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RESEARCH ARTICLE

ASSESSMENT OF GROUNDWATER QUALITY IN THANJAVUR DISTRICT TAMIL NADU, INDIA USING GIS PLATFORM

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ABSTRACT

In order to assess the groundwater quality, 100 groundwater samples have been collected in year 2010. The water samples collected in the field were analyzed for electrical conductivity, pH, total dissolved solids (TDS), major cations like calcium, magnesium, sodium, potassium, and anions like bicarbonate, carbonate, chloride, nitrate, and sulfate, in the laboratory using the standard methods given by the American Public Health Association. The results were evaluated in accordance with the drinking water quality standards given by the World Health Organization (WHO 1993). To know the distribution pattern of the concentration of different elements and to demarcate the higher concentration zones, the spatial distributin maps for various elements were also generated, discussed, and presented.

INTRODUCTION

The hydrology and geochemistry of waters have been discussed in the classic works of Stumm and Morgan (1981), Hem (1991), Drever (1988), Domenico and Schwartz (1990a, b), Adverse conditions increase investment in irrigations and health and decrease agricultural production, which, in turn, reduce agrarian economy and retard improvement in living conditions of rural people. Poor quality of water adversely affects the plant growth 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. The chemical character of any groundwater determines its quality and utilization. The quality is a function of the physical, chemical, and biological parameters and could be subjective, since it depends on a particular intended use. Various workers in our country have carried out extensive studies on water quality. 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 tations were poor in quality and beyond potable limit as per the standard set by WHO and ISI. Rapid increase in urbanization and industrialization leads in to 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. Patnaik *et al.* (2002) have studied water pollution generated from major industries. Similarly, waste effluents discharged in to streams may enter the aquifer body downstream, which also affects the groundwater quality. Abbasi *et al.* (2002) have studied the impacts of wastewater inputs on the water quality. Jagdap *et al.* (2002) and Sunitha *et al.* (2005) classify the water in order to assess the water quality for various purposes. Fluoride levels in drinking water from various sources in and around Jaipur and many villages and trace metals have been carried out in our laboratory (Jangir *et al.,* 1990; Sharma *et al.,* 1990) earlier. Study of industrial wastewater, groundwater, and pollution problems in groundwater have also been studied in our laboratory (Sharma *et al.,* 2004; Singh and Chandel 2003, 2006) recently. The specific objectives of this study is to find out the suitability of groundwater for irrigation and drinking purposes.

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Study Area

The Thanjavur District extends over approximately 1345.82 km2 and lies between 10°0'0"N and 11°15'0"N, East Longitude between 78°40'0" E and 79°25'0"E. longitudes in the Central part of Tamilnadu, India (Fig. 1). The Thanjavur District is generally hot and dry except during winter season. The mean maximum monthly temperature varies from 21.40°C in January to 36.60°C in July. The area receives an average annual rainfall of about 96.33 mm. The surface runoff goes to stream as instant flow. Rainfall is the direct recharge source and the irrigation return flow is the indirect source of groundwater in the Thanjavur District. The study area depends mainly on the northeast monsoon rains. Most of the farmers depend on the groundwater for their irrigational and drinking purposes.

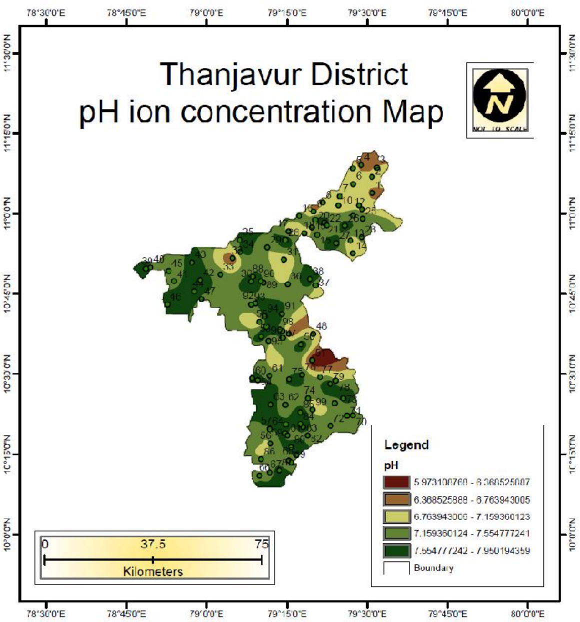

Fig. 1. Location map along with sampling stations

MATERIALS AND METHODS

The water samples collected in the field were analyzed for electrical conductivity (EC), pH, total dissolved solids (TDS), major cations like calcium, magnesium, sodium, potassium, and anions like bicarbonate, carbonate, chloride, nitrate, and sulfate, in the laboratory using the standard methods given by the American Public Health Association (APHA 1995). Sampling was carried out using precleaned polyethylene containers. The results were evaluated in accordance with the drinking water quality standards given by the World Health Organization (WHO 1993). Thematic maps pertaining to TDS, EC, Cl, NO3, SO4, and Na were created using ArcGIS 9.3 software.

