissible limit of 250 mg/l as per limit. High amount of alkalinity in water is harmful for irrigation which leads to soil damage and reduce crop yield[11].

Total hardness (TH) of water mainly depends upon the amount of calcium and magnesium salts or both[12]. Hardness gives an unpleasant taste to the water. Hardness values of water samples ranged from 16 to 2600 mg/l with an average value of 272.4 mg/l. The high TH may cause encrustation on water supply distribution system. The spatial distribution of total hardness in groundwater is shown in Figure 3 which shows that almost all the groundwater samples fall in the soft, hard to very hard category. The maximum allowable limit of TH for drinking water is 500 mg/l and the desirable limit is 100 mg/l as per standards. The total hardness is relatively high in all samples. The spatial distribution of bicarbonate and Total Hardness is shown in Fig. 3.

Fluoride (F^-) and Nitrate (NO_3^-):

The value of fluoride for the groundwater samples is recorded between 0 to 0.6 mg/l with an average value of 0.24 mg/l. Small concentration of fluoride in drinking water has beneficial effect on human health for preventing dental caries. Higher concentration of fluoride than that of 1.5 mg/l carry an increase risk of dental fluorosis and much higher concentration lead to skeletal fluorosis[13]. The desirable limit for fluoride in drinking water is 0.6 to 1.5 mg/l[14]. The impact of fluoride concentration in drinking water and possible health effects about 21 samples are less than 0.5 mg/l which will make limited growth and fertility (dental caries) 4 samples of which promotes dental health resulting in healthy teeth while fluoride content between 0.5 to 1.5 mg/l .

The value of nitrate in all the groundwater sampling locations is found between 1 to 9 mg/l and an average value of 5.16 mg/l. The presence of nitrate in groundwater may due to the application nitrogenous fertilizer to the agricultural fields, sewages and other wastes rich in nitrates[15]. All the samples fall within the permissible limit of 45 mg/l for drinking purpose. Moreover, the increased nitrate level in drinking water may adversely affect the central nervous system[16].

Classification of groundwater

The piper trilinear diagram is used to infer hydro-geochemical facies[17]. Chemical data of representative samples from the study area are presented by plotting them on a piper tri-linear diagram (Fig. 4). The diagram reveals similarities and differences among water samples because those with similar qualities will tend to plot together as group[18]. This diagram is useful in bringing out chemical relationships among water in more definite term[3]. On the basis of chemical analysis, groundwater is divided into six facies. The plot shows that groundwater samples fall in the field of Ca-HCO3, Na-Cl, mixed Ca-Na-HCO_3 and mixed Ca-Mg-Cl types.

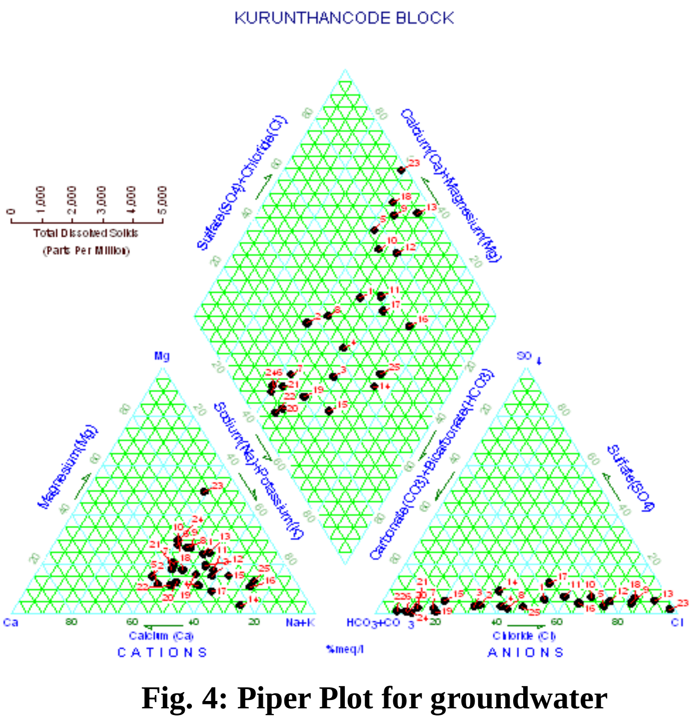

Fig. 4: Piper Plot for groundwater

Mechanism controlling groundwater chemistry:

The quality of groundwater is significantly changed by the influence of weathering and anthropogenic inputs. The Gibbs diagram is widely used to establish the relationship of water composition and aquifer lithological characteristics[19]. Three distinct fields such as precipitation dominance, evaporation dominance and rock-water interaction dominance areas as shown in the Gibb diagram (Fig. 5). The predominant samples fall in the rock-water interaction dominance and few samples evaporation and precipitation dominance field of the Gibbs diagram. The rock-water interaction dominance field indicates the interaction between rock chemistry and the chemistry of the percolation waters under the subsurface.

