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Assessment of Groundwater Quality of Chittur Block, Palghat, Kerala, India

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ABSTRACT

The geochemical characteristics of groundwater in the Chittur block, Palghat, Kerala have been studied to assess the water quality for domestic and irrigational purposes. During pre-monsoon (April-2010) period 89 groundwater samples were collected from 61 dug wells and 28 bore wells. Chemical analysis of the groundwater shows different ranges for different parameters (pH 6.25-8.29, EC 250-2400 µS/cm, TDS 160-1536 mg/L, TH 65-945 mg/L, Mg^{2+} 3.62-189.46 mg/L, F^- 0.02-6.3 mg/L, Cl^- 10-672 mg/L, Na^+ 1-126 mg/L, K^+ 1-23 mg/L, NO_3^- 1.42-23.15 mg/L, SO_4^{2-} 5.72-159.62 mg/L and PO_4^{3-} 0-2.12 mg/L). High fluoride (F^-) concentration is reported from 12% water samples. Piper diagram reveals that 42% of the samples are $MgCO_3$ type. Irrigational suitability of water is evaluated based on sodium adsorption ratio, residual sodium carbonate, sodium percent, salinity hazard and USSL diagram. Salinity hazards show that 52% of the samples fall in high salinity hazard (C3) and 1% in very high salinity hazard class (C4). The study shows that, groundwater beyond the acceptable limit of EC, TDS, TH, Mg^{2+} and F^- are not suitable for drinking, and groundwater fall in very high salinity hazard class is not suitable for irrigation.

INTRODUCTION

Groundwater is the main source for drinking, irrigation and industrial purposes. Chemistry of groundwater plays an important role in the usage of water for different purposes. Poor quality of water adversely affects the human health, and plant growth (Hem 1985, 1991, Karanth 1997). In India, the people suffer from health disorders mainly from occurrence of fluoride and arsenic in drinking water. Relatively, the health implications caused by F^- contamination are far more widespread than those of arsenic contamination in the country (Subba Rao 2011). Seventeen states in India have been identified as endemic for fluorosis (Mishra et al. 2006). Geochemically, fluorine is the most electronegative element and occurs primarily as a negatively charged ion in water. Low amount of fluoride (0.3-1.0 mg/L) in drinking water helps in the prevention of dental caries and osteoporosis. However, high intake of fluoride (>1.5 mg/L) in drinking water for a prolonged period can damage the teeth enamel and eventually lead to skeletal complications which ultimately can result in fluorosis (WHO 1984, ISI 1983). Thus, fluoride (F^-) concentration is an important aspect of hydrogeochemistry. Bureau of Indian Standards (BIS 1991) has prescribed a limit between 1.0 and 1.5 mg/L of F^- in drinking water. Potential sources of fluoride in groundwater include various minerals in rocks and soils, such as fluorite, apatite, amphiboles and micas (Handa 1975, Pickering 1985, Wenzel & Blum 1992, Bardsen et al. 1996, Subba Rao & Devadas 2003). High fluoride is reported from both phreatic and deeper aquifers in the eastern part of Palghat district (Shaji et al. 2007).

EC and Na^+ play a vital role in suitability of water for irrigation. Higher EC in water creates a saline soil. Harmful effects of irrigation water increase with the total salt concentration, irrespective of the ionic composition. Higher salt content in irrigation water causes an increase in soil solution osmotic pressure (Thorne & Peterson 1954). Sodium adsorption ratio (SAR), ratio of dissolved sodium (RDS) as sodium percent (%Na), or residual sodium carbonate (RSC) might equally be used calculating a value which can be utilized as an index of groundwater suitability for irrigation purposes (Shaki & Adeloye 2006). SAR is most commonly used for evaluating groundwater suitability for irrigation purposes (Ayers & Westcot 1985). The US salinity lab's diagram is used widely where SAR is plotted against EC (USSL 1954). The present study focuses attention on the evaluation of groundwater quality of Chittur area.

STUDY AREA

The study area falls in Chittur block of Palghat district, Kerala state which covers an area of 261 sq. km (Fig. 1). The Chittur block lies between 10°37' and 10°48' N latitudes and 76°41' and 76°54' E longitudes. The area is a rain shadow region and receives an average annual rainfall of 1413 mm. Chittur block is categorized as overexploited