RESULTS AND DISCUSSION

Groundwater chemistry results of the various physicochemical 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 110 to 2280 μS/cm with an average value of 1091.7 μS/cm. The pH value of groundwater ranges from 6.0 to 7.9 with an average value of 7.361. This shows that the groundwater of the study area is mainly of alkaline in nature. Acidic water is confined at eastern part while as the central part is dominated by the alkaline water (Fig. 3). TDS values ranges from 70.4 to 1459 mg/l with an average value of 698.688 mg/l. To know the distribution pattern of the concentration of different elements and to demarcate the higher concentration zones, the contour maps for various elements were also generated, discussed, and presented. From the Fig. 4, it is obvious that Na+ ion (average concentration of 108.4 mg/l) dominates the cation chemistry of the study area. While as HCO3− dominates the anionic chemistry of the study area (Fig. 5). Electrical conductivity Electrical conductivity of groundwater in study area is given in Table 4 and is found that 89%of the samples are within the permissible limit and 11% of the samples fall in not permissible limit, but they are marginally poor in quality and none of the sample locations were found as hazardous according to the WHO standard. The hazardous quality is due to the chemicals used for the textile processing in the study area. The electrical conductivity map is shown in Fig. 6. The occurrence of high EC values in the study area might also be due to addition of some salts through the prevailing agricultural activities.

Total dissolved solids

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 Tables 5 and 6 and displayed spatially in Figs. 7 and 8, respectively. The groundwater of the area is fresh water for 56.7% of the sample locations, and the rest of the samples represent brackish water based on Freeze and Cherry (1979). The study shows that only 96% 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.

Total hardness

The classification of groundwater (Table 7) based on total hardness (TH) shows that a majority of the ground water samples fall in the very hard water category. The hardness values range from 1500 to 7750 mg/l with an average value of 4224.5 mg/l (Table 2). The maximum allowable limit of TH for drinking purpose is 500 mg/l and the most desirable limit is 100 mg/l as per the WHO international standard. For total hardness, the most desirable limit is 80– 100 mg/l (Freeze and Cherry 1979). Groundwater exceeding the limit of 300 mg/l is considered to be very hard (Sawyer *et al.,* 2003). approximately 78% of groundwater samples out of 100 collected exceeds the maximum allowable limit of 500 mg/l.

Chloride

Chloride concentrations ranging from 18 to 390 mg/l have been found in shallow groundwater, and its possible source is tanneries where sodium chloride is used as a raw material. The chloride ion concentration in groundwater of the study area falls well within the maximum allowable limit of 600 mg/l (Table 2). The spatial distribution of chloride concentration in groundwater of the study area is illustrated in Fig. 9.

