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RESEARCH ARTICLE

ASSESSMENT OF GROUNDWATER QUALITY IN AMARAVATHI BASIN, TAMILNADU, INDIA

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ABSTRACT

The knowledge of groundwater quality is important as it the major factor which determining its suitability for drinking, domestic, agriculture, and industrial purpose. To evaluate the water quality 60 groundwater samples were collected in the year 2011. Thus collected water samples in the study area were analyzed for electrical conductivity, pH, total dissolved solids (TDS), major cations like calcium, magnesium, sodium, potassium, and anions like carbonate, chloride, nitrate, and sulfate, in the laboratory using the standard methods given by the American Public Health Association. The groundwater locations were selected to cover the entire study area where contamination is expected. The expected groundwater contaminants were chloride, nitrate, TDS, etc. The results were evaluated in accordance with the drinking water quality standards given by the World Health Organization (WHO 1993) etc. To know the distribution pattern of the concentration of different elements and to demarcate the higher concentration zones, the interpolation maps for various elements were also generated, discussed, and presented.

INTRODUCTION

In the recent years, quality of groundwater has become an acute problem. The quality of both surface and groundwater has reached a critical stage due to over exploitation, urbanization, industrialization, increasing irrigated agriculture, population and improve water management.

In India, the parameters mentioned above are more complicated due to judicial and socio- economic problems, hence the groundwater quality aspect is an important phenomena in which this particular study attempt understand the suitability of groundwater for agriculture compared to the physical and biological aspects. Chemistry of the groundwater is important in deciding its suitability for agriculture. The chemistry of the water depends either directly or indirectly on the geology of the area, soil, thickness of weathered zones, thickness of fractured zone, etc. Apart from these, the domestic wastes (sewage disposal) and industrial effluents are infiltrate and contaminating the groundwater.

The poor quality of groundwater naturally leads to a lot of agriculture problem which ultimately results with poor crop yield. No water is unfit for irrigation if it is properly utilized. The suitable arrangement and measurement of groundwater care yield good results in the agriculture. So, this chapter tries to understand the chemical aspect of groundwater and its suitability for agriculture.

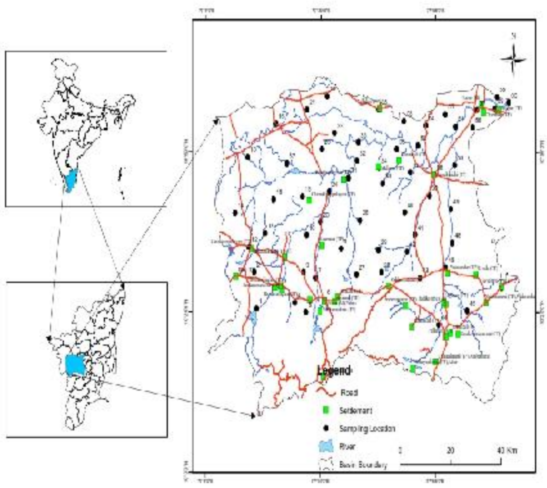

Figure 1 Location Map along with sampling stations

It is estimated that approximately one third of the world's population use groundwater for drinking (Nickson *et al*.2005).Groundwater is the major source of water supply for domestic purpose in Urban and rural parts of India . The most important reason is that non-availability of drinking surface water and a general belief that groundwater is pure and safer

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than surface water due to the protective qualities of the soil cover (Mishra *et al*. 2005).Anthropogenic activities can alter the relative contributions of the natural causes of variations and also introduce the effects of pollution (Whittemore *et al*.1989). nutrient and sediment cycling. The drastic increase in population, modern land use applications like agricultural and industrial and demands for water supply has limited the globally essential groundwater resources in terms of both its