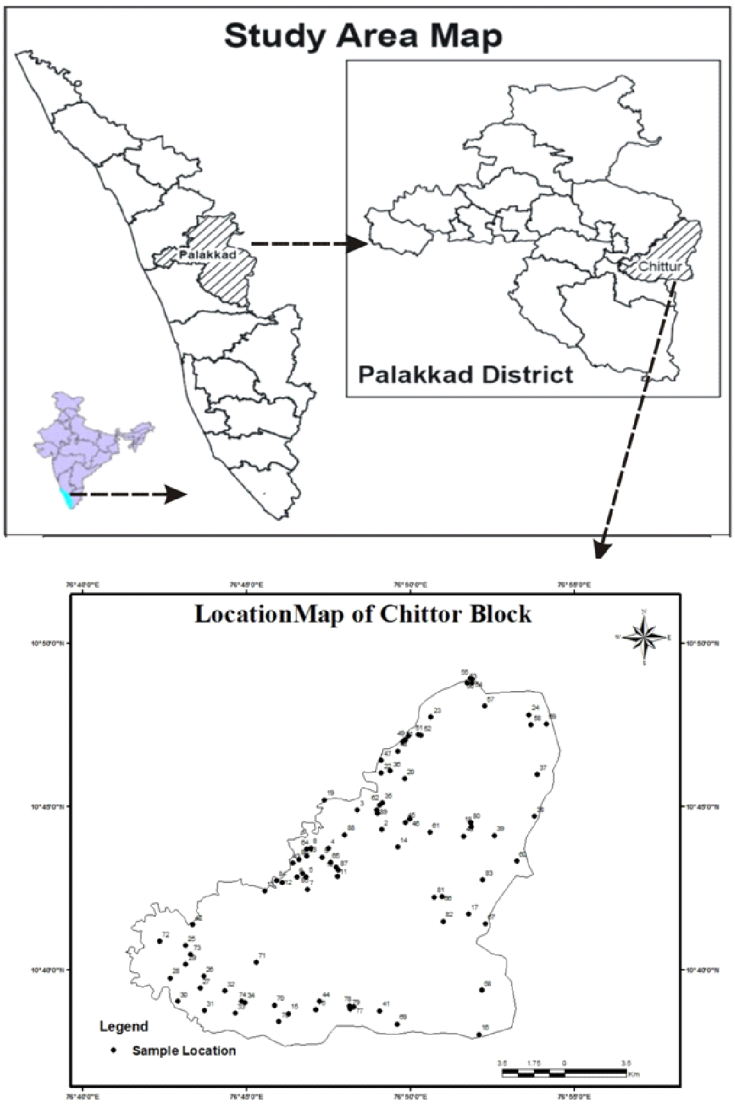

Fig. 1: Location map of the study area with sampling points.

area (CGWB 2013). This is an agrarian block with more focus on paddy cultivation. Chittur River with its tributaries is the major river flowing across the study area and show dendritic drainage pattern.

GEOLOGY OF THE AREA

The study area is mainly occupied by hard rock, metamorphosed crystalline rocks of Archaean age. The major rock units are hornblende biotite gneiss, biotite gneiss and migmatites in which the groundwater occurrence is controlled mainly by fractures. The lateritisation is moderately less and crystallines are covered by a thin mantle of topsoil. The weathered thickness vary from place to place, therefore the quantity of groundwater availability in the phreatic zone also vary within the block. The depth of the weathered strata controls the groundwater occurrence in dug wells.

MATERIALS AND METHODS

During April 2010 (pre-monsoon period) 89 groundwater samples were collected from 61 dug wells and 28 bore wells. Water samples were collected in special polythene bottles. The pH and electrical conductivity were measured in the field and then the samples were brought to the laboratory for the analysis of the major cations and anions. Calcium (Ca^{2+}), magnesium (Mg^{2+}), carbonate (CO_3^{2-}), bicarbonate (HCO_3^-) and chloride (Cl^-) were analysed by volumetric titration methods, sodium (Na^+) and potassium (K^+) were measured using the flame photometer, sulphate (SO_4^{2-}), ni-

trate (NO_3^-) and phosphate (PO_4^{3-}) were determined by spectrophotometric technique. Fluoride analysis was carried out in an instrument Spectroquant Nova 60. The methods used for the analyses were standardized as per the procedures laid down by APHA (1985). The chemical analyses data of groundwater are given in Table 1.

RESULTS AND DISCUSSION

Drinking Water Quality

Hydrogen ion activity (pH): The pH is used to express hydrogen ion concentration. The pH of an aqueous solution is controlled by interrelated chemical reactions that produce or consume hydrogen ions (Hem 1959). pH is the important parameter that determines the quality of water. The BIS limit for drinking water is 6.5-8.5. The pH of the groundwater samples ranges from 6.25-8.29 with a mean value of 7.29 during pre-monsoon, showing an alkaline trend. pH of majority of groundwater samples falls within the acceptable limit.