Table 1. Physicochemical parameters

S.No	EC	pH	Ca	Mg	Na	K	HCO3	Cl	SO4	NO3	F	Fe	PO4	TDS
1	1240	1240	26	64	136	19	445	160	38	0.12	3.16	65	0.02	793.6
2	580	6.9	32	32	30	23	250	57	10	0.16	2.89	45	0.03	371.2
3	780	6.8	32	41	55	18	275	106	19	0.13	2.75	49	0.04	499.2
4	2100	6.6	48	107	230	19	622	326	53	0.15	2.56	62	0.06	1344
5	790	7	28	44	58	20	311	92	15	0.09	3.06	60	0.02	505.6
6	770	6.9	28	33	74	20	415	28	12	0.12	3.16	60	0.02	492.8
7	540	7.1	20	28	41	18	293	18	14	0.11	2.25	55	0.03	345.6
8	1260	6.9	40	51	138	18	671	39	24	0.08	3.25	54	0.05	806.4
9	1650	6.7	20	43	253	19	616	202	43	0.13	3.25	66	0.02	1056
10	2170	6.9	40	90	276	18	836	213	82	0.12	2.25	68	0.01	1388.8
11	110	7.1	20	56	115	17	445	128	23	0.15	3.26	55	0.03	70.4
12	580	7.1	24	41	18	18	244	53	21	0.06	3.24	54	0.05	371.2
13	920	6.9	24	55	74	18	378	106	10	0.08	3.22	58	0.04	588.8
14	910	7.1	24	47	85	18	445	64	10	0.16	2.28	62	0.02	582.4
15	1090	7.3	14	58	117	19	378	117	62	0.12	3.24	64	0.03	697.6
16	790	7.3	14	36	90	18	427	26	12	0.12	3.12	45	0.02	505.6
17	1490	7	14	16	278	19	689	106	42	0.12	3.14	54	0.03	953.6
18	1050	7.1	24	57	106	19	445	99	64	0.15	3.24	52	0.02	672
19	940	7.2	14	63	74	20	403	92	65	0.19	3.12	55	0.03	601.6
20	470	7.6	18	28	28	19	415	18	45	0.01	2.32	48	0.05	300.8
21	1520	7.8	24	59	65	22	360	74	44	0.15	2.25	68	0.04	972.8
22	1650	7.2	20	52	45	18	360	85	48	0.16	2.14	72	0.06	1056
23	980	7.4	20	56	49	18	378	74	54	0.12	2.14	78	0.03	627.2
24	1260	7.3	32	58	62	39	311	72	57	0.15	2.25	74	0.02	806.4
25	510	7.4	30	62	60	18	555	88	54	0.06	2.36	75	0.06	326.4
26	1340	7.7	42	59	78	19	549	84	56	0.12	3.14	72	0.05	857.6
27	1480	7.7	22	58	72	20	561	102	52	0.16	3.15	74	0.04	947.2
28	1510	7.9	26	65	86	20	604	106	58	0.15	3.18	78	0.02	966.4
29	660	7.2	30	68	85	18	537	94	54	0.14	3.24	74	0.03	422.4
30	970	7.8	28	55	98	18	610	94	62	0.15	3.24	76	0.05	620.8
31	1350	6.8	28	59	93	19	531	82	54	0.34	3.12	52	0.04	864
32	990	6.5	34	58	92	18	610	88	56	0.33	3.14	54	0.06	633.6
33	940	7.4	38	54	87	17	561	86	66	0.42	3.08	57	0.02	601.6
34	990	7.6	30	55	118	21	455	96	10	0.31	3.06	59	0.02	633.6
35	1070	7.6	40	56	120	19	500	85	12	0.65	3.12	62	0.03	684.8
36	850	7.2	14	55	86	23	415	46	15	0.62	3.08	65	0.05	544
37	720	7.1	24	52	96	20	360	43	15	0.34	3.04	62	0.02	460.8
38	760	7.9	28	54	93	18	360	50	23	0.78	3.05	54	0.03	486.4
