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An Appraisal of Groundwater Quality for Drinking and Irrigation Purposes in Tirupur Taluk, Tamil Nadu, India

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Abstract

A study was carried out to understand the suitability of groundwater in the Tirupur Taluk of Tirupur District, Tamil Nadu, India. Forty five groundwater samples have been collected from bore wells and dug wells, the samples were analysed by using standard procedures (APHA, 1995). The analyzed parameters were hydrogen ion concentration (pH), electrical conductivity (EC), total hardness (TH), total dissolved solids (TDS) and important cations like Calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}) and anions like bicarbonate (HCO_{3-}), Chloride (Cl^{-}), Sulfate (SO_4^{2-}) and Calcium carbonate ($CaCO_3$). These parameters were compared with the Bureau of Indian Standards (BIS), 1991. The pH is within the desirable limits, whereas TDS, TH, Mg^{++}, Na^{++}, and SO_4^{2-} exceed the limit of BIS. SAR values reveal that the majority of the groundwater samples falls in excellent (S1) and good (S2) categories. The USSL, diagram illustrates that the groundwater samples fall in the field of (C1S1), (C2S1), (C3S1), (C3S2), (C4S1), (C4S2), (C4S3) and (C4S4) categories indicating low to very high salinity and low to high alkalinity hazard. The Soluble sodium percent (SSP) exhibits that the entire samples are within the maximum allowable limit. Based on RSC values, almost eighty five percentage of samples fall as safe categories. Anthropogenic pollutants and the nature of geological formations can be the factors for exceeding the permissible limits in certain locations of the study area. The overall groundwater study states that the majority of the sample locations are fitting for domestic and irrigation purposes.

Key Words: Anthropogenic pollutants; BIS (1991) Standard; physical; chemical parameters; Tirupur Taluk

Introduction

Water is an essential input not only for the human existence, but also for all developments. In the modern world all developmental activities; urban evolution, food production, drinking water requirement and industrial growth connect to water resources. Groundwater is a key source of fresh drinking water essential to life over the globe. It is estimated that approximately one third of the world's population uses groundwater for drinking (Nickson et al. 2005). The World Health Organization (WHO) has discriminated the major factor influencing the greater population is the lack of access to clean drinking water (Nash and McCall, 1995). Demand for groundwater has increased tremendously in recent years due to the industrialization, urbanization, population increase, and intense agricultural activities. In most of the industrialized area's groundwater is the first victim of the local contamination as effluents are more often let into open abandoned wells, which is a type of point source for contamination. Apart from this, human activities such as contamination due to industrial effluents, landfills, application of fertilizers, etc., may also play a role in influencing the groundwater composition (Mazari and MacKay, 1993; Kumaresan and Riyazuddin, 2006; Li et al. 2006; Al-Sabahi et al. 2009; Brindha et al. 2010; Aghazadeh and Mogaddam, 2011; Bakis and Tuncan, 2011; Vijay et al. 2011; Brindha and Elango, 2012). The quality of ground water depends on various chemical constituents and their concentration, which are mostly derived from the geological data of the particular region (Gupta et al. 2009). Groundwater quality variation is a function of physical and chemical patterns in an area influenced by geological and anthropogenic activities (Subramani et al. 2005). It is necessary to identify these geochemical reactions in the aquifer in order to assess the distribution of the major ion chemistry of the region (Fisher and Mullican, 1997; Rosen and Jones, 1998; Mohan et al. 2000; Satyanarayanan et al. 2007; Reddy and Kumar, 2010; Tirumalesh et al. 2010; Raju et al. 2011). The chemical alteration of the meteoric water depends on several factors such as soil-water interaction, dissolution of mineral species, duration of solids, water interaction and anthropogenic impact (Faure, 1998; Subba Rao, 2001). In Tamil Nadu, several researchers such as Ramesh et al. (1995), Sreedevi, (2002), Senthilkumar et al. (2006), Pichaiah et al. (2013), carried out some works in the groundwater quality studies. The problems of groundwater quality are more acute in areas that are densely populated and thickly industrialised and have shallow groundwater tube wells (Shivran et al. 2006). The present study area, Tirupur Taluk gains more significance in Tamil Nadu State, due to rapid growth of cotton hosiery industries popularly known as "Knitwear Industry". Because of this commercial development, laborers from various parts of India invade to Tirupur area ultimately the population density increases day to day and drinking water scarcity multiply into several folds. The available drinking water also in deteriorated nature. To gain a quantitative understanding to decipher the rates of interaction of surface earth parameters such as bedrock geology, geochemistry, geomorphology, soil characters, hydrogeology, climate and aquifer parameters are essential to note the change in the chemistry of groundwater. These data are fed to compute and generate maps, graphs and tables on the individual and combined themes on a systematic basis. These patterns could be recognized and used for future groundwater targeting program.