Electrical conductivity (EC): Electrical conductivity of groundwater samples ranges from 250-2400 µS/cm with a mean value of 823.34 µS/cm in pre-monsoon; majority of the groundwaters belong to medium to high conductive class and one sample comes under very high conductive class. The higher electrical conductivity values are due to natural concentration of ionized substances present in water and due to higher dissolved solids in the study area. The groundwater samples having higher electrical conductivity values are not suitable for human consumption.

Total dissolved solids (TDS): Total dissolved solids is an important parameter used in drinking water purpose. The highest desirable limit of TDS is 500 mg/L; beyond this palatability decreases and may cause gastrointestinal irritation. TDS in the groundwater sample was found in the range of 160-1536 mg/L with a mean value of 527.09 mg/L during pre-monsoon. TDS value of 46% of water samples exceeds highest desirable limit, and these waters are not suitable for drinking purposes.

Total hardness (TH): Total hardness (TH) of water is characterized by contents of calcium and magnesium. According to BIS, highest desirable limit of TH is 300 mg/L and maximum permissible limit is 600 mg/L. When total hardness values cross the desirable limit, it will cause encrustation in water supply structures and adverse effect on domestic use. TH in the groundwater sample ranged from 65-945 mg/L with a mean value of 310.11 mg/L in pre-monsoon. In the study area 39% of samples exceed desirable limit and 6% samples beyond permissible limit. The samples fall beyond the desirable limit are not suitable for drinking purposes.

Sodium (Na^+) and potassium (K^+): The sodium concentration of groundwater samples ranged from 1-126 mg/L with a mean value of 32.25 mg/L in pre-monsoon. BIS maximum permissible limit of Na^+ concentration is 200 mg/L. The results show that Na^+ concentration of all water samples falls within the permissible limit.

The potassium concentration of groundwater samples ranged from 1-23 mg/L with a mean value of 2.39 mg/L in pre-monsoon. BIS maximum permissible limit of K^+ concentration is 40 mg/L. The results show that K^+ concentration of all water samples lies within the permissible limit.

Calcium (Ca^{2+}) and magnesium (Mg^{2+}): Calcium is a major constituent of most igneous, metamorphic and sedimentary rocks. Because of its abundance in most rock types and solubility, calcium is present almost everywhere in groundwaters. According to BIS, highest desirable limit of Ca^{2+} is 75 mg/L, and maximum permissible limit is 200 mg/L. Ca^{2+} concentration beyond desirable limit may cause encrustation in water supply structures and adverse effects on domestic use. The calcium concentration of groundwater samples ranged from 10.02-106.21 mg/L with a mean value of 41.28 mg/L in pre-monsoon. 11% of sample exceeded desirable limit and are not suitable for drinking purposes.

According to BIS, highest desirable limit for Mg^{2+} is 30 mg/L, and maximum permissible limit is 100 mg/L. Mg^{2+} beyond desirable limit causes encrustation in water supply structures and adverse effects on domestic use. The magnesium concentration of groundwater samples ranged from 3.62-189.46 mg/L with a mean value of 49.85 mg/L in pre-monsoon, in which 69% of the samples exceeded desirable limit, and 7% samples beyond permissible limit. The groundwater samples falling beyond the desirable limit are not suitable for drinking purpose.

Chloride (Cl^-): As per the BIS limit of drinking water, the highest desirable limit for Cl^- is 250 mg/L, and the maximum permissible limit is 1000 mg/L. The Cl^- concentration beyond the desirable limit affects taste, corrosion and palatability. The chloride concentration of groundwater samples ranged from 10-672 mg/L with mean value of 111.06 mg/L. 9% of the samples exceeded desirable limit and are not suitable for domestic use.

Fluoride (F^-): Geochemically, fluorine is the most electronegative element and occurs primarily as a negatively charged ion in water. The important fluorine bearing minerals are fluorite, apatite, certain amphiboles and micas. According to BIS, highest desirable limit of F^- is 1 mg/L and maximum permissible limit is 1.5 mg/L. The fluoride concentration of groundwater samples ranged from 0.02-6.3 mg/L with a mean value of 0.74 mg/L, in which 6% of the samples exceed desirable limit, and 12% samples beyond permissible limit.

Table 1: Chemical analysis data of groundwater samples (pre-monsoon).