Table 1 Physicochemical parameters

S.No.	Sampling Station	EC	pH	Ca^+	Mg^+	Na^+	K^+	HCO_3^-	Co_3^-	Cl^-	SO_4^-	NO_3^-	TDS	TH
1	1	960	7.16	156	85	28	0.36	143	0	129	83	0.1	614	739
2	2	850	7.28	129	82	23	0.25	129	0	138	87	0.13	544	659
3	3	1060	7.23	123	85	32	0.16	156	0	128	85	0.12	678	656
4	4	1280	7.42	148	96	29	0.18	156	0	124	82	0.09	819	764
5	5	1250	7.46	142	79	35	0.13	148	0	136	96	0.09	800	679
6	6	1340	7.52	123	86	29	0.08	153	0	129	74	0.08	864	660
7	7	1080	7.89	128	92	24	0.1	163	0	113	82	0.06	691	697
8	8	1080	7.26	126	72	23	0.15	128	0	115	89	0.13	691	610
9	9	970	7.65	146	79	25	0.16	129	0	119	83	0.06	621	689
10	10	890	7.58	135	63	29	0.18	136	0	126	78	0.09	570	596
11	11	870	7.69	128	85	32	0.15	138	0	120	75	0.13	857	669
12	12	1030	7.91	123	73	26	0.15	150	0	168	92	0.12	659	607
13	13	1080	7.82	156	85	34	0.06	149	0	149	75	0.05	691	739
14	14	880	7.54	136	69	29	0.08	142	0	123	68	0.09	563	623
15	15	1550	7.42	148	96	32	0.08	163	0	157	83	0.06	736	764
16	16	1060	7.56	163	78	28	0.13	152	0	159	84	0.08	678	727
17	17	870	7.62	129	76	36	0.13	120	0	124	82	0.07	557	634
18	18	1080	7.28	138	71	24	0.08	152	0	135	84	0.09	691	636
19	19	1360	7.46	125	92	31	0.05	135	0	126	85	0.08	870	690
20	20	850	7.65	128	78	34	0.08	163	0	145	63	0.07	544	640
21	21	1080	7.26	136	116	58	0.13	145	0	152	64	0.06	691	816
22	22	1060	7.23	126	113	59	0.19	129	0	145	65	0.05	678	778
23	23	870	7.12	145	96	35	0.06	189	0	128	69	0.05	557	756
24	24	1150	7.63	145	82	28	0.09	148	0	142	89	0.12	736	699
25	25	1250	7.58	136	83	26	0.12	126	0	120	87	0.1	800	680
26	26	1130	7.14	153	123	54	0.26	138	0	123	62	0.09	723	887
27	27	1050	6.96	186	74	25	0.22	128	0	136	84	0.06	672	768
28	28	1030	7.26	136	95	24	0.09	132	0	136	96	0.05	659	730
29	29	1060	7.28	128	98	30	0.15	120	0	125	91	0.05	678	722
30	30	520	7.49	126	91	37	0.07	126	0	130	95	0.05	333	688
31	31	1160	7.29	145	120	65	0.23	135	0	152	67	0.04	742	855
32	32	920	7.29	165	89	65	0.12	175	0	126	65	0.08	589	777
33	33	740	7.34	175	95	39	0.06	148	0	126	78	0.02	474	827
34	34	650	7.59	116	52	26	0.08	106	0	112	72	0.15	416	503
35	35	1150	7.28	125	115	24	0.19	126	0	129	68	0.03	736	784
36	36	980	7.49	120	84	37	0.07	169	0	106	82	0.13	627	644
37	37	780	7.82	136	86	20	0.12	112	0	98	110	0.09	499	693
38	38	1480	7.2	120	86	25	0.18	175	0	203	112	0.04	947	653
39	39	980	7.66	254	142	32	0.12	356	0	189	89	0.09	628	1217
40	40	1260	7.2	259	135	36	0.19	216	0	187	95	0.25	794	1201
41	41	1050	7.31	263	123	48	0.24	236	0	182	85	0.23	672	1162
42	42	1060	7.42	236	136	46	0.16	262	0	196	96	0.21	682	1148
43	43	870	7.48	214	129	40	0.18	248	0	178	97	0.21	557	1064
44	44	1040	7.34	235	126	48	0.22	320	0	189	37	0.13	666	1104
45	45	840	7.62	269	126	42	0.36	319	0	179	87	0.12	538	1189
46	46	950	7.69	250	126	32	0.13	256	0	189	89	0.23	608	1142
47	47	790	7.43	248	135	56	0.24	348	0	185	59	0.15	506	1174
48	48	1060	7.36	261	148	32	0.29	361	0	179	68	0.06	678	1259
49	49	1630	7.48	123	85	30	0.13	152	0	242	78	0.06	1043	656
50	50	1090	7.56	153	75	29	0.2	145	0	125	86	0.12	698	690
51	51	1250	7.56	145	87	52	0.16	148	0	265	89	0.12	800	719
52	52	1200	7.52	132	72	36	0.13	146	0	189	106	0.05	768	625
53	53	1100	7.58	186	85	34	0.06	149	0	142	78	0.01	704	814
54	54	1260	7.89	145	79	28	0.08	158	0	158	69	0.12	806	686
55	55	1160	7.29	125	89	39	0.1	156	0	215	125	0.08	742	677
56	56	1160	7.58	150	85	59	0.1	136	0	146	68	0.03	742	724
57	57	1200	7.54	145	96	53	0.12	142	0	150	64	0.04	768	756
58	58	680	7.26	163	56	54	0.09	79	0	74	55	0.06	435	637
59	59	890	7.58	158	79	67	0.15	125	0	98	59	0.05	570	719
60	60	780	7.49	149	72	35	0.08	116	0	83	49	0.08	499	668

