ISSN: 2454-3659 (P), 2454-3861(E)
Volume I, Issue 7 December 2015
International Journal of Multidisciplinary Research Centre
Research Article / Survey Paper / Case Study

ASSESSMENT OF GROUNDWATER QUALITY FOR DRINKING AND IRRIGATIONAL USE IN THOPPUR, DHARMAPURI, TAMIL NADU

Authors Details
Name: Dr. N.Thangadurai
Affiliation: Jayalakshmi Institute of Technology Thoppur, Dharmapuri, Tamil Nadu
COUNTRY: India

Authors Details
Name: Mr.V.Sakthivel
Affiliation: Jayalakshmi Institute of Technology Thoppur, Dharmapuri, Tamil Nadu
COUNTRY: India

ABSTRACT

The groundwater quality assessment for drinking water has always been a paramount in the field of environmental quality management. In order to understand the hydrochemistry and the possible contamination of groundwater for drinking and irrigation purposes, fifteen groundwater samples have been collected from Thoppur region of Dharmapuri district in July 2015 and various physio-chemical characteristics (pH, EC, TDS, Turbidity, TH, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, NH_4, NO_2^-, NO_3^-, Cl^-, F^-, SO_4^{2-} and PO_4^{2-}) were analysed. The concentration of physiochemical parameters in the studied samples were compared with the BIS standards to study the suitability of water for drinking. Based on the analysis, most of the samples are suitable for drinking. Sodium Adsorption Ratio (SAR), Magnesium Adsorption Ratio (MAR), Kelley's ratio (KR), Soluble Sodium Percent (SSP) and Percent Sodium (Na %) were also studied to ascertain the suitability of water for irrigation purposes. It revealed that all the samples (100 %) are suitable for irrigation based on the SAR, whereas 80 % of the samples are suitable for irrigation based on KR and SSP.

Key words: Thoppur, groundwater quality, irrigation

INTRODUCTION

Groundwater is an important source of freshwater for agricultural, drinking and domestic uses in many regions of the world (Balachandar et al. 2010). There has been a tremendous increase in demand for fresh water due to population growth and intense agricultural activities. Quality of groundwater is equally important as its quantity owing to the suitability of water for various purposes. Variation of groundwater quality in an area is a function of physical and chemical parameters that are greatly influenced by geological formations and anthropogenic activities (Subramani et al., 2005). Groundwater has become the major source of water supply for domestic, industrial and agricultural sectors of many countries. The World Health Organization (WHO) has repeatedly insisted that the single major factor adversely influencing the general health and life expectancy of a population in many developing countries is lack of ready access to clean drinking water (Davies, 1995).

An appropriate assessment of the suitability of groundwater requires the determination of concentrations of some important parameters like pH, EC, TDS, Turbidity, TH, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, NH_4, NO_2^-, NO_3^-, Cl^-, F^-, SO_4^{2-} and PO_4^{2-} thereby comparing with the guideline values set for potable water (WHO, 2004; BIS, 1991).Groundwater assessment for drinking and irrigation has become a necessary and important task for present and future groundwater quality management. Nowadays, a lot of studies have focused on groundwater quality monitoring and evaluation for domestic and agricultural activities around the world (Mitra et al. 2007; Jain et al. 2009; Hakim et al. 2009; Nagarajan et al. 2010). The specific objectives of this work were to investigate the hydrochemical characteristics of the groundwater and to discuss its possibility for drinking and agricultural purposes. This study aims at providing a basis for an interpretation of the quality of water resources in the Thoppur region, trying to distinguish the different effects on groundwater quality.

STUDY AREA

Thoppur is a village in Dharmapuri district of Tamil Nadu, India. Thoppur is a small village on the Thoppur River, located just north of the border of Dharmapuri with Salem district. Thoppur lies between the city of Salem and the town of Dharmapuri on National Highway 7, at its junction with Mettur Dam Road (SH 20). It is 50 km north of the city of Salem and 164 kmsouth of the city of Bangalore.It is also connected by rail and only passenger trains will halt at the station which is approximately 3 to 4km to the town.

Normal and warm condition generally prevail in this area with the summer temperature reaching a maximum of up to 38^{O}C. The district has an average annual rainfall of 895.56 mm. The tropical forests here generally have short shrubs and thorned-plants. The map of the study area is shown in the figure 1.