39	780	7.9	12	45	97	18	378	50	16	0.82	3.06	52	0.02	499.2
40	710	7.3	12	46	95	18	311	64	13	0.29	3.08	58	0.06	454.4
41	1220	7.4	14	48	125	39	555	96	23	0.34	3.12	68	0.04	780.8
42	1480	7.7	12	47	124	19	549	142	78	0.33	3.14	64	0.08	947.2
43	1670	7.7	34	46	102	22	561	227	67	0.34	3.06	65	0.02	1068.8
44	1540	7.9	32	52	113	18	604	170	62	0.31	3.08	65	0.02	985.6
45	1400	7.2	44	55	119	20	537	181	25	0.65	3.04	62	0.03	896
46	2280	7.8	38	65	78	18	610	390	82	0.84	3.14	68	0.02	1459.2
47	1290	7.4	40	62	72	18	531	131	30	0.81	3.12	64	0.03	825.6
48	1970	7	28	64	85	39	610	305	65	0.31	3.05	62	0.05	1260.8
49	1280	6.5	24	68	98	18	561	116	33	0.32	3. 12	61	0.04	819.2
50	1200	7.8	24	62	87	18	494	128	20	0.64	3.14	67	0.06	768
51	1300	6	32	58	124	18	555	124	26	0.54	3.12	52	0.03	832
52	1470	7.9	44	48	112	20	622	142	28	0.64	3.14	55	0.02	940.8
53	870	7.8	36	49	125	20	311	121	16	0.34	3.06	56	0.06	556.8
54	780	7.7	32	55	207	18	216	156	83	0.63	3.08	58	0.05	499.2
55	710	6.8	22	65	131	18	235	147	65	0.31	3.04	64	0.04	454.4
56	480	7.2	38	45	76	39	242	159	68	0.94	3.16	65	0.02	307.2
57	500	7.7	20	44	232	19	251	165	57	0.29	3.12	56	0.03	320
58	820	7.6	40	48	242	22	263	103	49	0.12	3.12	68	0.05	524.8
59	1420	7.9	44	54	129	18	250	125	58	0.31	3.14	64	0.06	908.8
60	1220	7.6	30	57	196	20	239	115	45	0.62	2.14	62	0.04	780.8
61	800	7.4	34	54	28	18	248	119	42	0.12	3.14	85	0.04	512
62	1060	7.2	44	56	216	18	230	124	48	0.16	2.87	39	0.08	678.4
63	1080	7.8	32	52	216	39	243	126	47	0.13	2.96	64	0.02	691.2
64	1150	7.2	44	58	290	18	213	123	43	0.15	2.84	66	0.12	736
65	1160	7.6	24	54	53	19	256	136	58	0.09	2.95	68	0.06	742.4
66	1130	7.5	26	64	131	20	234	120	59	0.12	2.64	48	0.08	723.2
67	1230	7.4	28	62	214	20	225	126	62	0.11	2.59	42	0.06	787.2
68	1090	7.1	48	62	138	18	263	145	63	0.08	2.65	44	0.02	697.6
69	1200	7.3	46	64	55	18	283	152	67	0.13	2.48	66	0.04	768
70	1240	7.2	48	54	51	19	269	129	65	0.12	2.47	64	0.08	793.6
71	1230	7.3	34	54	30	18	256	152	64	0.15	2.65	39	0.06	787.2
72	1200	7.4	36	58	23	17	274	123	68	0.06	3.69	39	0.06	768
73	1120	7.7	36	54	87	18	261	136	67	0.08	3.48	85	0.08	716.8
74	1030	7.2	42	65	45	18	289	125	62	0.16	5.26	43	0.06	659.2
75	1200	7.6	44	64	49	18	287	136	58	0.12	4.36	34	0.06	768
76	1090	7.6	48	65	62	19	298	134	54	0.12	4.12	45	0.04	697.6