Geological Landscape

The area is underlined and surrounded by a wide range of Archaen group, composed of high-grade metamorphic rocks of Peninsular gneiss complex, extensively weathered and overlain by recent valley fills and alluvium at places. The most common rock types of the area are hornblende biotite gneisses and with alluvial rocks, few quartz veins and limestone bands. The study area comprises of fissile hornblende biotite gneiss and hornblende biotite gneiss. It occupies in northern and southern parts. The charnockite are mostly occupied in the central and southern part of the study area. It shows weakly developed gneissic structure and has been referred to as charnockitic gneiss. The granite intrusives are in the form of veins, they show a concordant relationship with the country rocks. Calc granulite and limestone occurred at the southern part of the study area. Anorthosite and amphibole are seen in some parts of the study area. Tirupur is situated on a plateau in a part of the Precambrian shield area called Indian Peninsular complex, which has a wide range of metamorphic rocks usually referred to as hard or crystalline rock characteristics. They have a very low hydraulic conductivity and have no primary porosity and incapable of storing and transporting water. However, a secondary porosity permits flow and storage of substantial amounts of groundwater, this porosity is the result of weathering and fracturing (Larsson, 1984). Soils are moderately very deep red and deep red, deep black, moderately deep black and moderately shallow black soil having different depth and profiles.

Methodology

To understand the groundwater quality scenario of Tirupur Taluk, forty five groundwater samples were collected from the bore wells and tube wells to spread over the study area and the samples were collected during post-monsoon period (February 2014) with utmost care. Pre-cleaned poly ethylene containers used to collect the groundwater samples in the

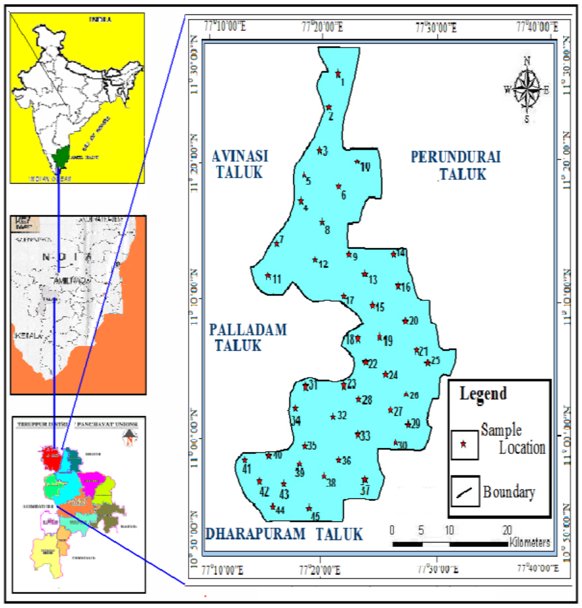

Fig. 1. Map showing groundwater sample locations

field.

The important parameters like electrical conductivity (EC), pH, total dissolved solids (TDS), major cations such as calcium, magnesium, sodium, potassium and anions of bicarbonate, carbonate, chloride, nitrate and sulphate. In the laboratory the water samples were analysed with a standard procedure of the American Public Health Association (APHA, 1995). The analytical results of the study area are shown in Table 1.

Results and Discussion

Groundwater quality appraisal for Domestic use

The assessment on the quality of groundwater was carried out to determine its suitability on the basis of drinking and irrigation purposes. The analytical results of physical and chemical parameters of groundwater were compared with the standard guideline values as recommended by the Bureau of Indian Standards (BIS, 1991) for drinking and public health purposes **(**Table 2**)** which shows the maximum desirable and most allowable limits for various parameters.