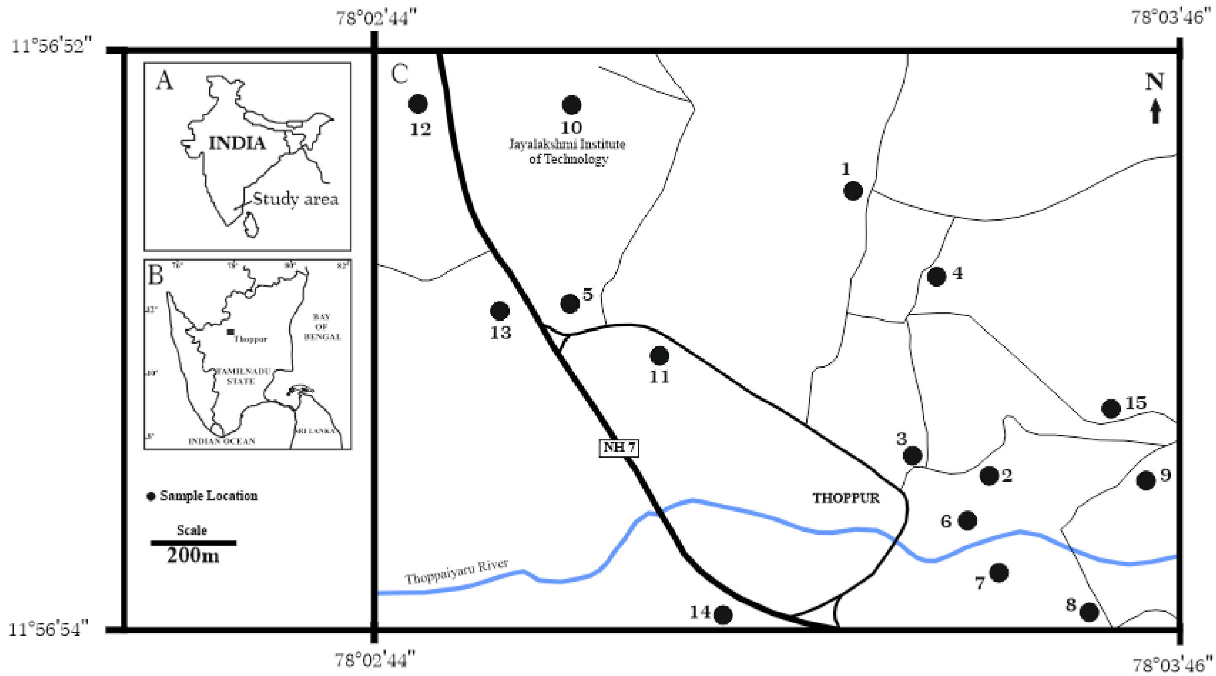

Figure 1. Study area map showing sampling locations

The study area forms part of the upland plateau region of Tamil Nadu with many hill ranges and undulating plains. The western part of the district between Pennagaram and Denkanikottai has hill ranges of Mysore Plateau with a chain of undulating hills. The southern boundary of the district is occupied by the Shevaroy hill ranges. The plains occupying the central, eastern and southern parts of the district have an average elevation of 488m above mean sea level. The Plateau region along the western boundary and the northwestern part of the district has an average elevation of 914m above mean sea level. The soils types in the study area are Red, Brown and alluvial soil. The soils are mostly in-situ in nature, lateritic, earthy and pale reddish in colour. They are derived from laterisation of gneisses. The soils derived from gneisses are mostly brownish. The thickness of soils in the mounts is almost negligible whereas in the valleys it is around 2m.

Materials And Methods

Groundwater samples were collected from 15 dug wells and bore wells of the study area during July 2015 following the standard guidelines (APHA, 1980). The location of the sampling points is shown in the figure 1. The groundwater samples were collected in prewashed polyethylene narrow-mouth bottles from the dug wells and frequently used bore wells. The samples was collected after pumping the wells for 5-10 min and rinsing the bottles for two to three times with water to be sampled. The parameters like pH, Electrical Conductivity (EC) were measured on the spot during sampling and the groundwater samples collected were stored in plastic containers and transferred to the laboratory for further analysis as recommended by American Public Health Association (APHA, 1995).

The analysed parameters includes hydrogen ion concentration (pH), electrical conductivity (EC), Total Dissolved Solids (TDS), Turbidity, Total hardness (TH) and important cations such as Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Sodium (Na^{+}) and Potassium (K^{+}) as well as anions such as Ammonia (NH_4), Nitrite (NO_2^{-}), Nitrate (NO_3^{-}), Chloride (Cl^{-}), Fluoride (F^{-}), Sulphate(SO_4^{2-}) and Phosphate (PO_4^{2-}).

Statistical analysis based on various parameters was effectively used for interpretation and R-mode factor analysis was applied commonly to all the samples to establish the inter-element relationship. It is also used to identify the association between each factor, which are represented as factor 1 (F1), factor 2 (F2) and factor 3 (F3) (Bridgman 1992; SPSS 1995).

RESULTS AND DISCUSSION

Physico-Chemical Parameters Of Groundwater

The physical observations of the studied samples are colourless and odourless in nature. The graphical representations of various ionic concentrations in all the groundwater samples (15 Nos.) are shown in the figure 2. The pH values in the study area ranges from 7.08 at location 4 to 7.59 at location 11 with an average value of 7.35(fig. 2a). It reveals that all the samples falls in near neutral in nature. The Electrical Conductivity (EC) denotes the concentration of dissolved solids in the given water body. The EC in the groundwater varies from 1070 to 2300µmho/cm at locations 2 and 11 respectively (fig. 2b). The mean value of EC for the study area is 1581µmho/cm. The EC values in 8 samples (sample 1,3,4,5,9,11,12 and 3) are higher than the permissible limits of 1400 µmho/cm. The groundwater is classified into four major types based on EC. It's found that 13 samples were in the permissible limits (780-2250 µmho/cm) and the rest 2 samples (sample no. 1 and 11) are unsuitable for drinking and domestic use (table 2).

Table 2: Classification of groundwater from EC values

EC (µmho/cm)	Water class	Representing wells	Total no. of wells
<250	Soft	Nil	Nil
250–750	Moderately hard	Nil	Nil
750–2250	Permissible	2-10, 12-15	13
>2250	Unsuitable	1,11	2

The Total Dissolved Solids (TDS) is the concentrations of all dissolved minerals in water. The TDS observed in the study area is between 749-1610 mg/L with an average value of 1106 mg/L (fig.2c). The studied groundwater samples have been classified based on the values.