Human and ecological use of groundwater depends on ambient water quality. Human alteration of the landscape has an extensive influence on watershed hydrology (Claessens *et al.* 2006; Chang 2007), which subsequently increases water temperature (Nelson and palmer 2007) and modifies groundwater biogeochemical processes which make oxygen, quality and quantity. Even though urban aquifers are the only natural resource for drinking water supply and they are often perceived as of less relevance for the drinking water supply, leading to crisis in terms of drinking water scarcity, becoming increasingly polluted thereby decreasing their potability (Dixit *et al*.2005). Laluraj *et al*. (2005) have studied ground water chemistry of shallow aquifers in the coastal zones of Cochin and concluded that groundwaters present in the shallow aquifers of some of the stations were poor in quality and beyond potable limit as per the standard set by WHO and ISI.

Table 2 Statistical measures such as maximum minimum average median and mode.

Water quality parameters	Units	maximum concentration	Minimum concentration	Average	Median	Mode
EC	(µS/cm)	1630	520	1043.89	1060	1060
Ph	mg/l	7.91	6.96	7.46	7.48	7.58
Ca^{2+}	mg/l	269	116	159.10	145	145
Mg^{2+}	mg/l	148	52	93.50	86	85
Na^{+}	mg/l	67	20	36.42	32	32
K^{+}	mg/l	0.36	0.05	0.14	0.13	0.08
HCO_3^-	mg/l	361	79	166.94	148	148
CO_3^-	mg/l	0	0	0	0	0
Cl^-	mg/l	265	74	145.37	136	126
SO_4^{2-}	mg/l	112	37	79.47	82.5	89
NO_3^-	mg/l	0.25	0.01	0.09	0.08	0.09
TDS	mg/l	1043	143	660.77	678	691
TH	mg/l	1259	503	779	719	656

quality of groundwater is the resultant of all the processes and reaction that act on the water from the moment it condenses in the atmosphere to the time it is discharged by a well.

Therefore, determination of groundwater quality is important to observe the suitability of water for a particular use.

Changes in groundwater quality are due to variation in climatic conditions, residence time of water with aquifer materials and inputs from soil during percolation of water (Mitra *et al*.,2007; Krishna kumar *et al*.,2008). Many hydrogeochemical processes have been highlighted in the control of the chemical composition of groundwater, like carbonates and silicates weathering, ion exchange (Giridharan *et al*., 2008;Subba Rao 2008).

The knowledge of hydrochemistry is essential to determine the origin of chemical composition of groundwater (Zaporozec 1972).

Table 3 The number and percentage of samples exceeding the allowable limits set by WHO (1993)

Water quality Parameters	Unit	WHO (1993)/ Most desirable limit	WHO (1993)/ Maximum allowable limit	Number of sample exceeding allowable limit	Percentage exceeding allowable limit	Undesirable effects
PH	Mg/I	6.5-8.5	9.2	0	0	Taste
Ca^{2-}	Mg/I	75	200	10	16.6	Scale formation
Mg^{2+}	Mg/I	50	150	0	0	
Na^{+}	Mg/I		200	0	0	
K^{+}	Mg/I		12	0	0	Bitter in taste
CI^-	Mg/I	200	600	0	0	Salty taste
$so4^{2-\backslash}$	Mg/I	200	400	0	0	Laxative effective
$No_2 + No_3$	Mg/I	45		0	0	Blue baby
TDS	Mg/I	500	1,500	0	0	Gastrointestinal irritation

Rapid increase in urbanization and industrialization leads into deterioration in groundwater quality. Srinivas *et al*. (2000) and Jha and Verma (2000) have reported the degradation of water quality in Hyderabad and Bihar, respectively. Untreated industrial waste effluents when discharged in unlined drains can percolate underground directly affecting the quality of groundwater.