Many important hydrochemical processes are dependent on pH. It is a very important control parameter for numerous hydrochemical reactions and for assessing the usability of the water in technical systems. pH indicates the state of equilibrium reaction in which the water precipitate. It is a quantitative expression of acidity or alkalinity of water. The pH value of groundwater ranged from 7.0 to 8.1 with an average value of 7.7. The entire samples fall within the desirable limit of BIS, 1991, indicating alkaline nature of the groundwater. Measurement of EC provides an indication of ionic concentration. It depends up thermal concentration and types of ions present in the area. The specific electrical conductivity is a sum parameter which approximately describes the salt concentration in the water. Electrical Conductivity (EC) varies from 230 to 6060 µS/cm, with an average value of 1719.3 µS/cm. Very high (>6,000) and higher EC concentrations (1,500 to 4000) are observed due to domestic, agricultural activities and industries effluent disposal. Total dissolved solids (TDS) are a measure of the total amount of dissolved minerals in water. It has been indicated in many groundwater investigations shallow groundwater in recharge area is lower in TDS than the discharge area. The TDS values range from 177 to 5285 mg/l with an average value of 1641.5 mg/l, the sample No. (1, 9, 10, 13, 14, 17, 18, 19, 22, 24, 26, 31, 33, 35, 39, 41 & 44) are exceeding the maximum permissible limit of BIS standard. In general 38% of the groundwater in the study area are unsuitable for drinking purpose. Calcium is a key element in many geochemical processes and different minerals like gypsum, anhydrate, dolomite calcite and aragonite, serve as a primary source for Ca ions in water. The calcium ranges from 6 to 208 mg/l, with an average of 55.8 mg/l in the tube wells. The groundwater of the study area is suitable for drinking purposes except the location no. 31 as per the BIS Standard. Magnesium is the seventh most abundant element in the earth's crust. The solubility of magnesium carbonate is also controlled by the presence of carbon dioxide. It also ends up in the environment from fertilizer application and from cattle feed. The concentration of magnesium in groundwater of the study area ranged from 5 to 243 mg/l, with an average value of 68.7 mg/l. From the result, it is inferred that the majority of sample locations are within the permissible limit of BIS, 1991 except the locations 9, 10, 13, 18, 19, 22, 26, 27, 31, 33, 35 & 43. Total hardness is considered as a key point of drinking water. Minerals are dissolved from bedrock and soil as water passes through them and the high hardness values are often associated with limestone formations. TH values ranged from 85 to 1500 mg/l with an average value of 422.1 mg/l. The maximum allowable limit of TH for drinking water is 600 mg/l, and the most desirable limit is 300 mg/l as per the BIS standard, which represents (22%) of the samples exceeding the permissible limit. It is inferred that the sample locations 10, 13, 18, 19, 26, 27, 31, 33, 35 & 43 records higher TH as permanent hardness. Chloride is a minor constituent of the earth's crust; it is a major dissolved constituent of most natural waters. It is considered as a “mobile” element in groundwater because factor other than internal-fluid reactions determine its concentration. Chlorides are within the maximum allowable limits for drinking standards, but except the location No.26. Sodium salts are soluble and will not precipitate unless concentrations of thousands of parts per million are reached (Bell, 1998). The source of Na+ into the groundwater is due to the weathering of feldspar and due to over exploitation of groundwater (Hem, 1985). Sodium varied from 7 to 782 mg/l, with an average value of 190.3 mg/l. So 40% of samples (Loc.1, 10, 13, 14, 17, 18, 19, 20, 22, 24, 26, 29, 31, 33, 35, 39, 40 & 44) exceeds the maximum permissible limit prescribed by BIS (1991). The Higher Sodium concentration indicates that the contribution from the leaching process of Na+ plagioclase in peninsular gneiss. Potassium is an essential element for both plants and animals. Potassium ion released during the formation of secondary minerals normally reduces the K ion concentration in the groundwater forever anomaly is due to urban pollution and fertilizer reaching. The values of potassium ranged from 5 to 375 mg/l, with an average value of 64.5 mg/l.