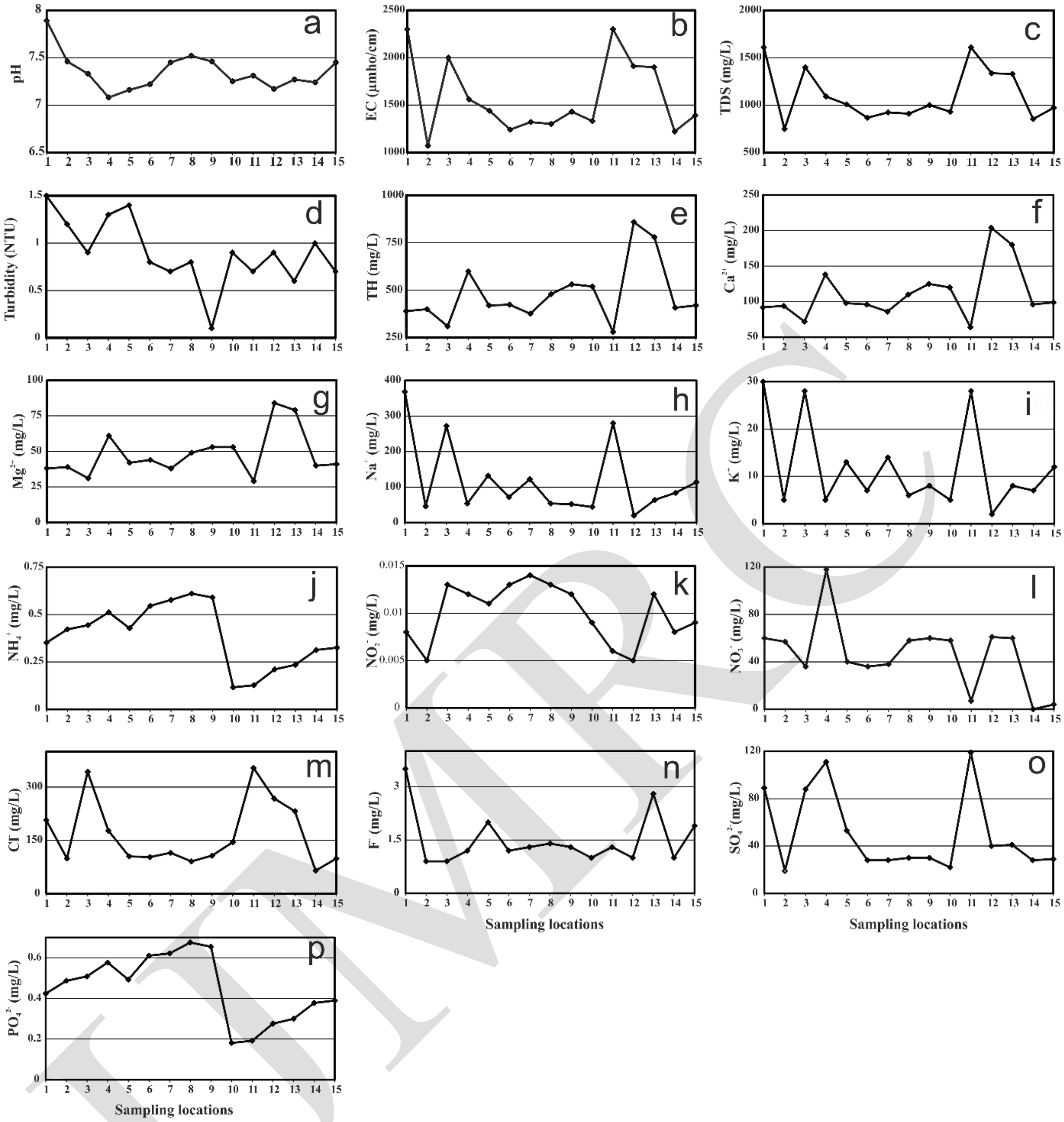

Figure 2. Graphical representation of various physic chemical paratetets

It is found that 7 samples (2,6,7,8,10,14,15) comes under fresh water type and the remaining 8 samples (1,3,4,5,9,11,12,13) is a brackish water type (TDS between 1000-10000mg/L) as shown in table 3. The higher TDS values causes gastro intestinal irritation to human beings, but a prolonged intake causes kidney stones (Garg et. al, 2009). Domestic sewage, septic tanks and rock-water interaction also influence high TDS values.

Table 3: Classification of groundwater from TDS values

TDS (mg/L)	Nature of water	Representing wells	Total no. of wells
<1000	Fresh water	2,6,7,8,10,14,15	7
1000-10000	Brackish water	1,3,4,5,9,11,12,13	8
10000-100000	Saline water	Nil	Nil

The turbidity of the studied samples varies from 0.1 to 1.5 NTU with an average value of 0.90 NTU (fig. 2d). The turbidity values in all the locations were well within the standard limits. Total hardness (TH) is considered as major character for drinking water. TH has no adverse effects; however, some evidences indicates its role in heart diseases (Schroeder, 1960) and hardness of 150-300mg/L may cause kidney stone formation (Jain, 1998). In the study area, the TH values ranges from a minimum of 280mg/L at location 11 and a maximum of 860 mg/L at station 12 with an average value of 480mg/L (fig. 2e). According to the grading standards of TH, groundwater can be divided into soft water (TH<75mg/L), moderately hard water (75<TH<150mg/L), hard water (150<TH<300mg/L), very hard water (TH>300mg/L). Based on the classification all the 15 samples are in the category of hard to very hard (table 4) and it is caused by the presence of calcium, magnesium, chloride and sulphate (Ramesh and Soorya Vennila, 2012). Higher values of TH may be due to the inputs from industrial discharge, sewage effluents and also from the rocks (Sawyer and McCarthy, 2003).

Table 4: Classification of groundwater from Total Hardness values

Total hardness as $CaCO_3$ (mg/l)	Water class	Representing wells	Total no. of wells
<75	Soft	Nil	Nil
75-150	Moderately hard	Nil	Nil
150-300	Hard	11	1
>300	Very hard	1-10, 12-15	14

Ca^{2+} is naturally present in water. Ca^{2+} is a determinant of water hardness, because it can be found in water as Ca^{2+} ions. Ca^{2+} content in the groundwater varies from 64 to 204 mg/L. One sample (No.12) exceeds the permissible limit of 200 mg/L prescribed by the BIS. Mg^{2+} is a constituent of bones, which is essential for normal metabolism of Ca^{2+} and its deficiency leads to protein energy malnutrition and distribution of calcium is shown in fig. 2f. Magnesium has many different purposes and consequently may end up in water in many different ways. Chemical industries add Mg^{2+} to plastics and other materials as a fire protection measure or as filler. It also ends up in the environment from fertilizer application and from cattle feed. The values of Mg^{2+} ranges from 29 to 84 mg/L with an average of 48mg/L (fig. 2g).