Loc. No.	pH	EC µS/cm	TDS	Na	K	TH	Ca	Mg	Cl	HCO_3	CO_3	SO_4	PO_4	NO_3	F
								Values in mg/L							
1	6.82	1380	883	46	1	560	70.54	93.23	340	225	0	42.78	0	21.07	3.80
2	7.1	970	629	16	0	360	20.04	75.31	55	325	0	69.10	0	22.48	0.72
3	6.94	670	429	36	1	225	40.08	30.33	17	200	60	11.67	0	8.13	1.79
4	7.26	440	282	19	2	150	28.06	19.41	28	145	15	9.87	0	1.48	0.44
5	7.6	550	352	24	3	245	20.04	47.36	65	130	20	16.15	0	7.75	0.54
6	7.39	475	304	20	1	145	40.08	10.89	24	140	25	24.52	0	2.30	0.64
7	7.19	431	276	16	2	150	38.08	13.32	18	145	15	8.92	0.45	5.16	0.63
8	7.15	890	570	48	2	290	88.18	16.90	75	240	65	33.23	1.89	14.94	0.55
9	6.89	800	512	29	1	380	60.12	55.82	105	175	30	20.84	0	5.37	0.57
10	6.88	604	387	26	1	265	42.08	38.83	47	150	25	16.34	0	16.32	0.54
11	7.12	630	403	33	1	275	32.06	47.35	78	150	20	15.87	0	4.89	0.68
12	7.22	465	298	28	2	140	38.08	10.89	39	130	10	12.91	0	10.28	0.71
13	7.11	250	160	9	2	65	20.04	3.62	11	60	0	9.84	1.05	10.28	0.13
14	7.48	620	397	22	3	300	32.06	53.42	77	145	25	12.02	0	8.01	0.02
15	7.13	600	384	29	3	230	46.09	27.89	50	165	30	9.05	0	5.09	0.43
16	7.43	590	378	35	2	175	34.07	21.83	71	120	45	19.34	0	8.55	0.77
17	7.55	800	512	46	5	350	40.08	60.70	125	140	30	12.43	0	22.82	0.68
18	7.18	2000	1280	126	4	620	50.10	120.16	495	220	25	144.54	0	23.00	1.56
19	7.66	720	461	81	1	200	28.06	31.56	105	150	0	37.45	0	3.27	6.3
20	7.37	2400	1536	68	2	945	66.13	189.46	672	435	0	12.59	0	17.6	0.65
21	6.7	1010	646	46	1	315	34.07	55.85	156	195	0	99.18	0	20.28	0.68
22	7.39	1250	800	68	4	545	34.07	111.74	205	300	15	14.66	0	7.37	1.30
23	7.43	800	512	37	1	340	34.07	61.92	138	145	50	10.72	0	4.84	0.42
24	7.54	1400	896	84	23	420	80.16	53.36	325	165	25	68.28	0	23.15	0.55
25	7.22	1440	922	104	23	410	64.13	60.67	181	310	80	40.84	0	22.68	0.6
26	6.95	600	384	54	3	155	28.06	20.62	57	145	55	10.03	0	5.45	1.74
27	6.67	650	416	37	2	290	42.08	44.90	84	155	30	9.14	0	3.65	0.47
28	6.6	880	563	78	2	315	60.12	40.02	135	150	35	18.78	0.6	15.31	0.76
29	6.25	620	397	25	1	270	26.05	49.78	67	170	25	7.53	0	4.64	0.20
30	6.9	500	320	30	3	140	34.07	13.32	78	105	15	18.53	0	9.47	0.36
31	6.7	801	513	49	2	295	36.07	49.77	124	145	50	20.92	0	9.99	0.54
32	6.78	560	358	30	3	190	38.08	23.04	46	160	25	9.81	1.42	4.47	0.48
33	7.02	900	576	61	20	245	32.06	40.06	121	200	40	19.86	0	10.50	0.90
34	6.93	420	269	13	2	185	38.08	21.82	32	130	10	6.44	0	2.09	0.46
35	7.53	1020	653	45	1	310	36.07	53.42	107	300	0	65.15	0	7.76	1.30
36	7.54	860	550	41	2	310	32.06	55.85	82	280	0	22.07	0	6.04	1.84
37	7.44	960	614	29	2	355	34.07	65.57	74	345	0	26.38	0	4.99	1.75
38	7.87	950	608	37	2	365	86.17	36.35	106	280	0	25.30	0	1.65	1.16
39	7.58	1200	768	31	2	530	86.17	36.35	48	385	0	138.97	0	1.68	1.94
40	7.47	1090	698	56	1	370	24.05	75.30	10	350	0	120.61	0	22.92	1.17
41	7.93	590	378	67	1	145	20.04	23.06	65	135	0	24.51	0	20.23	0.89
42	7.22	610	390	1	1	265	32.06	44.92	42.6	190	0	54.05	0	1.97	0.59
43	6.96	940	601	22	0	395	22.04	82.59	174	250	0	14.25	0	4.62	0.96
44	6.98	770	493	3	1	310	28.06	58.29	111	205	0	41.37	0	19.92	1.56
45	7	1170	749	47	1	380	60.12	55.82	203	225	0	90.48	0	21.98	0.41
46	7.5	1140	730	34	3	390	42.08	69.20	172	260	0	85.80	0	21.19	0.63
47	7.03	890	570	37	3	305	36.07	52.20	145	175	55	31.82	0	2.28	0.1
48	7.62	940	602	9	1	435	100.2	44.83	71	190	0	145.49	0.35	4.84	0.51
49	7.22	1080	691	30	1	375	56.11	57.04	137	255	0	97.30	0	22.14	0.05
50	7.66	880	563	16	2	340	50.10	52.18	85	250	0	70.83	0	7.28	0.43
51	7.37	1500	960	15	2	675	106.21	99.50	419	205	0	47.78	0	20.52	0.47
52	7.09	468	300	6	0	170	34.07	20.62	38	135	0	33.02	0	14.17	0.36
53	7.21	790	506	21	2	290	46.09	42.47	82	255	0	27.62	0	3.51	0.66
54	7.65	598	383	13	1	250	48.10	31.53	60	190	0	23.34	0	4.64	0.10
55	7.61	1220	781	33	1	410	88.18	46.06	163	335	0	47.60	0	22.68	0.02
56	7.97	1100	704	33	3	380	54.11	59.47	121	365	0	47.98	0	6.27	0.63
57	7.05	710	454	14	1	305	62.12	36.37	67	190	0	39.23	0	21.78	0.36