Table 1. Chemical analysis result (Post Monsoon) of Tirupur Taluk

S.No	Location	Ca	Mg	Na	K	Cl	HCO3	SO4	NO3	CO3	F	pH	EC	TDS	TH
1	Sullipalayam	50	29	414	375	390	689	236	73	0	0.75	8.1	2990	3265	245
2	Appiyapalaiyam	16	12	7	9	28	55	29	2	0	0.12	8.1	230	177	90
3	Perumanallur	24	11	9	23	35	98	10	4	0	1.44	7.9	270	245	105
4	Chettipalayam	40	57	37	196	177	183	58	56	0	0.38	7.8	1310	1755	335
5	Parameswarapalaiyam	20	12	18SS	23	18	153	10	3	0	1.72	7.9	330	231	100
6	Vavipalaiyam	6	35	90	16	43	329	15	9	0	2.09	7.8	700	547	160
7	Anuppalaiyam	44	34	81	156	89	134	250	35	0	1.06	7.7	1230	1407	250
8	Kavundanyakkan palaiyam	52	49	35	27	117	238	19	17	0	1.96	8	870	746	330
9	Kasipalaiyam	84	126	106	27	269	378	72	67	0	1.8	7.4	1810	2179	730
10	Kaliapalaiyam pudur	80	107	322	196	737	232	288	17	0	2.12	7.9	3110	2174	640
11	Chinnakavundanpur	24	47	92	51	82	275	96	21	0	0.95	7.9	1020	941	255
12	Tirupur	48	63	161	274	376	464	96	18	0	2.32	7.7	2100	1609	380
13	Chennimalaipalaiyam	160	112	207	14	461	110	384	58	0	1	7.8	2660	2531	860
14	Ganganayakkanpalaiyam	56	63	621	31	496	232	730	34	0	0.93	7	3380	2786	400
15	Kangayampalaiyam	16	34	32	13	32	207	19	12	0	1.15	8.1	500	493	180
16	Nachchipalaiyam	14	34	110	29	64	427	19	2	0	1.62	8	860	528	175
17	Ramakavundampalaiyam	64	88	336	16	503	226	216	42	0	1.7	7.7	2440	2160	520
18	Pollikalipaliyam	52	139	276	25	284	360	288	91	0	0.97	8	2550	3029	700
19	Paruvaikkaipalayam	200	112	322	137	709	73	557	46	0	0.43	7.6	3560	2981	960
20	Andipalaiyam	12	68	345	59	96	549	29	2	0	1.06	7.9	1180	923	310
21	Kavungulipalaiyam	36	67	110	39	195	336	43	21	0	1.33	8	1230	1070	365
22	Kadaganthirudipalaiyam	56	112	230	5	333	293	168	68	0	0.9	7	2010	2384	600
23	Kattupalaiyam	20	62	115	32	170	262	58	22	0	1.33	7.3	1230	1026	305
24	Velayudampalaiyam	40	36	511	35	461	122	336	97	0	0.97	7	2730	3389	250
25	Pusaripalaiyam	20	57	92	34	202	159	48	14	0	1.62	7.9	960	807	285
26	Tayampalaiyam	200	243	782	27	1631	268	346	98	0	1.4	7.3	6060	5285	1500
27	Avinahsi palayam south	64	117	48	176	298	390	48	48	0	2.24	7.7	1870	1880	640
28	Chettipalaiyam	54	52	117	35	241	43	226	12	0	0.43	7.4	1300	981	350
29	Chellapalaiyam	12	68	345	59	96	549	29	2	0	1.06	7.9	1180	923	310
30	Koduvay	32	84	83	13	124	323	86	26	0	1.38	8	1170	1084	425
31	Singanurpudur	208	105	209	47	312	323	384	98	0	2.34	7.8	2930	3349	950
32	Pongalur	26	5	37	12	60	49	31	8	0	1.19	8	370	359	85
33	Katturpudur	96	129	230	43	404	305	168	87	0	0.4	7	2610	2923	770
34	Chinnakavundanpalayam	20	13	67	20	21	171	48	15	0	1.55	7.7	360	576	105
35	Tattaripalaiyam	112	102	212	19	411	92	192	91	0	0.68	7.9	2270	2879	700
36	Thirumalainayakkanpalayam	88	66	161	39	248	165	336	14	0	0.73	6.9	1810	1295	490
37	Dharmarpudur	20	32	133	16	191	171	48	8	0	0.67	7.5	980	676	180
38	Puttarichchal	14	50	124	27	106	409	48	4	0	0.61	7.9	1070	649	240
39	Kallaipalaiyam	56	80	304	176	418	275	259	84	0	0.94	7.9	2620	3078	470
40	Karasamadai	40	92	359	39	390	311	432	25	0	1.48	7.9	2590	2004	480
41	Kettanur	18	26	74	176	131	293	48	15	0	0.62	8	1050	921	150
42	Mandripalaiyam	34	62	51	38	117	256	29	25	0	1.34	7.7	960	955	340
43	Kottapalaiyam	80	122	184	38	355	153	192	84	0	1.1	6.7	2150	2695	700
44	Matturnattam	12	38	294	39	255	244	288	1	0	1.2	7.9	1670	1066	185
45	Garudapalaiyam	90	41	69	20	163	85	206	14	0	0.78	7.9	1090	906	395