Sodium (Na^{+}) occurs as a major cation in the water samples. The primary source of sodium in natural water is from the release of the soluble products during the weathering of plagioclase feldspars. The concentration of sodium in the area varies from 20-368 mg/L in locations 12 and 1 respectively. The graphical representation of sodium in groundwater of the study area is shown in figure 2h. The sodium concentration more than 50 mg/L makes the water unsuitable for domestic use because it causes severe health problems like hypertension (Patnaik et., al, 2002). Groundwater in 3 studied locations (1,3 and 11) comes under the non-safe zone for drinking with reference to the concentration of sodium, which is more than 250 mg/l. Therefore, sodium restricted diet is suggested to the patients, who suffer from the heart diseases and also from the kidney problems. The higher concentration of sodium may pose a risk to a person's suffering from cardiac, renal and circulatory diseases (Haritash, et. al, 2008). Sodium is derived from untreated industrial and domestic waste, weathering of feldspar rocks and also due to over exploitation of groundwater sources in this area (Ramesh and Soorya Vennila, 2012).

Generally the behaviour of potassium (K^{+}) is similar to the sodium content in the water but not found in the concentration as much as the sodium in groundwater. The most common minerals which are the potassium source are the orthoclase, feldspar, microcline, leucite, biotite are present in granites of the area (Sathish Kumar et al, 2007). The concentration of K^{+} in the studied samples recorded a minimum concentration of 2mg/L in location 12 and a maximum concentration of 30mg/L in location 1 with an average value of 12mg/L (fig. 2i). The permissible limit of potassium is 10 mg/L and in study area nearly 40% of the samples exceed the permissible limit. Thus, the excess amount of potassium present in the water sample may lead nervous and digestive disorder (Tiwari and Mishra, 1985). The higher values in this area may be contributed due to the effluent discharged by industries and domestic sewages. However, excessive fertilizer usage may also increase its concentration in groundwater. Though potassium is extensively found in some of igneous and sedimentary rocks, its concentration in natural waters is usually quite low. This is due to the fact that potassium minerals offer resistance to weathering and dissolution.

Ammonia (NH_4^+) is a key metabolite in mammals. It has an essential role in acid-base regulation and the biosynthesis of purines, pyrimidines, and non-essential amino acids. Ammonia can be present in source water used for drinking water production or added to treated water with chlorine to form chloramines as a disinfectant. However, the presence of ammonia in drinking water is undesirable because nitrification might lead to toxic levels of nitrite (Wilczak, 1996) or adverse effects on water taste and odour (Bouwer and Crowe. 1988) and might increase heterotrophic bacteria, including opportunistic pathogens (Wilczak, 1996). Natural levels in groundwaters are usually below 0.2 mg of ammonia per litre. Higher natural Contents (up to 3 mg/litre) are found in strata rich in humic substances or iron or in forests. Surface waters may contain up to 12 mg/litre. The concentration of NH_4^+ in the studied samples ranges from 0.116 to 0.611 mg/L with an average value of 0.039 mg/L (fig. 2j).

Nitrites (NO_2^-) can cause problems in young children and farm animals, as they bind very strongly to hemoglobin, and can affect the blood's ability to carry and release oxygen. The serious illness in infants is due to the conversion of nitrate to nitrite by the body, which can interfere with the oxygen-carrying capacity of the child's blood. This can be an acute condition in which health deteriorates rapidly over a period of days. Symptoms include shortness of breath and blueness of the skin. The NO_2^-content in study area has shown variation from 0.005 to 0.014 mg/L with an average of 0.01mg/L (fig. 2k).

Nitrate (NO_3^-) is the main form of N in the groundwater. Several authors (Steinich et al., 1998; Daskalaki et al., 1998; Antonakos and Lambrakis, 2000) have related groundwater nitrates to different sources, such as leaching of organic and inorganic fertilizers, animal waste, domestic effluents and industry. Nitrate is a common surface water and groundwater contaminant that can cause health problems in infants and animals, as well as the eutrophication of water bodies (Fennesy and Cronk, 1997). As shown in figure 2l, the nitrate concentrations, in the studied area, ranges from 0-118 mg/L in locations 14 and 4 respectively, with mean value of 46 mg/L. The main sources of the nitrate in the studied area are from the human wastes, animal's wastes and fertilizers.

Chloride (Cl^-) is a widely distributed element in all types of rocks in one or the other form. Therefore, its concentration is high in groundwater, where the temperature is high and rainfall is less. Mostly, the chlorides are found in the form of NaCl in the groundwater. Soil porosity and permeability also has a key role in building up the Cl^- concentration. Cl^- imparts a salty taste and some times higher consumption causes the crucial for the development of essential hypertension, risk for stroke, left ventricular hypertension, osteoporosis, renal stones and asthma in human beings (McCarthy, 2004). Although, the chloride plays an important role in balancing level of electrolyte in blood plasma, but higher concentration can produce some physical disorders. The chloride concentration varied from 65 - 354 mg/L with an average concentration of 167 mg/L (fig. 2m). All the samples in the study area have their concentrations lesser than the standard limits.

The occurrence of Fluoride (F^-) in groundwater is mainly due to the natural and geogenic contamination and the source of contamination is often unknown (Handa, 1975).

While the F^- bearing minerals like apatite, muscovite, hornblende and fluorite, in the country rocks are the principal sources of F^- in the groundwater, the application of fertilizers is the supplementary sources of F^- in the water (Narsimha, 2013). Exposure to excessive consumption of F^- over a lifetime may lead to increased likelihood of bone fractures in adults, and may result in effects on bone leading to pain and tenderness. The permissible limit of fluoride in drinking water is 1.5 mg/l as per BIS standards. The F^- concentration in groundwater of the study area varies from 0.9 to 3.5 mg/L in with an average value of 1.51mg/L. The concentration is higher than 1.5 mg/l in 3 locations (1, 13 and 15). According to UNESCO specifications, water containing more than 1.5 mg/l of fluoride cause mottled tooth enamel in children and are not suitable for drinking purpose. Excess F^- may also lead to fluorosis that can result in skeletal damage. Clinical report indicate that adequate calcium intake is directly associated with reduced a risk of dental fluorosis (Dinesh, 1998). The distribution of fluoride ion concentration in groundwater is shown in fig. 2n. In this area fluoride is higher due to leaching from fluoride rich rocks, long term irrigation processes, semi-arid climate and long term residence time of groundwater.