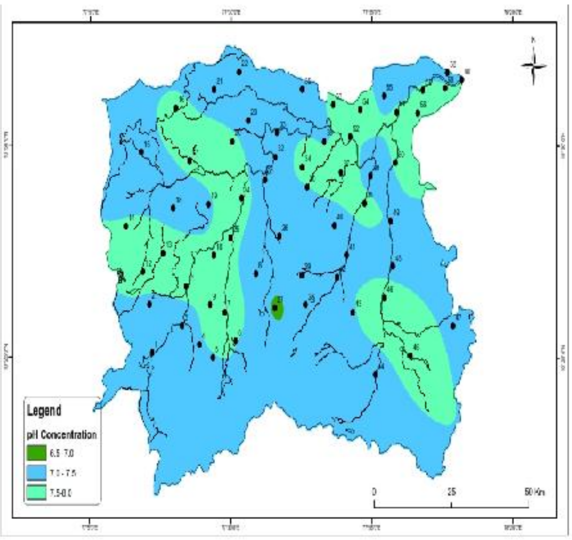

Figure 2 Spacial distribution of pH

Burston *et al*. (1993) discussed that the quality of groundwater is often assessed by reference to drinking water standards. The

The hydrology and geochemistry of waters have been further discussed in the classic works of Stumm and Morgan (1981), Hem (1991), Drever (1988), Domenico and Schwartz (1990a, b), ImranAhmad Dar *et al*. (2009), Imran Ahmad Dar *et al*. (2010a, b) and Mithas AhmadDar *et al*. (2010c). Adverse conditions increase investment in irrigations and health and decrease agricultural production, which, inturn, reduce agrarian economy and retard improvement in living conditions of rural people. Poor quality of water adversely affects the plantgrowth and human health (Wilcox 1948; Thorne and Peterson 1954; US Salinity Laboratory Staff 1954; Holden 1971; Todd 1980; ISI 1983; WHO1984; Hem 1991; Karanth 1997). Water quality is influenced by natural and anthropogenic effects including local climate, geology, and irrigation practices.

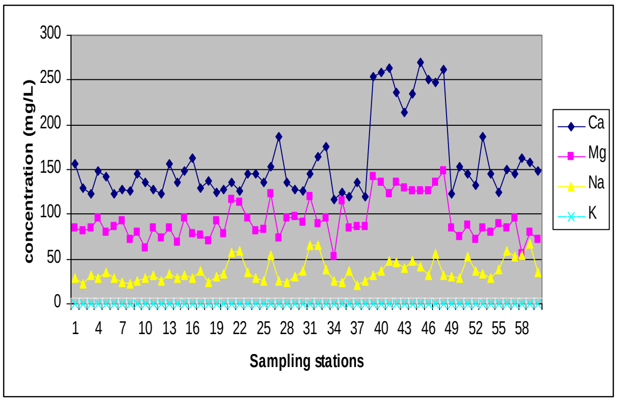

Figure 3 Cationic chemistry

The specific objectives of this study are

1. The investigation and interpretation of the groundwater quality of Amaravathi basin.
2. Find out the suitability of groundwater for irrigation and drinking purposes.

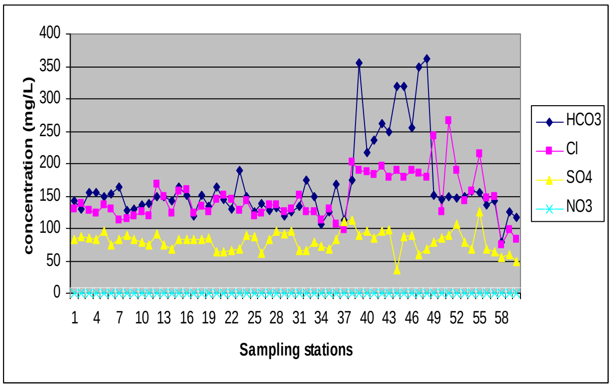

Figure 4 Anionic chemistry

Study Area

Amaravathi river is one among the major tributaries of the Cauvery river system in southern India. It originates from Anaimalai hills at an altitude of 1827m which drains from south to the north east and confluences with the main river, Cauvery at Thirumukudalur which is situated around 10km east of Karur, (Karur) district, Tamilnadu. This basin is located between latitudes 10º 8´ N to 11º 1´N and longitudes 77º3´E to 78º 8´E covering an area of about 8280sq.km. The river is of north flowing type. Topographically, the basin is enclosed by coimbatore uplands, on the west and by the Anaimalais, palani and sirumalai hills on the south and southeast. Further on the east, the plain slopes gently towards the Cauvery and is flanked by Aiyalur Reserve Forest and Kadavur hills. The northern part of the basin has an undulating plain with an average elevation of 300m, forming an effective topographic barrier between Noyal and other sub-basins of the Cauvery River Similarly, the headwaters of this basin are separated from those of Vaigai River, existing in the south by the Anaimalais and Kodaikanal-Palani hills. These hill ranges rise to a height of more than 2700m the valleys represent a low relief from those of the hills with a difference in height ranging from 1500 to 2500m.The study area experiences tropical monsoonal climate. The temperature on the hills differs from that of the plains, which lies between 15ºC and38ºC on the low land and 10ºC to 18ºC on the hills. The average annual rainfall is about 855mm.Strong winds from the southwestprevail during June,July and August. Vegetation on the northern slopes of the hills are of dry type than the southern and western windward sides. The hills are covered with dry monsoon forests. At some places, medicinal shrubs have also grown within the palani hills.