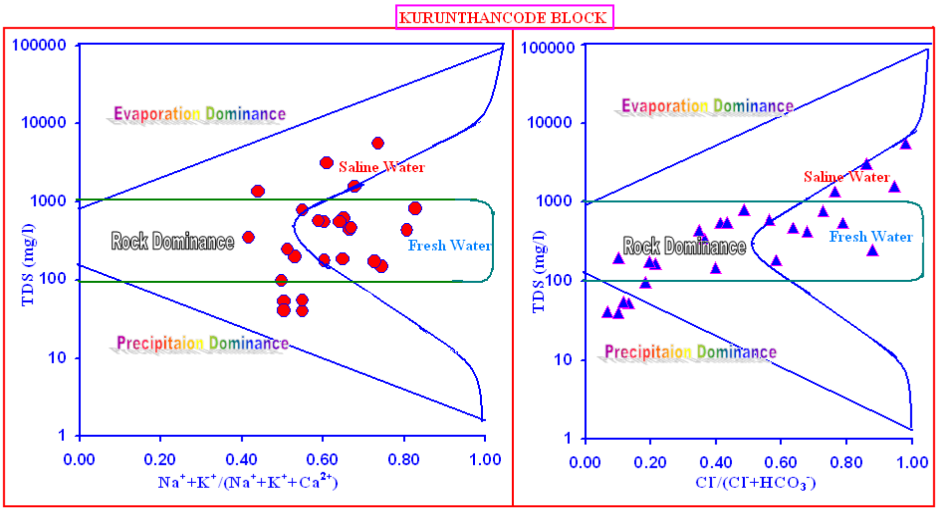

Fig .5: Gibbs plot for water samples

Stuyfzand Classification of groundwater

Stuyfzand[20] has classified the groundwater based on chlorinity into 8 types as shown in Table 2. It is used for identification of freshwater flow zone from the zone of salt-water intrusion. There was no samples falls in Oligohaline water types occur. Fresh water occurs in location 2,3,4,6,7,11,14,15,16,17,18,19,20,21,22 and 24. Fresh-Brackish water found in sampling locations 1, 4, 8, 9, 10 and 12. All the remaining sampling locations 5, 13, 23 and 25 the brackish water type exists.

Table 2: Stuyfzand Classification of groundwater

Main Type	Cl- (mg/l)	Main Type	Cl- (mg/l)
Very Oligohaline	<5	Brackish	$300\text{-}10^3$
Oligohaline	5-30	Brackish-Salt	$103\text{-}10^4$
Fresh	30-150	Salt	$104\text{-}2x10^4$
Fresh-Brackish	150-300	Hyperhaline	$>2x10^4$

Criteria for Reorganization of Salt Water Intrusion

Table 3: Criteria for Reorganization of Salt water Intrusion

Type	Range	Description	Water Samples
Cl^-/HCO_3^-	<0.05	Normally fresh groundwater	22,24
	0.05-1.30	Slightly contaminated groundwater	1,2,3,4,6,7,11,16,17,19,20,21,24
	1.30-2.80	Moderately contaminated groundwater	5,8,10,12,14,15,18,22,25
	2.80-6.60	Injuriously contaminated groundwater	9,17
	6.60-15.50	Highly contaminated groundwater	13

The salinization amount in the groundwater can be classified using the Cl^-/HCO_3^- ratios [21]. The Cl^-/HCO_3^- ratio was computed for the groundwater samples of the study area and given in Table 3. Chloride is most dominant in ocean water and normally occurs in small amount in groundwater while HCO_3^{2-} is usually the most abundant negative ion in groundwater but it occurs in minor amount in the sea water. The degree of concentration is as follows. From the above the limits majority of the area shows slightly to moderately contaminated groundwater with the values of 0.05 to 2.80. There is fresh groundwater occurs in Kallukottam and Colachel II indicated that the groundwater is normally good, 13 samples fall in slightly contaminated groundwater, 9 samples fall in moderately contaminated. Nettancode south and Mondaikadu areas were seem in injuriously contaminated groundwater. However, the Colachel I values of Cl^-/HCO_3^- indicate the water is highly saline which may due to saline water intrusion according to the ratio as shown in Table 3.

Mg^{2+}/Ca^{2+} ratio

Mg^{2+}/Ca^{2+} ionic ratios in groundwater samples were normally in the range of 0.5 – 0.7. But the values obtained by analysis are ranges from 0.16 to 2.52, indicated that in Colachel I the groundwater may be affected by intrusion of Arabian Sea. The remaining samples fall within the limit.