Sulphate (SO_4^{2-}) occurs in water as the inorganic sulphate salts as well as dissolved gas (H_2S). Sulphate is not a noxious substance although high sulphate in water may have a laxative effect. The sulphide minerals add the soluble sulphate into the groundwater through oxidation process. The concentration of sulphate (SO_4^{2-}) in study area ranges from 19-119mg/L with the mean value of 50 mg/L (fig. 2o), the highest value was recorded in location 11 and the minimum in location 2. The concentration in samples in all the locations are well within the standard limits of WHO (2006) standards.

The Phosphate (PO_4^{2-}) in the study area was very low, possibly because of phosphate adsorption by soils as well as its limiting factor nature due to which whatever PO_4^{2-} is applied to the agricultural field is used up by the plants. The minimum concentration of PO_4^{2-} in the study area is 0.181mg/L (location 10) and the maximum concentration is 0.676mg/L (location 8) with a mean value of 0.45mg/L (fig. 2p). The results show that the PO_4^{2-} in all the studied samples are well within the standards of 5mg/L.

Assessment Of Ground Water Quality For Irrigation Purposes

Assessment of the groundwater quality of the study area was carried out to determine its suitability for domestic and agricultural purposes. Water for each of these purposes should meetcertain safety standard that have been set by either Indian Standard Organization or World Health Organization.

Sodium Absorption Ratio

EC is a good measure of salinity hazard to crops as it reflects the TDS in groundwater. Excess salinity reduces the osmotic activity of plants and thus interferes with the absorption of water and nutrients from the soil (Saleh et al., 1999). Sodium Absorption Ratio (SAR) is an important parameter for determining the suitability of groundwater for irrigation because it's a measure of alkali/sodium hazard to crops (Karanth, 1987). The SAR indicates the effect of relative cation concentration on sodium accumulation in the soil; thus, SAR is a more reliable method for determining this effect (Richards, 1954). Sodium adsorption ration (SAR) is calculated using the following formula:

$$\mathrm{SAR} = \frac{\mathrm{Na}^+}{\sqrt{\frac{\mathrm{Ca}^{2+}+\mathrm{Mg}^{2+}}{2}}}$$

Where the concentrations of Ca^{2+}, Mg^{2+} and Na^+ are expressed in milliequivalents per litre (meq/L). The potential for a sodium hazard increases in water with higher sodium adsorption ratio (SAR) values. The sodium adsorption ration (SAR) content in study area has shown variation from 0.297 to 8.119 with an average value 2.637(table 5).

Table 5: Values of SAR, KR, SSP and % Na in meq/L

Sample Locations	SAR	MAR	KR	SSP	% Na
1	8.119	40.773	2.060	67.321	68.346
2	1.003	40.881	0.252	20.101	21.117
3	6.726	41.779	1.913	65.666	66.982
4	0.959	42.420	0.196	16.383	17.124
5	2.800	41.667	0.683	40.590	41.959
6	1.521	43.307	0.370	26.993	28.106
7	2.745	42.411	0.710	41.534	43.133
8	1.073	42.609	0.245	19.678	20.701
9	0.979	41.406	0.212	17.489	18.778
10	0.838	42.400	0.184	15.516	16.385
11	7.265	43.027	2.167	68.429	69.654
12	0.297	40.698	0.051	4.812	5.082
13	0.997	42.246	0.179	15.151	16.088
14	1.811	40.984	0.449	30.989	32.024
15	2.423	40.837	0.592	37.202	38.620

95% SAR for all the groundwater samples of the study area are less than 10 indicate excellent quality for irrigation and samples fall in excellent (S1) category. It clearly indicates that all the samples are suitable for irrigation (table 6).

Table 6: Classification of groundwater on the basis of SAR, KR, SSP and % Na

Parameter	Range	Water Class	Total no of samples	Representing samples	%
SAR	<10	Excellent (S1)	15	1-15	100
	10–18	Good (S2)	Nil	Nil	Nil
	18–26	Doubtful (S3)	Nil	Nil	Nil
	>26	Unsuitable (S4)	Nil	Nil	Nil
KR	<1	Good	12	2,4-10,12-15	80
	>1	Unsuitable	3	1,3,11	20
SSP	<50	Good	12	2,4-10,12-15	80
	>50	Bad	3	1,3,11	20
% Na	<20	Excellent	5	4,9,10,12,13	33
	20-40	Good	5	2,6,8,14,15	33
	40-60	Permissible	2	5,7	13
	60-80	Doubtful	3	1,3,11	20

Magnesium Adsorption Ratio

Magnesium content of water is considered as one of the most important qualitative criteria in determining the quality of water for irrigation. Generally, calcium and magnesium maintain a state of equilibrium in most waters. More magnesium in water will adversely affect crop yields as the soils become more saline (Joshi et al., 2009). The Magnesium Adsorption Ratio (MAR) was calculated using the following equation (Raghunath 1987):

$$\mathrm{MAR} = \frac{\mathrm{Mg^{2+} x\ 100}}{\mathrm{Ca^{2+} + Mg^{2+}}}$$

where, all the ionic constituents are expressed in meq/L. The values of the magnesium adsorption ratio of groundwater in present study varies from 40.698 to 43.307 with an average value of 41.829 indicating that they are below the acceptable limit of 50% and suitable for irrigation purpose (Ayers and Westcot, 1985).