77	1050	7.2	46	64	60	26	295	129	52	0.18	3.25	124	0.02	672
78	1090	7.1	14	62	78	25	236	169	65	0.18	3.65	114	0.06	697.6
79	1280	7.9	14	68	72	23	216	178	69	0.04	3.27	50	0.03	819.2
80	960	7.9	12	65	86	20	235	146	56	0.12	3.19	225	0.03	614.4
81	850	7.3	18	48	85	21	242	123	54	0.5	3.48	115	0.02	544
82	960	7.4	22	47	98	29	251	143	63	0.32	3.15	68	0.03	614.4
83	890	7.7	24	46	96	37	263	136	48	0.16	3.26	72	0.05	569.6
84	1120	7.7	26	52	92	35	216	125	59	0.23	3.19	74	0.04	716.8
85	1030	7.9	32	55	94	31	263	124	84	0.48	3.16	68	0.06	659.2
86	1540	7.2	38	65	78	36	245	78	86	0.1	3.26	175	0.03	985.6
87	1290	7.8	40	62	82	23	256	75	82	0.37	2.15	52	0.02	825.6
88	1120	7.6	44	64	86	26	236	72	68	0.23	2.36	96	0.06	716.8
89	980	7.2	24	65	216	28	265	86	64	0.05	2.54	51	0.05	627.2
90	740	7.8	24	45	216	29	254	85	65	0.25	2.58	40	0.04	473.6
91	890	7.6	22	44	290	24	202	75	64	0.16	2.48	107	0.02	569.6
92	750	7.6	14	48	53	18	222	86	62	0.18	3.19	134	0.03	480
93	690	7.3	28	54	131	18	233	78	68	0.2	3.26	85	0.05	441.6
94	1060	7.8	26	57	214	39	314	89	65	0.28	3.27	83	0.04	678.4
95	1120	7.2	28	54	138	19	356	74	48	0.16	3.19	71	0.06	716.8
96	1060	7.6	30	56	55	22	324	88	47	0.24	3.24	68	0.02	678.4
97	1080	7.5	32	52	78	18	322	80	46	0.28	3.65	219	0.02	691.2
98	1150	7.4	44	58	84	20	321	85	52	0.28	6.59	64	0.03	736
99	1160	7.1	48	54	82	18	256	84	55	0.34	3.48	94	0.05	742.4
100	1130	7.3	24	62	58	18	224	84	65	0.16	3.74	79	0.02	723.2

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

Water quality Parameter	Units	Average	Maximum Concentration	Minimum	Median	Mode
EC	µS/cm	1091.7	2280	110	1090	1085
pH	mg/l	7.361	7.9	6	7.2	7.4
Ca	mg/l	29.54	48	12	24	28
Mg	mg/l	54.95	107	16	54	55
Na	mg/l	108.4	290	18	78	88.5
K	mg/l	21.37	39	17	18	19
Cl	mg/l	114.54	390	18	106	106
SO4	mg/l	48.77	86	10	65	54
No2+No3	mg/l	0.25665	0.94	0.01	0.12	0.16
TDS	mg/l	698.688	1459.	70.4	697.6	694.4
TH	mg/l	4224.5	7750	1500	4500	4275
HCO3	mg/l	374.81	836.00	202	312.50	445.0

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

Water quality parameters	units	WHO (1993)		Number of exceeding limits	sampling allowable	Perectage of sample exceeding allowable limits	Undesirable effects
		Most desirable imits	Maximum allowable limits				
pH	mg/l	6.5-8.5	9.2	0		0	Taste
Ca^{2+}	mg/l	75	200	0		0	Scale formation
Mg^{2+}	mg/l	50	150	0		0	
Na+	mg/l		200	13		13	
K^{+}	mg/l		12	40		40	Bitter in taste
Cl^{-}	mg/l	200	600	0		0	Salty taste
$SO4^{2-}$	mg/l	200	400	0		0	Laxative effective
NO2+NO3	mg/l	45		15		15	Blue Bady
TDS	mg/l	500	1500	0		0	Gastrointestinal irriratin