Table cont....

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58	8.29	490	314	7	1	225	36.07	32.76	34	175	0	6.95	0	4.37	0.13
59	7.41	630	403	13	1	245	64.13	20.58	60	170	0	26.84	0	22.12	0.34
60	7.29	1430	915	44	3	485	36.07	97.76	225	390	0	55.77	0	11.06	1.42
61	7.50	1030	659	44	2	325	24.05	64.37	145	220	0	115.37	0	12.90	0.52
62	6.74	1130	723	18	2	460	40.08	87.43	275	200	0	45.79	0	12.10	0.40
63	7.15	760	486	17	0	300	10.02	66.81	96	250	0	17.10	0	1.42	0.33
64	7.50	710	454	7	1	275	70.14	24.21	63.9	245	0	16.62	0	1.51	0.10
65	6.97	1070	685	14	0	440	10.02	100.83	135	410	0	25.89	2.12	21.40	0.87
66	7.18	830	531	2	0	315	16.03	66.81	65	300	0	29.42	0	22.14	0.21
67	8.03	620	397	17	0	230	12.02	48.59	19	220	0	47.40	0	10.38	0.61
68	7.90	315	202	16	2	110	24.05	12.12	30	90	0	11.89	0	5.31	0.12
69	7.95	590	378	24	4	225	26.05	38.85	39	205	0	15.94	0	3.51	0.82
70	7.18	560	358	3	0	210	28.06	33.92	43	195	0	31.13	0	3.40	0.66
71	6.99	620	397	1	1	235	22.04	43.71	60	230	0	9.80	0	4.59	0.53
72	7.02	720	461	3	1	275	34.07	46.13	67	240	0	18.25	0	22.12	0.20
73	6.58	465	298	23	2	205	30.06	31.55	50	100	25	10.08	0	9.37	0.20
74	7.04	550	352	16	1	240	40.08	33.97	60	140	20	8.92	0	14.49	0.29
75	6.40	350	224	16	1	150	20.04	24.28	42	85	0	5.72	0	17.21	0.24
76	6.88	450	288	17	1	150	36.07	14.57	25	110	45	9.09	0	15.66	0.10
77	7.75	1100	704	42	3	375	32.06	71.65	67	365	55	16.55	0	11.68	0.44
78	7.32	410	262	19	1	175	36.07	20.61	28	100	25	9.52	0	8.14	0.28
79	7.32	520	333	13	1	200	24.05	33.99	28	170	35	6.18	0	1.71	0.22
80	7.63	1570	1005	100	3	710	30.06	154.27	312	215	20	99.72	0	22.51	1.76
81	7.37	820	525	59	3	285	44.09	42.47	142	125	5	53.08	0	22.96	0.38
82	6.99	600	384	24	2	195	40.08	23.04	46	140	25	41.57	0	22.97	0.25
83	7.90	730	467	29	4	350	36.07	63.14	98	145	30	17.17	0	18.54	0.65
84	7.45	375	240	22	3	125	42.08	4.81	25	100	20	9.45	0	1.61	0.26
85	7.60	465	298	17	1	205	32.06	30.34	21	145	25	8.00	0	1.88	0.37
86	7.40	580	371	18	2	290	34.07	49.77	96	115	15	9.29	0	10.26	0.27
87	6.95	615	394	33	1	260	26.05	47.35	46	155	30	18.7	0	14.56	0.35
88	7.53	680	435	27	1	310	38.08	52.20	87	170	20	15.56	0	2.98	0.86
89	6.77	1900	1216	52	2	775	80.36	139.51	522	185	0	159.62	0	2.38	2.30

Low amount of F^- (0.3-1.0 mg/L) prevent dental caries and osteoporosis but high intake of F^- (>1.5 mg/L) in drinking water eventually leads to fluorosis. Dental fluorosis has been noticed in the study area especially among children. The water samples falling beyond desirable limit of F^- concentrations are not suitable for drinking purpose.