Kelley's ratio

Sodium measured against Ca^{2+} and Mg^{2+} is used to calculate Kelley's ratio (Kelley et. al, 1940). The formula used in the estimation of Kelley's ratio is expressed as,

$$\text{Kelley's Ratio (KR)} = \frac{Na^{+}}{Ca^{2+} + Mg^{2+}}$$

A KR of more than one indicates an excess level of sodium in waters. Hence, waters with a KR less than one are suitable for irrigation, while those with a ratio more than one are unsuitable for irrigation. The KR value in the studied samples ranges from 0.051 to 2.167 with an average value of 0.684. 80 % KR values for the groundwater of study area are less than 1 and indicate good quality water for irrigation purpose while remaining 20% is more than 1 indicates the unsuitable water quality for irrigation (table 6).

Soluble Sodium Percent

The Soluble Sodium Percent (SSP) for groundwater as calculated by the formula,

$$SSP = \frac{Na^{+}\ x\ 100}{Ca^{2+} + Mg^{2+} + Na^{+}}$$

Where the concentrations of Ca^{2+}, Mg^{2+} and Na^{+} are expressed in milliequivalents per liter (meq/L). The SSP values less than 50 or equal to 50 indicates good quality water and if it is more than 50 indicates the unsuitable water quality for irrigation. The values of SSP ranges from 4.812 to 68.429 with an average value 32.524 (table 5). 80 % Soluble Sodium Percent (SSP) values for the groundwater of study area are less than 50 and indicate good quality water for irrigation purpose while remaining 20 % is more than 50 indicate the unsuitable water quality for irrigation (table 6).

Percentage Sodium

Sodium is an important parameter for irrigation water and is denoted as Na% which was calculated from the below mentioned formula and all concentrations were expressed in meq/L.

$$Na^{+}\% = \frac{(Na^{+} + K^{+})x100}{(Ca^{2+} + Mg^{2+} + Na^{+} + K^{+})}$$

The % Na^{+} in the studied samples ranges from 5.082 to 69.654 with an average value of 33.606. It is observed that about 5 samples have high sodium percent (above 33%) falls under permissible to doubtful and is not suitable for irrigation purposes and the rest of the samples were within excellent and good category (table 6).

Inter-element relationships and factor analysis

In order to find out the significant process controlling the chemistry of ground water, inter-element relationship and factor analysis were used (table 7 and Fig. 3.).

Table 7: Correlation coefficient matrix(R^2) of the physic chemical parameters

	pH	EC	TDS	TUR	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	NH_4	NO_2^-	NO_3^-	Cl^-	F^-	SO_4^{2-}	PO_4^{2-}
pH	1															
EC	.219	1														
TDS	.219	1.000	1													
TUR	.044	.100	.100	1												
TH	-.355	.060	.060	-.152	1											
Ca^{2+}	-.342	.066	.066	-.145	.999	1										
Mg^{2+}	-.376	.054	.054	-.166	.998	.994	1									
Na^+	.528	.727	.727	.300	-.592	-.583	-.601	1								
K^+	.482	.720	.720	.170	-.618	-.612	-.624	.983	1							
NH_4	.184	-.448	-.448	-.094	-.208	-.217	-.198	-.158	-.135	1						
NO_2^-	-.066	-.219	-.219	-.277	-.082	-.110	-.042	-.080	-.010	.673	1					
NO_3^-	-.096	.016	.016	.242	.523	.511	.539	-.291	-.333	.275	.204	1				
Cl^-	-.081	.875	.875	-.010	.065	.067	.067	.546	.591	-.477	-.207	.022	1			
F^-	.542	.473	.473	.246	.097	.097	.093	.465	.393	-.116	.053	.071	.063	1		
SO_4^{2-}	-.023	.754	.754	.332	-.215	-.218	-.206	.669	.662	-.167	-.061	.191	.714	.197	1	
PO_4^{2-}	.190	-.442	-.442	-.084	-.206	-.215	-.196	-.153	-.132	.999	.667	.281	-.476	-.107	-.159	1

The factors were extracted using principal component extraction method and subjected to varimax normalization rotation for better interpretation. Three factors were extracted (factor having Eigen values >1 and loadings >0.7) which accounted for 76 % of total variance (table 8). Therefore, these three factors were assumed to represent adequately the overall variance of the data set. It showed that 3 factors were meaningful to explain the groundwater chemistry.

Table 8: The factor scores of the parameters in the study area

Parameters	Components		
	Factor 1	Factor 2	Factor 3
pH	.395	-.367	.248
EC	**.844**	.455	.221
TDS	**.844**	.455	.221
TUR	.264	-.012	.069
TH	-.458	**.843**	.229
Ca^{2+}	-.449	**.847**	.215
Mg^{2+}	-.466	**.839**	.246
Na^{+}	.956	-.231	.118
K^{+}	.947	-.258	.105
NH_4	-.386	-.631	.619
NO_2^-	-.249	-.386	.620
NO_3^-	-.280	.364	.685
Cl^-	**.713**	.483	.055
F^-	.421	.148	.423
SO_4^{2-}	**.752**	.158	.293
PO_4^{2-}	-.380	-.627	.626
% of variance	36.103	25.963	14.031

Bold numbers indicate significantly important values

The first factor (F1) accounts for 36.103% of total variance and loaded positively with EC, TDS, Na^+, K^+, Cl^-, SO_4^{2-}. The positive correlation of EC with TDS (r = 1.0), Na^+ (r = 0.727), K^+ (r = 0.720), Cl^- (r = 0.875), reveals that these species have the same source of origin and arisen from single source. TH shows very good positive correlation with Ca^{2+} (r = 0.999), and Mg^{2+}(r = 0.998), The second factor (F2) accounts for 25.963 % of the total variance and positively loaded with TH, Ca^{2+} and Mg^{2+}. The third factor (F3) accounts for 14.031 % of the total variance and positively loaded with NH_4, NO_2^-, NO_3^- and PO_4^{2-} (fig. 3).