Table 4. Groundwater classification according to electrical conductivity values

Electrical conductivity (µS/cm)	Classification	Sample numbers of samples	Number of Percentage samples
<1500	Permissible	1, 8, 17, 18, 24, 26, 27, 31, 32, 33, 34, 35, 41, 42, 45, 47, 49, 50, 51, 52, 59, 60, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 84, 85, 87, 88, 94, 95, 96, 97, 98, 99, 100, 11, 20, 56, 2, 3, 5, 6, 7, 12, 13, 14, 15, 16, 19, 23, 25, 29, 30, 36, 37, 38, 39, 40, 53, 54, 55, 57, 58, 61, 80, 81, 82, 83, 89, 90, 91, 92, 9	89
1500-3000	Not Permissible	9,11, 22, 28, 43, 44, 48, 86, 4, 10, 46	11
>3000	Hazardous	0	0

Table 5. Groundwater quality classification according to Davis and DeWiest (1966)

TDS (mg/ l)	Classification	Sample numbers	No. of samples	Percentage of samples
< 1000	Fresh water type	2, 3, 6, 7, 11, 12, 20, 25, 29, 30, 37, 38, 39, 40, 55, 56, 57, 90, 92, 93, 5, 9, 10, 17, 21, 22, 24, 26, 27, 28, 31, 42, 44, 45, 47, 49, 51, 52, 53, 59, 78, 86, 89 13, 14, 36, 54, 58, 61, 80, 82, 83, 91, 15, 18, 19, 23, 32, 33, 34, 35, 62, 63, 68, 73, 75, 76, 77, 79, 81, 85, 89, 94, 95, 1, 8, 41, 50, 60, 64, 65, 66, 67, 69, 70, 71, 72, 74, 84, 88, 96, 97, 98, 99, 100	96	96
1000- 10,000	Brackish water type	4, 10, 43, 46, 48	4	4
10,000- 100,000	Saline water type		-	-
> 100,000	Brine water type		-	-

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

Parameters	Classification	Sample numbers	No. of samples	Percentage of samples
500 >	Desirable for drinking	2, 3, 6, 7, 11, 12, 20, 25, 29, 30, 37, 38, 39, 40, 55, 56, 57, 90, 92, 93	22	22
500-1000		5, 9, 10, 17, 21, 22, 24, 26, 27, 28, 31, 42, 44, 45, 47, 49, 51, 52, 53, 59, 78, 86, 89 13, 14, 36, 54, 58, 61, 80, 82, 83, 91, 15, 18, 19, 23, 32, 33, 34, 35, 62, 63, 68, 73, 75, 76, 77, 79, 81, 85, 89, 94, 95, 1, 8, 41, 50, 60, 64, 65, 66, 67, 69, 70, 71, 72, 74, 84, 88, 96, 97, 98, 99, 100	73	73
1000-1500		4, 10, 43, 46, 48	5	5

Table 7. Ground water classification according to TH values

Total hardness (mg/l)	Type of water	Numbers of Sample	Number of Percentage Sample
2000 >	Soft	7, 16, 17, 20, 42	10
3000-4000	Moderately high	2, 3, 5, 6, 9, 11, 12, 13, 14, 15, 19, 22, 23, 27, 36, 37, 40, 41, 43, 57, 65, 78, 80, 81, 82, 83, 84, 90, 91	58
4000-5000	Hard	1, 8, 18, 21, 24, 25, 28, 29, 30, 31, 32, 34, 35, 38, 39, 44, 45, 48, 49, 50, 51, 52, 53, 54, 55, 56, 58, 59, 60, 61, 62, 63, 66, 67, 71 ,72, 73, 79, 85, 89, 92, 93, 94, 95, 96, 97, 100	96
5000 <	Very hard	4, 10, 26, 46, 47, 64, 68, 69, 70, 74, 75, 76, 77, 86, 87, 88, 98, 99	36

Table 8. Ground water classification according to Na%values

Na %	Classification	Sample numbers of samples	Number of Percentage samples
20-40	Good	13, 61, 69, 70, 71, 72, 74	7
40-60	Permissible	2, 3, 5, 6, 7, 13, 14, 18, 19, 20,21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 35, 38, 45, 46, 47, 48, 49, 50, 52, 56, 65, 68, 73, 75, 76, 77, 78, 79, 84, 85, 86, 87, 91, 92, 95, 96, 97, 98, 99, 100	53
60-80	Doubtful	1, 4, 8, 10, 11, 12, 15, 16, 34, 36, 37, 39, 40, 41, 42, 43, 44, 51, 53, 54, 55, 57, 58, 59, 60 62, 63, 64, 66, 67, 80, 82, 83, 88, 89, 93, 94	37
80 <	Unsuitable	9, 17, 90	3