Nitrate (NO_3^-), sulphate (SO_4^{2-}) and phosphate (PO_4^{3-}): According to BIS, the highest desirable limit of NO_3^- is 45 mg/L and the maximum permissible limit is 100 mg/L. NO_3^- concentrations beyond desirable limit cause methaemoglobinaemia, also called blue baby disease. The NO_3^- concentration of groundwater samples ranged from 1.42-23.15 mg/L with a mean value of 11.07 mg/L in pre-monsoon. NO_3^- values of all water samples fall within the desirable limit.

Sulphate is an important constituent of hardness. Excess sulphate has laxative effect and cause adverse effect on human health. It also imparts a particular taste to water. According to BIS, highest desirable limit of SO_4^{2-} is 200 mg/L and maximum permissible limit is 400 mg/L. SO_4^{2-} concentration beyond desirable limit causes gastrointestinal irritation when magnesium or sodium is present. The SO_4^{2-} concentration of groundwater samples ranged from 5.72-159.62 mg/L with a mean value of 35.81 mg/L in pre-monsoon. SO_4^{2-} concentrations of all water samples fall within the desirable limit.

The maximum permissible limit of BIS for PO_4^{3-} is 5 mg/L. The PO_4^{3-} concentration of groundwater samples ranged from 0-2.12 mg/L with a mean value of 0.09 mg/L in pre-monsoon. PO_4^{3-} concentrations of all water samples are within the desirable limit. The mean and range values of all the parameters are given in Table 2.

Piper diagram: The Piper trilinear diagram (Piper 1944) is the most widely used graphical representation of groundwater quality. The diagram is based on the ionic concentrations of the anions and cations, and it brings about the chemical relationships more accurately than with the other possible plotting methods. Chemical composition of the analysed samples of the study area is represented in the Piper diagram (Fig. 2) for pre monsoon. The different water types obtained from the diagram for pre-monsoon are Mg-HCO_3 (42%), Mg-Cl (28%), Ca-HCO_3 (25%), Na-HCO_3 (2%),

Table 2: Water sample chemistry in comparison with the drinking water quality standards.

Parameter		Pre-monsoon values	BIS Standard	
			Highest desirable	Maximum permissible
pH	Range	6.25-8.29	6.5-8.5	No relaxation
	Mean	7.26		
EC (µS/cm)	Range	250-2400	-	-
	Mean	823.34		
TDS (mg/L)	Range	160-1536	500	2000
	Mean	527.09		
Hardness (mg/L)	Range	65-945	300	600
	Mean	310.11		
Ca^{2+} (mg/L)	Range	10.02-106.21	75	200
	Mean	41.28		
Mg^{2+} (mg/L)	Range	3.62-189.46	30	100
	Mean	49.85		
Cl^{-} (mg/L)	Range	10-672	250	1000
	Mean	111.06		
F^{-} (mg/L)	Range	0.02-6.3	1	1.5
	Mean	0.74		
Na^{+} (mg/L)	Range	1-126		200
	Mean	32.25		
K^{+} (mg/L)	Range	0-23		40
	Mean	2.39		
NO_3^{-} (mg/L)	Range	1.42-23.15	45	100
	Mean	11.07		
SO_4^{2-} (mg/L)	Range	5.72-159.62	200	400
	Mean	35.81		
PO_4^{3-} (mg/L)	Range	0-2.12		5
	Mean	0.09		

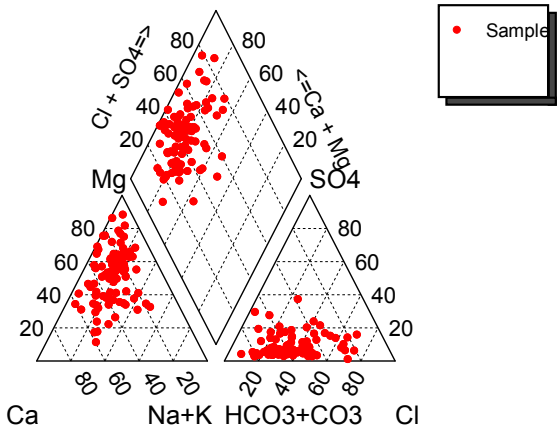

Fig. 2: Piper trilinear diagram (pre-monsoon).