Geology

Several digital image processing techniques, including standard color composites, intensity-hue saturation (IHS) transformation, and decorrelation stretch (DS) were applied to map rock types. The statistical technique adopted by Sheffield (1985) was employed to select the most effective. Three-band color composite image. The bandcombination 1, 4, and 5 is the best triplet and was used to create color composites with Landsat TM bands 5, 4, and 1 in red, green, and blue, respectively.

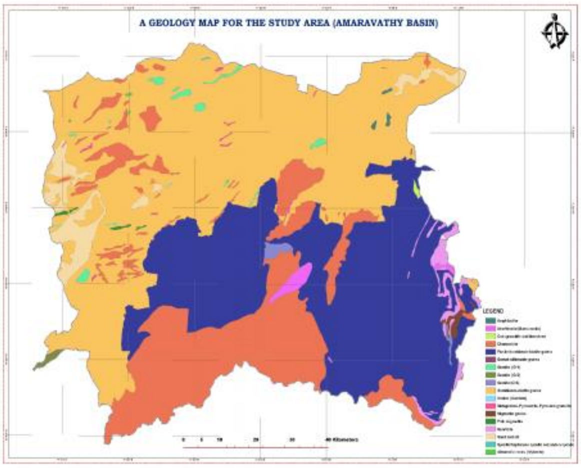

Figure 4a Geology Map

IHS transformation and DS were also applied to the selected band combination in order to enhance the difference between rock types. Better contrast was obtained due to color enhancement, and this facilitated visual discrimination of various rock types. Eighteen rock types were mapped and could be distinguished by distinct colours in the processed images. They are Amphibolite, Anothosite (Basic rocks),Calc-granulite and limestone, Charnockite, Fissile hornblende blotite gneiss, Garnet-sillimanite gneiss, Granite (Gr1),Granite (Gr2),Granite (G3),Hornblende-blotite gneiss, Kankar (Calcrete),Pyroxenite,

Table 4 Groundwater classification according to electrical conductivity values

Electrical conductivity (µS/cm)	Classification	Sample numbers	Numbers of samples	Percentages of samples
<1,500	Permissible	1,2,3,4,5,6,7,8,9,10,11,12 ,13,14,16,17,18,19,20,21, 22,23,24,25,26,27,28,29, 30,31,32,33,34,35,36,37, 38,39,40,41,42,43,44,45, 46,47,48,50,51,52,53,54, 55,56,57,58,59,60	58	96.7
1,500-3,000	Not Permissible	15,49	2	3.3
>3,000	Hazardous	----	---	---

Table 5 Ground water quality classification according to Davis and DeWiest (!966)

TDS(mg/l)	Classification	Sample numbers	Number of samples	Percentage of Samples
<500	Desirable for drinking	30,33,34,37,58,60	6	10.0
500-1000	Permissible for drinking	1,2,3,4,5,6,7,8,9,10,11, 12,13,14,15,16,17,18, 19,20,21,22,23,24,25,2 6,27,28,29,31,32,35,36, 38,39,40,41,42,43,44, 45,46,47,48,50,51,52, 53,54,55,56,57,59	53	88.3
1000-3000	Useful for irrigation	49	1	1.7
>3000	Unfit for drinking and irrigation	--------	--------	--------

Migmatite gneiss, Pink migmatite, Quartzite, Sand and silt, Syenite and Ultramafic rocks. A map of the interpreted distribution of rock types in the study area is shown in Fig.(4 a).Source: GIS 1994

METHODS

In order to assess the groundwater 60 groundwater samples have been collected. The samples collected in the field were analysed for PH, electrical conductivity(EC),total dissolved solids(TDS), major cations like calcium, magnesium, sodium, potassium and anions like bicarbonate, carbonate, chloride, Nitrateand and Sulphate in the laboratory using the standard methods given by the American Public Health Association(APHA 1995).The groundwater locations were selected to cover the entire study area, and attention has been given to the area where contamination is expected.