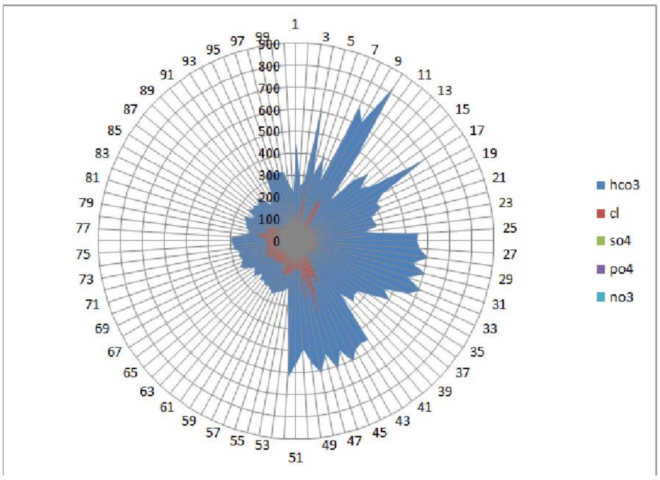

Fig. 4. Cation chemistry

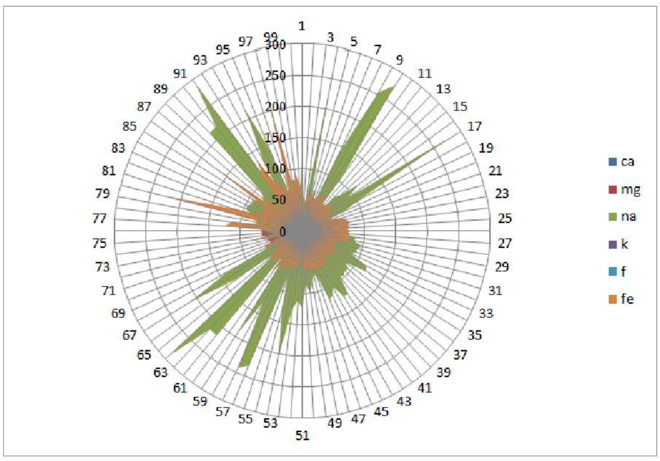

Fig. 5. Anion chemistry

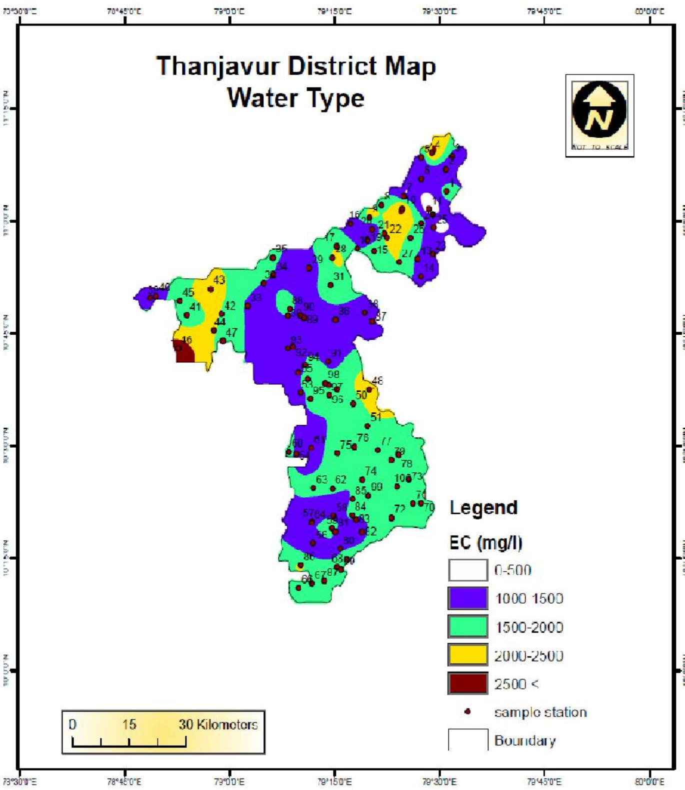

Fig. 6. Spatial distribution of electrical conductivity

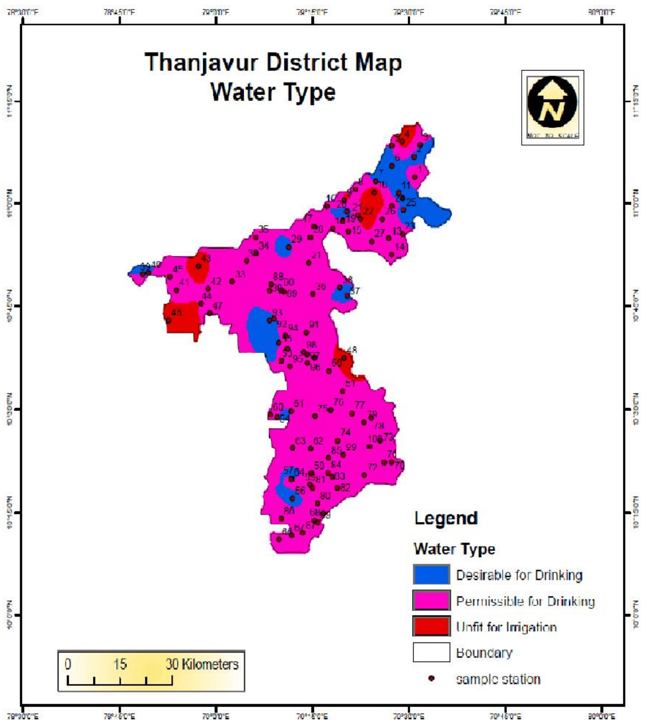

Fig. 8. Spatial distribution of total dissolved solids according to Freeze and Cherry (1979) classification

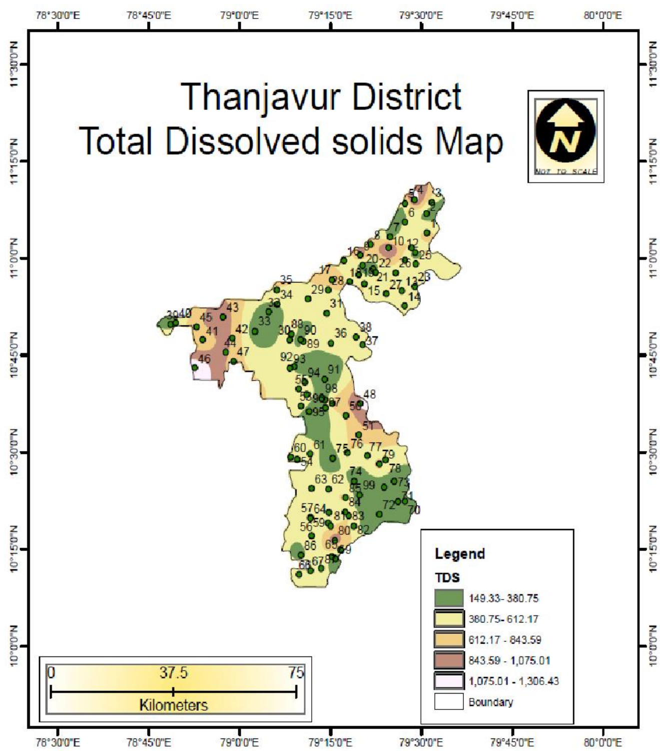

Fig. 7. Spatial distribution of total dissolved solids according to Davis and DeWiest (1966) classification