Table 2. Comparison of groundwater quality with BIS standards for drinking purposes

Parameter	BIS, 1991 Standard		Total no. of samples under desirable limit	Total no. of samples exceeds max. allow. limit	Sample location exceeds max. allow. limit	Percentage
	Desirable Limit	Max.allow. Limit				
pH		6.5 to 8.5	45	0	NIL	-
TDS	500	2000	45	17	1,9,10,13,14,17,18,19,22,24,26,31,33, 35,39,41,44	38 %
Ca^{++}	75	200	45	1	31	2%
Mg^{++}	75	100	45	12	9,10,13,18,19,22,26,27,31,33,35,43	27%
Na^{+}	-	200	45	18	1,10,13,14,17,18,19,20,22,24,26,29,31,33,35,39,40,44	40 %
Cl^{-}	250	1000	45	1	26	2 %
SO_4^{-}	200	400	45	3	14,19,40	2 %
TH	300	600	45	10	10,13,18,19,26,27, 31,33,35,43	22 %

Table 3. Classification of groundwater on the basis of SAR, SSP, RSC and USSL range

Parameter	Range	Water Class	No. of Samples
SAR	< 10	Excellent (S1)	31
	10–18	Good (S2)	11
	18–26	Doubtful (S3)	03
	> 26	Unsuitable (S4)	Nil
SSP	<200	Maximum allowable limit (safe)	45
	>200	Above allowable limit (unsafe)	-
RSC	<1.25	Good	39
	1.25–2.50	Doubtful	02
	> 2.5	Unsuitable	04
USSL	(C4S4)	L.sodium-H.salinity	02
	(C4S3)	M.sodium-H.salinity	01
	(C4S2)	M.sodium-V.H.salinity	06
	(C3S2)	L.sodium-M.salinity	02
	(C4S1)	H.sodium-V.H.salinity	03
	(C3S1)	H.sodium-H.salinity	25
	(C2S1)	L.sodium-M.salinity	05
	(C1S1)	L.sodium-L.salinity	01

Suitability of Groundwater for Irrigation

Groundwater is the key face for irrigation. The suitability of water for irrigation purpose is based on quality and quantity which includes the exact growth of plants, soil and crop tolerance. The quality of water utilized for irrigation should be in permissible limit. Constantly irrigating the poor quality water it might affect the development of plants and may lead to saline and sodic soil, especially in clayey soils. The quality of water used for irrigation plays a vital role in productivity of crops, yield and quality. So a proper appraisal is necessary on the quality and quantity of groundwater before applying for irrigation. So the suitability of water for irrigation is based on the sodium absorption ratio (SAR) and residual sodium carbonate (RSC).

Sodium Absorption Ratio (SAR):

The sodium adsorption ratio (SAR) is an important parameter for determining the suitability of groundwater for irrigation which is computed with standard formula of Hem, 1991. It is a measure of alkali/sodium hazard to crops. Excess salinity reduces the osmotic activity of plants (Subramani et al. 2005). Total salt concentration and probable sodium hazard of the irrigation water are the two major constituents for determining SAR. There is a close relationship between SAR values in irrigation water and the extent to which Na+ is absorbed (Subba Rao, 2006). Salinity hazard is based on EC measurements. This indicates 93% of the samples are suitable for irrigation. SAR values less than 10 indicate excellent quality for irrigation, during post-monsoon period thirty one groundwater samples of the area fall excellent (S1) class and 11 samples that fall in good (S2) category (Table 3). A total of three samples represent doubtful categories respectively indicating the alkali azard and chances for water to cause permeability problems on shrinking and sweeping and swelling types of clayey soils (Saleh et al., 1999).

Soluble Sodium Percentage (SSP):

Sodium plays a vital role for irrigation classification of water due to its reaction with soil, reduces permeability. It is usually expressed as %Na (Wilcox, 1955). All the ions are expressed in meq/l. It is observed that all the sample locations are falls within the maximum allowable limit. So, it is highly recommended that all locations in the study area are suitable for irrigation purposes.