Wilcox diagram

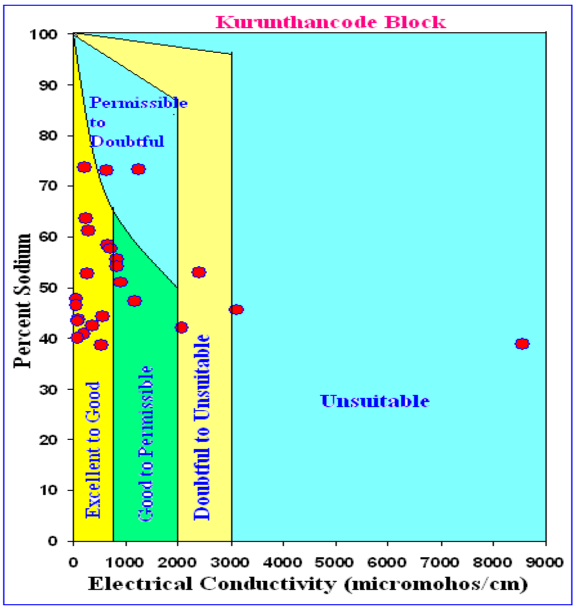

Fig.6: Wilcox classification of Irrigation

Wilcox[22] classified groundwater for irrigation purposes based on percent sodium and electrical conductivity. The sodium percentage in the study area ranges from 38.63 to 73.60% majority of samples is less than 60% and 2 samples exceed the limit. A maximum of 60% of Na^+ in groundwater is allowed for agricultural purpose. Sodium concentration is important in classifying irrigation water because sodium reacts with soil to reduce its permeability, texture makes the soil hard to plough and unsuitable for seeding emergence[23]. According to Wilcox , the water quality diagram (Fig. 6) for irrigation purposes indicates that most of the groundwater samples fall in the fields of good to permissible which is suitable, 2 samples fall in doubtful to unsuitable and 2 sample to unsuitable category.

USSL diagram

The United States of Salinity Laboratory's (USSL) classification of the water is based on the EC and SAR. The U. S. Salinity Laboratory of the Department of Agriculture 1954 proposed a diagram in which EC is taken as salinity hazard and SAR as sodium hazard. The diagram is divided into good water, moderate water and poor water. In the present study the groundwater in different aquifers of the study area falls mostly on good water types few samples falls into moderate and poor water types. SAR values vary from 0.61 to 6.40. Based on the SAR values alone, the groundwater samples come under excellent categories.

Residual Sodium Carbonate (RSC)

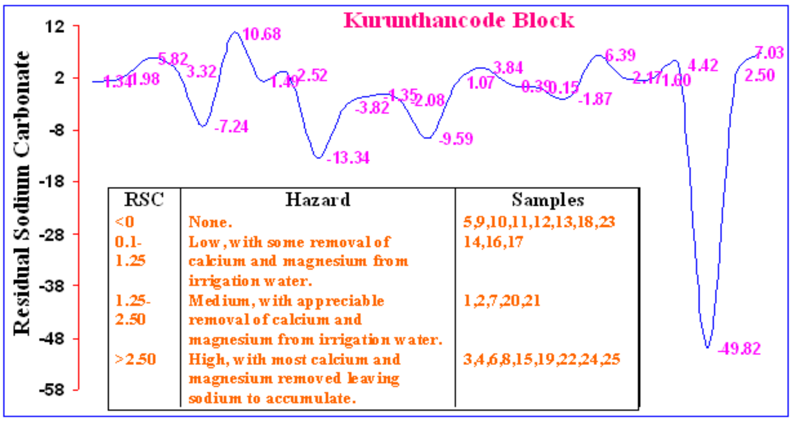

Fig. 7: Residual Sodium Carbonates of Irrigation

In addition to the SAR, the excess amount of CO_3^{2-} and HCO_3^{-} in groundwater over the sum of Ca^{2+} and Mg^{2+} also influences the suitability in groundwater for irrigation (Fig.7). Eaton[24] recommended the concentration of residual sodium carbonate to determine the suitability of water for irrigation purposes. An excess amount of sodium bi-carbonate and carbonate is considered to be detrimental to the physical properties of soils as it causes dissolution of organic matter in the soil, which turn leaves a black stain on the soil surface on drying. RSC values should be preferably less than 1.25 to be rendered suitable for irrigation purpose and hence in the present study where RSC values range between -49.82 to 10.68 and 9 samples have RSC>2.5 (Fig 2); it can be concluded that few samples in the area poses an alkaline hazard to the soil indicating localized hazard.

Conclusions

The hydro-chemical analysis of the study reveals that the groundwater in Kuranthocode block is soft, hard to very hard category and slightly alkaline in nature. The type of water that predominates in the area is Ca-HCO3, Na-Cl, mixed Ca-Na-HCO_3 and mixed Ca-Mg-Cl types. Comparing to standard limits the constituents of the sampled water are within the permissible level and hence the groundwater is considered to be suitable for domestic and irrigation purpose. About 84% of samples have TDS less than 1000 mg/l; hence suitable for drinking. The SAR values of the study area are to be less than 10 and TDS is less than 1500 could be utilized for irrigation. On the basis of USSL diagram and Wilcox diagram the groundwater are within the safe limit of irrigation except few locations. Natural and anthropogenic activities affect the spatial variation of groundwater quality in the area. Hence continuous monitoring of groundwater quality is essential in order to supply potable water to the rural people.

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