Table 6 Groundwater Quality classification according to Freeze and Cherry (1979)

TDS (mg/l)	Classification	Sample numbers	Number of Samples	Percentage of samples
<1000	Freshwater type	1,2,3,4,5,6,7,8,9,10,11,12, 13,14,15,16,,17,18,19,20,2 1,22,23,24,25,26,27,28,29, 30,31,32,33,34,35,36,37, 38,39,40,41,42,43,44,45, 46,47,48,50,51,52,53,54, 55,56,57,59,60	59	98.3
1000-10,000	Brackish water type	49	1	1.7
10,000-1,00,000	Saline water type	---------	----	----------
>1,00,000	Brine water type	------------	----	-----------

The expected contaminants were chloride, nitrate, TDS, etc. Samples were carried out using precleaned plastic containers. the results were evaluated in accordance with the drinking water quality standards given by the World Health Organization.(WHO1993).Spatial distribution maps for TDS, EC, Cl, $NO_{3,}$andK were created using Arc Gis 9.3.1 software.

RESULTS AND DISCUSSION

Groundwater chemistry

The observed values of various physiochemical parameters is shown in Table 1 and their statistical measures such as minimum, maximum, average, median and mode are given in Table 2.The number and percentage of samples exceeding the allowable limits set by WHO (1993) is given in Table 3.

The EC values ranges from 520 to1630 µS/cm with an average value of 1043.89 µS/cm. The pH value of groundwater ranges from 6.96 to 7.91 with an average value of 7.46. This shows that the groundwater of the study area is mainly of alkaline in nature. Acidic water is confined at south central part, while the rest of the region is dominated by the alkaline water fig.5.

TDS values ranges from 143 to 1043 mg/l with an average value of 660.77 mg/l. To know the distribution pattern of the concentration of different elements and to demarcate the higher concentration zones, the interpolation maps for various elements were also generated, discussed, and presented.

Ionic chemistry

From the Fig.4, it is obvious that ca^{+} ion (average concentration of 159.10 mg/l) dominates the cation chemistry of the study area . Sample no.45 showed the highest concentration of calcium ion (269mg/l). While as the K^{+} ions is found in a least concentration (average value of 0.14 mg/l). While as Hco_3^{-} dominates the anionic chemistry of the study area (fig.4).

Electrical conductivity

Electrical conductivity of groundwater in the study area is given in Table 4 and is found that 96.7% of the samples are within the permissible limit and 3.3% of the samples belongs to not permissible limit, but they are marginally poor in quality.

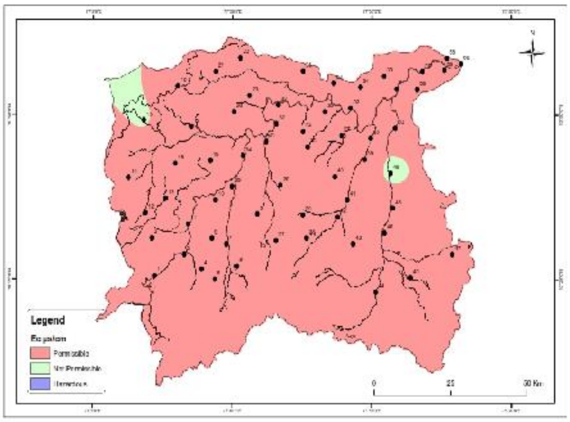

Figure 5 Spatial distribution of Electrical conductivity

Total dissolved solids

To ascertain the suitability of groundwater of any purposes, it is essential to classify the groundwater depending upon their hydrochemical properties based on their TDS values (Davis and DeWiest 1966; Freeze and Cherry 1979) which are represented In Table 5 and 6 and displayed spatially in Fig 6. The groundwater Of the area is fresh water for 98.3% of the sample locations, and the remaining 1.7% of The samples represent brackish water based on Freeze and Cherry (1979).

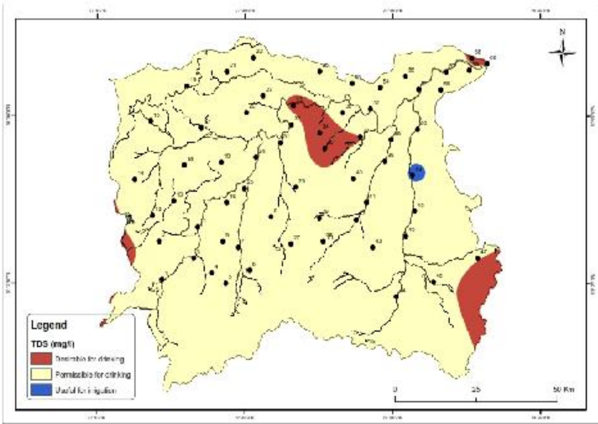

Figure 6 a spatial distribution of Total Dissolved Solids according to Davis and DeWiest (1966) classification

The study shows that only 10% of the sample is below 500mg/l of TDS which can be used for drinking without any risk.88.3% of the sample ranger from 500-1000mg/l

Which comes under permissible for drinking. Higher content of TDS can be attributed to the contribution of salts from the thick mantle of soil and the weathered media of the rock and further due to higher residence time of groundwater in contact with the aquifer body.