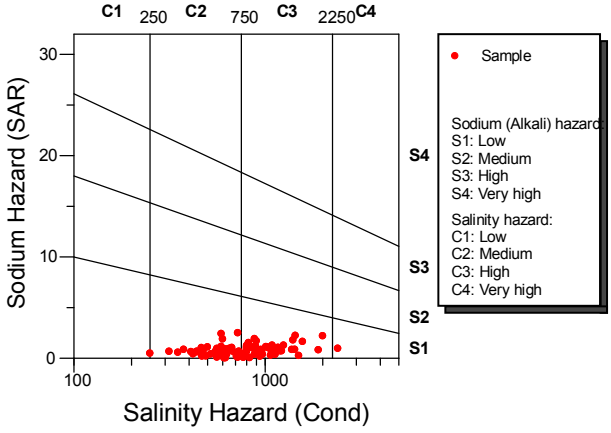

Fig. 3: USSL diagram (pre-monsoon).

Na-Cl (2%) and Ca-Cl (1%).

Evaluation of Groundwater Quality for Irrigation

Percent sodium (%Na): The irrigation water containing a high proportion of sodium will increase the exchange of sodium content of the soil, affecting the soil permeability, and the texture makes the soil hard to plough and unsuitable for seedling emergence (Trivedy & Goel 1984). Agricultural utility data chart is given in Table 3.

$$\%Na = (Na^{+} + K^{+})\ 100 / (Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}) \quad ...(1)$$

The calculated values of percent sodium of samples in pre-monsoon ranged from 1- 50. The percent sodium values show that 49% of groundwater samples are excellent (%Na = 0-20%), 37% of groundwater sample are good (%Na = 20-

Table 3: Agricultural utility chart of the groundwater.

No	SAR	RSC	%Na	No	SAR	RSC	%Na	No	SAR	RSC	%Na
1	0.84	-7.61	15.21	31	1.24	-1.91	26.83	61	1.06	-2.96	23.03
2	0.36	-1.95	8.72	32	0.94	-0.37	26.54	62	0.36	-6.01	8.24
3	1.04	0.75	25.98	33	1.69	-0.33	39.04	63	0.42	-1.97	10.86
4	0.67	-0.14	22.51	34	0.41	-1.26	14.21	64	0.18	-1.51	5.64
5	0.66	-2.15	18.46	35	1.11	-1.34	24.06	65	0.29	-2.18	6.40
6	0.72	0.22	23.52	36	1.01	-1.67	22.67	66	0.05	-1.45	1.35
7	0.57	-0.14	19.86	37	0.67	-1.51	15.47	67	0.48	-1.04	13.71
8	1.22	0.28	26.88	38	0.84	-2.75	18.45	68	0.66	-0.74	25.24
9	0.64	-3.79	14.38	39	0.70	-1.03	16.01	69	0.69	-1.18	20.16
10	0.69	-2.05	17.80	40	1.26	-1.74	24.76	70	0.09	-1.03	2.99
11	0.86	-2.42	20.84	41	2.41	-0.71	50.13	71	0.03	-0.97	1.44
12	1.03	-0.35	31.09	42	0.03	-2.23	1.27	72	0.08	-1.61	2.74
13	0.92	-0.82	33.82	43	0.48	-3.89	10.70	73	0.70	-1.66	20.28
14	0.55	-2.84	14.58	44	0.07	-2.90	2.43	74	0.45	-1.87	12.98
15	0.83	-0.92	22.42	45	1.04	-3.97	21.27	75	0.57	-1.63	19.25
16	1.15	-0.06	30.87	46	0.75	-3.61	16.50	76	0.60	0.29	20.22
17	1.06	-3.77	23.16	47	0.92	-1.45	21.50	77	0.94	0.24	20.08
18	2.19	-8.08	30.83	48	0.19	-5.63	4.55	78	0.62	-1.05	19.48
19	2.48	-1.57	46.80	49	0.67	-3.38	14.96	79	0.40	-0.08	12.77
20	0.96	-12.00	13.61	50	0.38	-2.75	9.82	80	1.62	-10.20	23.56
21	1.12	-3.16	24.16	51	0.25	-10.2	4.92	81	1.51	-3.53	31.51
22	1.26	-5.60	21.74	52	0.20	-1.21	7.08	82	0.74	-0.80	21.81
23	0.87	-2.82	19.23	53	0.53	-1.66	14.16	83	0.67	-3.69	16.18
24	1.78	-4.92	33.41	54	0.36	-1.92	10.51	84	0.85	-0.20	29.21
25	2.22	-0.51	38.22	55	0.71	-2.76	15.04	85	0.51	-0.92	15.62
26	1.88	1.09	43.72	56	0.73	-1.68	16.48	86	0.46	-3.47	12.47
27	0.94	-2.30	22.12	57	0.35	-3.02	9.37	87	0.89	-1.71	21.77
28	1.90	-2.72	35.19	58	0.2	-1.66	6.78	88	0.66	-2.80	16.09
29	0.66	-1.83	16.95	59	0.36	-2.13	10.72	89	0.81	-12.60	12.88
30	1.10	-0.59	32.93	60	0.86	-3.56	16.67				