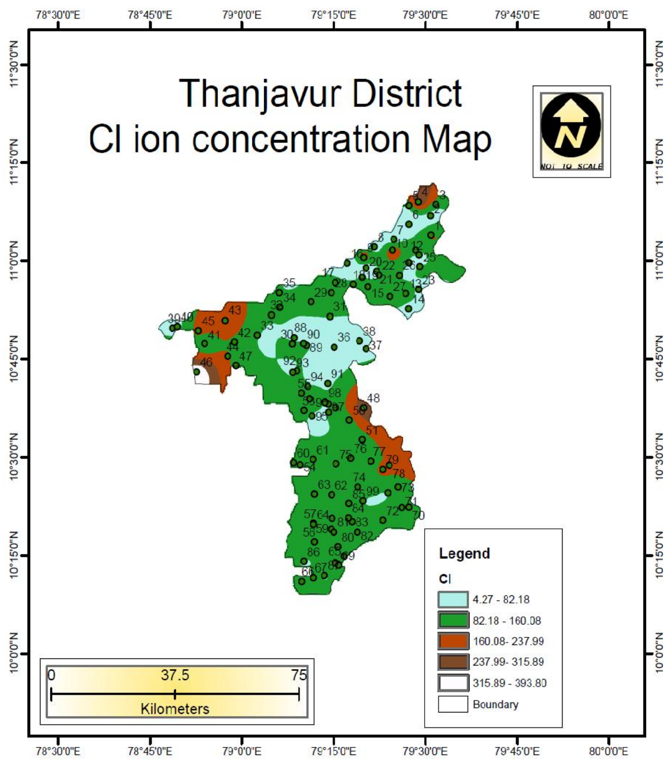

Fig. 9. The spatial distribution of chloride concentration

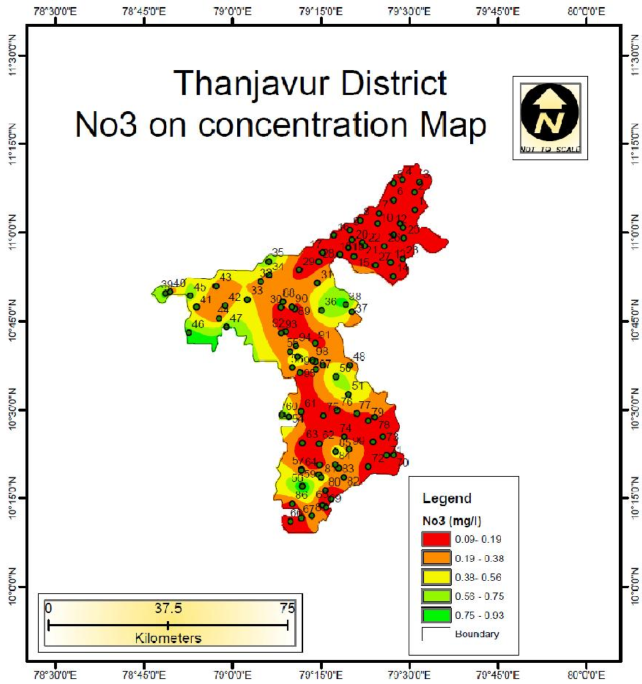

Fig. 10. Spatial distribution of NO3

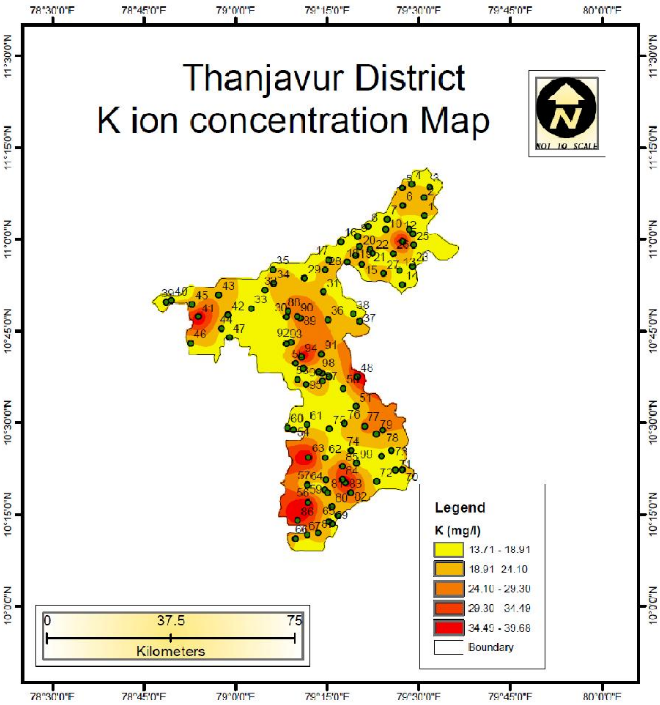

Fig. 11. The spatial distribution map for potassium

Nitrate

The nitrate ion concentration varies from 0.01 to 0.94 mg/l with an average value of 0.2566 5mg/l. The concentration of nitrogen in groundwater is derived from the biosphere (Saleh *et al.,* 1999). Three samples exceed the desirable limit of 45 mg/l as per WHO standard. The high concentration of nitrate in drinking water is toxic and causes blue baby disease/methaemoglobinemia in children and gastric carcinomas (Comly 1945). The high Nitrate concentration is due to the intensive urbanization and industrialization. The spatial variation of nitrate in groundwater of the study area is illustrated in Fig. 10.

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. However, the sulfate concentration 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, all of the collected samples exceed this permissible limit. The spatial distribution map for potassium is shown in Fig. 11.

Irrigation water quality

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). 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). Na% in three groundwater samples (viz. 9,17,90) are high and are not suitable for irrigation (Table 8). More than 53 (53%) percentages of the groundwater samples are permissible for irrigation in almost all types of soil with little danger of exchangeable sodium. While as sample numbers 1, 4, 8, 10, 11, 12, 15, 16, 34, 36, 37, 39, 40, 41, 42, 43, 44, 51, 53, 54, 55, 57, 58, 59, 60 62, 63, 64, 66, 67, 80, 82, 83, 88, 89, 93, 94 (comprising 37%) are categorized under doubt full for irrigation.

Conclusion

The study reveals that more than fifty-three (53%) percentages of the groundwater samples are permissible for irrigation in almost all types of soil with little danger of exchangeable sodium. The groundwater in the study area is hard to very hard, fresh to brackish, and alkaline in nature. Na+ ion (with average concentration of 108.4 mg/l) dominates the cation chemistry of the study area, while as HCO3− 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 96% of the sample locations and the rest of the samples represent brackish water based on Freeze and Cherry (1979). The study showed that only 22% of the sample is below 500 mg/l of TDS which can be used for drinking without any risk. Na% in three groundwater samples are high and are not suitable for irrigation.

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