Residual Sodium Carbonate (RSC):

In addition to the SAR and Na%, the excess sum of carbonate and bicarbonate in groundwater over the sum of calcium and magnesium also influences the unsuitability of groundwater for irrigation. RSC is calculated to determine the hazardous effect of carbonate and bicarbonate on the quality of water used for agricultural activities (Janardhana Raju, 2007). The classification of irrigation water according to the RSC values is shown in Table 3. The RSC values of groundwater which is less than 1.25 epm is safe water for irrigation purpose, water between less than 1.25 to 2.5 epm is marginally suitable whereas more than 2.5 epm is not suitable for irrigation purposes. From the RSC values, thirty nine samples of study area showing the values less than 1.25 and are safe for irrigation and two samples shows the values between 1.25 and 2.50 are doughtful and four samples shows more than 2.5 and are unsuitable. (Table 3).

US Salinity diagram:

On the basis of salinity hazards and sodium

hazards water is divided into low (C1), medium (C2), high (C3) and very high (C4) types and low (S1), medium (S2), high (S3) and very high (S4) types. The SAR values ranges between 0.31 and 34.57. The analytical data plotted on the US salinity diagram (Richards, 1954) the study area groundwater samples falls in C1S1 (2%), C2S1 (11%), C3S1 (56%), C3S2 (4%), C4S1 (7%), C4S2 (13%), C4S3 (2%), C4S4 (4%) indicating low to very high salinity and low to high sodium water, field indicating water is poorly suitable for usual agro-

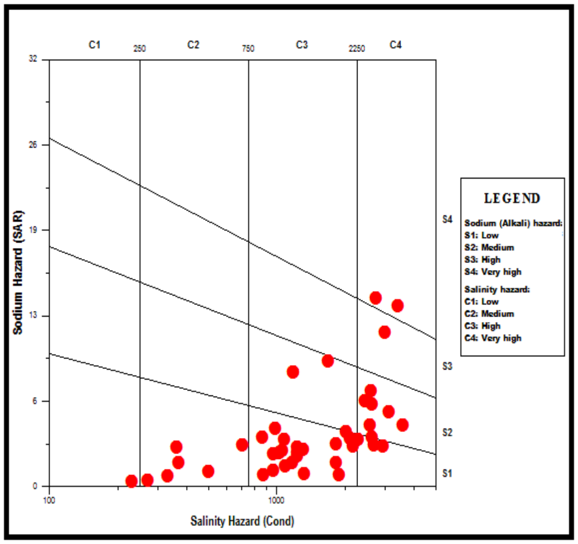

Fig.2. U S Salinity diagram of groundwater of study area

purpose but applied for the cultivation of barley, millets, date, palm and cotton. The rest of area is occupied by moderately suitable water type, which can be used for semi tolerant crops like rice, sugarcane, cotton, maize, onion, potato, brinjal, plantain tree, barley, Lucerne, safflower, spinach, lettuce, cluster beans, pearl-millet and grasses and also for semi-tolerant crops like coconut tree, chilly, ragi and maize. Few samples fall in the field of C4S3 and C4S1 indicates very high salinity and high alkalinity hazard and C3S1 zone signifies high salinity and low sodium water, which can be used for irrigation in almost all types of soil with little danger of exchangeable sodium (Kumar et al. 2007). Representations are also noted in C4S1 category specifies water suitable for plants having good salt tolerance but unsuitable for irrigation in soils with restricted drainage (Mohan et al. 2000). Representations is also noted in C4S3 and C4S2 category indicating samples not suitable for irrigation purposes due to very high salinity and sodium hazards which affects the plant growth.

Conclusion

The values of TDS, Mg^{++}, Na^{+} and TH concentration is higher in few of the samples when compared with the BIS standard. In most of the samples the value of Ca^{++}, $Cl^{-}$and SO_4^{-} ion concentration is within the allowable limits. Due to industrial effluent, affluent anthropogenic factors and geological characteristics the excess amount of TDS, Mg^{++}, TH and Na+ are noticed in groundwater. The suitability of irrigation water quality is assessed based on SAR, SSP, and RSC values. From the observed values either from the SAR, SSP or RSC most of the samples in Tirupur Taluk falls in the suitable range for irrigation. USSL, diagram indicates that the groundwater samples fall in the field of (C1S1), (C2S1), (C3S1), (C3S2), (C4S1), (C4S2), (C4S3) and (C4S4) indicating low to very high salinity and low to high alkalinity hazard. SSP states that all the samples falls within the maximum allowable limit which is safe for irrigation purpose. The overall hydrogeochemical studies indicates that in the study area majority of the sample locations are fitting for domestic and irrigation purposes, while compared with BIS, (1991).

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