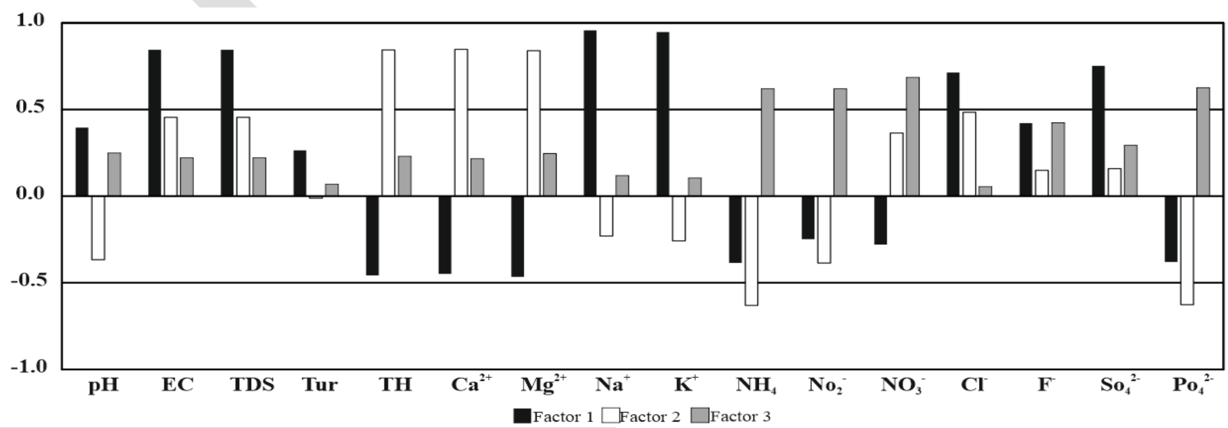

Figure 3. Results of factor analysis (R-mode) showing three primary factors (F1, F2, F3)

CONCLUSION

Hydrochemical characteristics of groundwater was carried out in Thoppur to know its suitability for drinking and irrigational use. The physical appearance of the water is colourless which is also supported by the turbidity. The pH of the studied samples were almost neutral. It's found that EC in 13 samples were within the permissible limits and the rest 2 samples are unsuitable for drinking and domestic use. The studied TDS in groundwater samples have been classified based on the values and found that 7 samples comes under fresh water type and the remaining 8 samples is a brackish water type. Total hardness does not cause any impact in our study. All the 15 samples are in the category of hard to very hard and well within the limits.For Ca^{2+} One sample (No.12) exceeds the permissible limit of 200 mg/L prescribed by the BIS. Sodium is derived from untreated industrial and domestic waste, weathering of feldspar rocks and also due to over exploitation of groundwater sources in this area. The permissible limit of potassium is 10 mg/l and in study area nearly 40% of the samples exceed the permissible limit. The main sources of the nitrate in the studied area are from the human wastes, animal's wastes and fertilizers. The higher concentration of fluoride in the study area are due to leaching from fluoride rich rocks, long term irrigation processes, semi-arid climate and long term residence time of groundwater.

The groundwater quality were also used to assess its suitability for irrigational use. The SAR clearly indicate that 100% of the samples have an excellent water quality and can be used for irrigation. KR, SSP and Na % were also used to understand the suitability of groundwater for irrigational purpose. On the whole, it was observed that the quality of groundwater is worsening both for drinking and irrigation purpose due to anthropogenic activities and increased human interventions. A long term management strategy should be formulated for the protection of existing groundwater resources for drinking and agricultural activities.

ACKNOWLEDGEMENTS

The authors wish to express their thanks to the Management of JIT and the staff of the Department of Civil Engineering, for cooperation to publish this research work. We are also thankful to anonymous persons that help to proof read the manuscript and also for technical information.

REFERENCE

1. Antonakos, A. and Lambrakis, N., 2000. Hydrodynamic characteristics and nitrate propagation in Sparta aquifer, Water Res., Vol.34, p. 3977 – 2000.
2. APHA (1995) Standard methods for the examination of water and waste water, 19th edn. American Public Health Association, Washington, DC
3. APHA–AWWA–WPCF (1980) Standard methods for the examination of water and wastewater, 15th Ed. Publ. By American Public Health Association (APHA), Washington D.C
4. Ayers, R.S. and D.W. Westcot, 1985. Water quality for agriculture FAO irrigation and drain. Paper No 29(1):1-109.
5. Balachandar D., Sundararaj P., Rutharvel M.K.and Kumaraswamy K., 2010. An investigation of groundwater quality and its suitability to irrigated agriculture in Coimbatore District, Tamil Nadu, India – A GIS approach. International Journal of Environmental Sciences, 1(2), pp 176190.
6. BIS., Indian standards specifications for drinking water, Bureau of Indian Standards, IS:10500, (1991).
7. Bouwer, E. J., and P. B. Crowe. 1988. Biological processes in drinking water treatment. J. Am. Water Works Assoc. 80:82-93.