As the host rocks belongs to charnockites and granitic suits, there can be some oxidation and reduction processes in groundwater and surface water, thereby also causing enrichment in the total dissolved solids.

Total hardness

The classification of groundwater (Table 7) based on total hardness (TH) shows that a majority of the groundwater samples fall in the very hard water category. The hardness values range from 503 to 1259mg/l with an average value of 779mg/l(Table2). The maximum allowable limit of TH for drinking purpose is 500mg/land the most desirable limit is 100mg/l as per the WHO international standard. For total hardness, the most desirable limit is 80-100mg/l (Freeze and Cherry1979).Groundwater exceeding the limit of 300mg/l is considered to be very hard (Sawyer *et al*.2003). All the groundwater samples were exceeds the maximum allowable limit of 500mg/l.

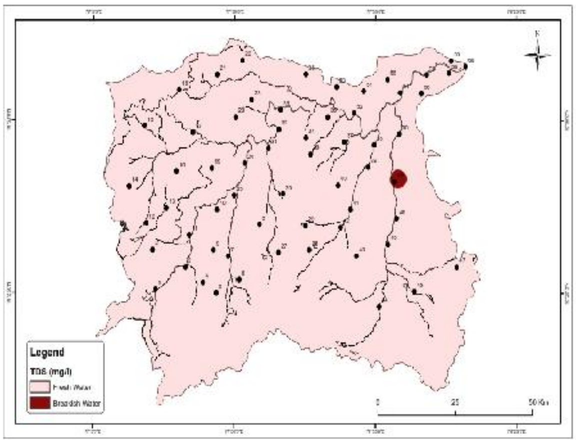

Figure 7 Groundwater classification according to TH values

600mg/l (Table2). The spatial distribution of chloride Concentration in groundwater of the study area is illustrated in Fig.8

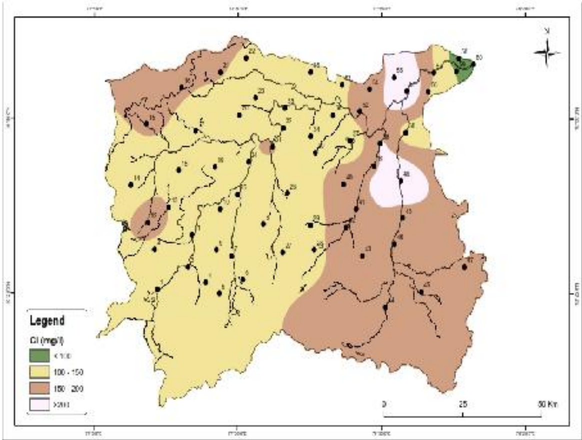

Figure 8 Spatial Distribution of Chloride concentration

Nitrate

The nitrate ion concentration varies from 0.01 to 0.25mg/l with an average Value of 0.09 mg/l. The concentration of nitrogen in groundwater is derived from the Biosphere (Saleh *et al*. 1999). Nitrogen is originally fixed from the atmosphere and then mineralized by soil bacteria into ammonium. No samples exceed the desirable limit of 45mg/l as per WHO standard.

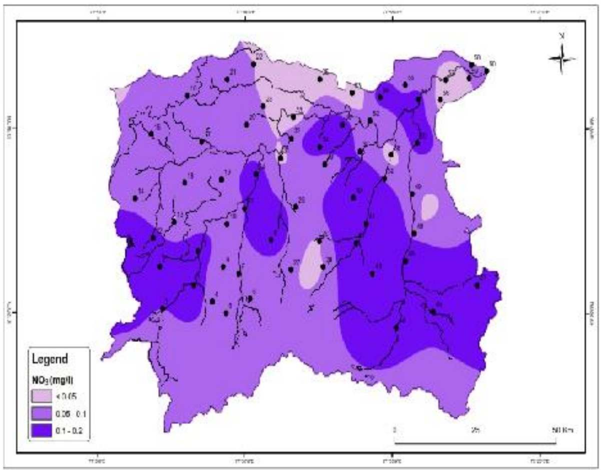

Figure 9 Spatial distribution NO_3

Table 7 Groundwater classification according to TH values

Total hardness (mg/l)	Type of water	Sample numbers	Number of samples	Percentage of Samples
<75	Soft	-----------	-----------	-----------
75-150	Moderately hard	-------------	-----------	-----------
150-300	Hard	-------------	-----------	-----------
>300	Very hard	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,,17,18, 19,20,21,22,23,24,25,26,27,28,29,30,31,32, 33,34,35,36,37,38,39,40,41,42,43,44,45,46, 47,48,49,50,51,52,53,54,55,56,57,59,60	60	100