40%) and 3% of groundwater samples are in permissible limit (%Na = 40-60%) in pre-monsoon. According to percent sodium, the groundwater samples are excellent to permissible category for irrigation.

Residual sodium carbonate (RSC): RSC has been calculated to determine the hazardous effect of carbonate and bicarbonate on the quality of water for agricultural purpose (Eaton 1950) and has been determined by the formula.

$$RSC = (CO_3^{2-}+HCO_3^{-}) - (Ca^{2+}+Mg^{2+}) \quad ...(2)$$

According to the US Department of Agriculture, water having more than 2.5 epm of RSC is not suitable for irrigation purposes while those having 1.25-2.5 epm are marginally suitable and those with less than 1.25 epm are safe for irrigation. The results show that all the groundwater samples show RSC value less than 1.25 epm and are safe for irrigation (Table 3).

Sodium adsorption ratio (SAR): SAR is important parameter for determining the suitability of groundwater for irrigation because it is a measure of sodium hazard to crops. SAR can be estimated by the formula (Karanth 1987):

$$SAR = (Na^{+}) / \sqrt{\{(Ca^{2+}) + (Mg^{2+})\}} /2 \quad ...(3)$$

SAR values ranged from 0.02 to 2.48 (Table 3) with an average value of 0.81. All the groundwater samples fall in the excellent category because none of the samples exceeded the value of SAR = 10.

Suitability of water for irrigation through U.S.S.L. diagram: The classification of irrigation proposed by the US Salinity Laboratory (1954), based on the salinity and sodium hazards is much in vogue. Salinity hazard is a measure of electrical conductivity while sodium hazard is in terms of sodium adsorption ratio (SAR). US Salinity Laboratory diagram based on the present data is shown in Fig. 3. US salinity hazard (USSL 1954) reveals that for water samples in the Chittur Block, 47% samples fall under C2S1 (medium salinity hazard and low sodium hazard) class, 52% samples fall under C3S1 (high salinity hazard and low sodium hazard) class and 1% samples in C4S1 (very high salinity hazard and low sodium hazard) class. Groundwater that is present in medium salinity class (C2) can be used in most cases without any special salinity control. The groundwater observed from high salinity water (C3) is con-

sidered to be of moderate quality to irrigate semi-tolerant crops. However, water samples that fall in very high salinity water (C4) are not suitable for irrigation under ordinary condition, but may be used for salt tolerant plants on permeable soil with special management practices (Khodapanah et al. 2009).

CONCLUSION

The study shows that EC, TDS, TH, Mg^{2+} and F^- values are high whereas Na^+, K^+, NO_3^-, SO_4^{2-} and PO_4^{3-} values are within the desirable limit. EC ranges from 250-2400 µS/cm. TDS ranges from 160-1536 mg/L with 46% of samples exceed desirable limit. TH ranges from 65-945 mg/L in pre-monsoon, in which 39% of the samples exceed desirable limit, and 6% samples beyond permissible limit. The Mg^{2+} concentration ranges from 3.62-189.46 mg/L in pre-monsoon, in which 69% of samples exceed desirable limit, and 7% samples beyond permissible limit. The F^- concentration ranges from 0.02-6.3 mg/L, in which 12% samples are in beyond permissible limit. Dental fluorosis is noticed in the study area especially among children. The water samples beyond the acceptable limit of EC, TDS, TH, Mg^{2+} and F^- are not suitable for drinking purpose.

Percent sodium values of water samples in pre-monsoon are range from 1-50. The percent sodium values show that 49% of the samples are excellent (%Na = 0-20%), 37% are good (%Na = 20-40%) and 3% are in permissible limit (%Na = 40-60%) in pre-monsoon. Percent sodium values indicate that groundwater samples are excellent to permissible category for irrigation. RSC values show that all are less than 1.25 epm, and safe for irrigation. SAR values range from 0.02 to 2.48 with an average value of 0.81. All the ground water samples fall in the excellent category because none of the samples exceeded SAR value of 10. From USSL diagram, the groundwater samples falling under high salinity water (C3) are considered to be moderate quality while water samples falling in very high salinity water (C4) are not suitable for irrigation.

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