8. Bridgman HA (1992) Evaluating rainwater contamination and sources in the southwest Australia using factor analysis. Atmos Environ Gen Top 26A:2401–2412
9. Daskalaki, P., Voudouris, K. and Diamantopoulou, P., 1998. Hydrochemical study of North Peloponnesus Quaternary and Plio – Pleistocene aquifers. Proc. Int. Conf. Protection and Restoration of the Environment, IV, Sani, Greece.
10. Davies, J., 1995. The Hydrochemistry of Alluvial Aquifers in Central Bangladesh. In: Nash, H. and G.J.H. McCall (Eds.), Groundwater Quality. Chapman and Hall, London, pp: 9-18.
11. Dinesh C., Fluoride and human health-cause for concern, Indian J. of Environ Prot, 19(2), 81–89, (1998).
12. Fennesy, M.S. and Cronk, J.K., 1997. The effectiveness and restoration potential of riparian ecotones for the management of non point source pollution, particularly nitrate. Crit. Rev. Environ. Sci. Technol., Vol.27, p. 285 – 317.
13. Garg, S.; Gupta, R.K. and Jain, K.L. (2009): Sublethal effects of heavy metals on biochemical composition and their recovery in Indian major carps. J. Hazard. Mater. 163:1369-1384.
14. Hakim M.A., Juraimi A.S., Begum M., Hasanuzzaman M., Uddin M.K.and Islam M.M., 2009. Suitability evaluation of groundwater for irrigation, drinking and industrial purposes. American Journal of Environmental Sciences, 5(3), pp 413419.
15. Handa B. K. (1975). Geochemistry and Genesis of Fluoride-Containing Ground Waters in India, Groundwater, 13: pp 275–281.
16. Haritash A.K, kaushik C.P, Kanal A. and Kumar Y.A., Suitability assessment of groundwater for drinking, irrigation and industrial use in some North Indian Villages, Environ Mont Assess, 145, 397-406, (2008).
17. Jain C. K., Bandyopadhyay A. and Bhadra A., 2010. Assessment of ground water quality for drinking purpose, District Nainital, Uttarakhand, India. Environ Monit Assess., 166, pp 663676.
18. Jain P.K., Hydrology and quality of groundwater around Hirapur district, Sagar (M.P)- A case study of protozoic rocks, Pollution Research, 17 (1), 91-94, (1998).
19. Joshi, D.M., A. Kumar and N. Agrawal, 2009. Assessment of the irrigation water quality of River Ganga in Haridwar District India. J. Chem., 2(2):285-292.
20. Karanth K.R (1987). Groundwater assessment, development and management. Tata McGraw Hill, New Delhi, pp.720.
21. Kelley W.P., Brown S.M. and Liebig G.F. Jr. Chemical effects of saline irrigation waters on soils, Soil Sci., 49,95-107 (1940).
22. McCarthy M. F., Should we restrict chloride rather than sodium, Medical Hypotheses, 63, 138–148. doi:10.1016/j.mehy.2003.11.005, (2004).
23. Mitra B.K., Sasaki C., Enari K. and Matsuyama N., 2007. Suitability assessment of shallow groundwater for irrigation in Sand Dune area of Northwest Honshu Island, Japan. International Journal of Agricultural Research, 2(6), pp 518527.
24. Nagarajan R., Rajmohan N., Mahendran U. and Senthamilkumar S., 2010. Evaluation of groundwater quality and its suitability for drinking and agricultural use in Thanjavur city, Tamil Nadu, India. Environ Monit Assess., 171, pp 289308.
25. Narsimha. A., Anitha. N., Sudarshan. V. and Manjulatha, 2013. Evaluation of groundwater quality and its suitability for drinking purposes in Gunthakal Area, Ananthapur District, Andhra Pradesh, India, Advances in Applied Science Research, 2013, 4(2):70-76
26. Patnaik K.N, Sathanarayan S.V. and Rout Swoyam P., Water Pollution from major industries in Pradip Area- A case study, Ind J. .Environ Health, 44(3), 203-211, (2002).

27. Raghunath, I.M., 1987. Groundwater. 2nd Edn., WileyEastern Ltd., New Delhi, India.
28. Ramesh. K., Soorya Vennila, 2012, Hydrochemical Analysis and Evaluation of Groundwater Quality in and around Hosur, Krishnagiri District, Tamil Nadu, India, International Journal of Research in Chemistry and Environment, Vol. 2 Issue 3 July 2012(113-122).
29. Richards L.A., Diagnosis on improvement of saline and alkali soils, U.S.D.A., Handbook no.60, Agri. Handb. U.S. Dep. Agric., 160 (1954).
30. Saleh A, Al Ruwaih, F and Shehata, M (1999), Hydrogelochemical processes operating within the main aquifers of Kuwait. J. arid Environ, 42: 195-209.
31. Sathish Kumar T, Sudarshan V. and Kalpana G., Geochemical characterization of groundwater, banks of Musi river, Hyderbad city, Ind Pollution. Research, 26(4), 795-800, (2007)
32. Sawyer G.N. and MxCarthy D.L., Chemistry of sanitary Engineers, 2nd edn, McGraw Hill, New York, 518, (2003).
33. Schroeder H. A., Relations between hardness of water and death rates from certain chronic and degenerative diseases in the United States, J. Chron disease, 12, 586-591, (1960).
34. Soltan M.E., Characterization, classification and evaluation of some groundwater samples in upper Egypt, J.Chemosphere., 37 735-745 (1998)
35. SPSS (1995) Professional Statistics 6.1. Marija J. Norusis/SPSS Inc., Chicago
36. Steinich, B., Escolero, O. and Marin, L., 1998. Salt-water intrusion and nitrate contamination in the Valley of Hermosillo and El Sahuaral coastal aquifers, Sonora, Mexico. Hydrogeology Jour., Vol.6, p. 518 – 526.
37. Subramani, T., L. Elango and S.R. Damodarasamy, 2005. Groundwater quality and its suitability for drinking and agricultural use in Chithar River Basin, Tamil Nadu, India. Env. Geol., 47: 1099-1110.
38. Tiwari T.K. and Mishra M.A., A preliminary assignment of water quality index of major Indian rivers, Ind J. Environ Prot, 5, 276-279, (1985)
39. WHO, 2004. Guidelines for Drinking-Water Quality: Training Pack. WHO, Geneva, Switzerland.
40. WHO, 2006. Guideline for Drinking Water Quality. Vol. Recommendations, World Health Organization, Geneva, pp: 130.
41. Wilczak, A., J. G. Jacangelo, J. P. Marcinko, L. H. Odell, G. J. Kirmeyer, and R. L. Wolfe. 1996. Occurrence of nitrification in chloraminated distribution systems. J. Am. Water Works Assoc. 80:74-85.