Chloride

Chloride concentrations ranging from 74 to 265 mg/l with an average of 145.37mg/l.The chloride ion concentration in groundwater does not exceeds the maximum allowable limit of

The high concentration of nitrate in drinking water is toxic and causes blue baby disease/methaemoglobinemia in children and gastric Carcinomas (Comly 1945). The spatial variation of nitrate in groundwater of the study area is shown in Fig.9

Sulfate

The concentration of sulfate is likely to react with human organs if the value exceeds the maximum allowable limit of 400 mg/l and causes a laxative effect on human system with the excess magnesium in groundwater of the study area is within the maximum allowable limit in all the sample locations.

Potassium

As per WHO (1993), the maximum allowable limit for potassium is 12 mg/l.

From the analysis of water samples of the study area, no samples exceed this permissible limit. The spatial distribution map for potassium is shown in Fig.10.

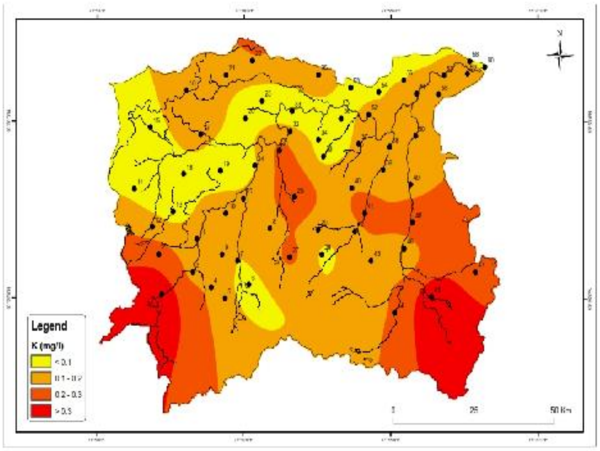

Figure 10 Spatial Distribution of potassium

Sodium concentration plays an important role in evaluating the groundwater quality for irrigation because sodium causes an increase in the hardness of soil as well as a reduction in its permeability (Tijani 1994).More than 73%(73.3%) percentages of the groundwater samples are good for irrigation. While 21.7% of the samples are permissible for irrigation in almost all types of soil with little danger of exchangeable sodium and remaining (5%) as sample numbers 31, 32,59 are grouped under doubtful for irrigation.

CONCLUSION

The hydrochemical analysis of the study reveals that the groundwater in the study area is very hard , fresh to brackish, and alkaline in nature. Ca^{+} ion (with average concentration of 159.10 mg/l)dominates the cation chemistry of the study area, while as Hco_3^- dominates the anionic chemistry of the study area. The occurrence of high EC values in the study area reflected the addition of some salts through the prevailing agricultural activities.

The groundwater of the area is fresh water for 98.3% of the sample locations and the rest of the samples represent brackish water based on Freeze and Cherry (1979). The study shows that only 10% of the sample is below 500 mg/l of TDS which can be used for drinking without any risk. Higher content of TDS can be attributed to the contribution of salts from the thick mantle of soil and the weathered media of the rock and further due to higher residence time of groundwater in contact with the aquifer body.

Table 8 Groundwater classification according to Na % values:

Percentage of sodium	Classification	Sample numbers	Number of samples	Percentage of Samples
<20	Excellent	----------	--------	------
20-40	Good	1,2,3,4,5,6,7,8,9,10,11,12,13, 14,15,16,17,18,19,20,23,24, 25,27,28,29,30,33,34,35,36,37, 38,39,40,46,48,49,50,52,53,54, 55,60	44	73.3
40-60	Permissible	21,22,26,41,42,43,44,,45,47,51, 56,57,58,	13	21.7
60-80	Doubtful	31,32,59,	3	5.0
>80	Unsuitable	------------	--------	------

Irrigation water quality

Excessive amount of dissolved ion such as sodium, bicarbonate, and carbonate in irrigation water affects plants and agricultural soil physically and chemically, thus redusing the productivity. The physical effects of these ions are to lower the osmotic pressure in the plant structural cells, thus preventing water from reaching the branches and leaves.

The chemical effects disrupt plant metabolism. It is the quantity of certain ions, such as sodium and boron, rather than the total salt concentration that affects plant development (Sahinci 1991). 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).

As the host rocks belong to charnockites and granitic suits, there can be some oxidation and reduction processes in groundwater and surface water, thereby also causing enrichment in the total dissolved solids. Na% in 44 groundwater samples are good. (Table 8). More than twenty one (21.7%) percentages of the groundwater samples are permissible for irrigation in almost all types of soil with little danger of exchangeable
sodium.

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