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QUALITY OF GROUNDWATER IN SELECTED AREAS OF SANDUR TALUK IN KARNATAKA STATE, INDIA

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ABSTRACT
Hydrogeochemical investigations were carried out in Sandur taluk, a major mining taluk of Bellary district in Karnataka. Water samples of 43 bore wells at various locations were collected and analysed for its suitability for domestic and irrigation purposes. Most of the physico-chemical parameters were within the permissible limits of WHO and ISI standards for drinking water. However, some samples show very high NO_3, Cl and F content than the desirable limit. The data was also subjected to various hydrochemical interpretations. According to USSL classification, the groundwater of the study area falls under mostly three types as C_2 S_1, C_2 S_2 and C_3 S_1. In eight locations it was found to be of C_3 S_2 type with moderately high salinity. The value of SAR was in the range of excellent to good type. Based on the Piper trilinear diagram, the study area was characterized by water having temporary hardness. Fluoride was most dominant ion responsible for the contamination of the groundwater. Ten samples of the study area were prone to excess fluoride and not suitable for drinking. Water samples were also subjected to microbiological analysis. Few samples were found to be highly contaminated with coliforms while most of the samples were suitable for human consumption.
Keywords: Corrosivity ratio; Piper trilinear diagram; USSL; SAR; Fluorosis.

INTRODUCTION
Groundwater is the principle source of drinking water in rural areas of Karnataka state. Groundwater is generally considered to be cleaner than surface waters. Nevertheless, several factors, like agricultural and domestic waste, land use practices, geological formation, infiltration rate etc., are found to affect the quality of groundwater. Study of groundwater classification of bore wells of Mysore city based on salinity and sodium adsorption ratio was reported by Meenakumari et al.[1] Harish Babu et al.[2] have made an attempt to study the status of drinking water quality of Tarikere taluk in Karnataka with special reference to fluoride concentration. From the survey of literature it is found that only few reports are made on physico-chemical characteristics of groundwaters for drinking and irrigation in Karnataka. Therefore, in this report we have made a sincere effort to evaluate systematically the environmental quality of groundwaters of Sandur taluk in Karnataka. Sandur taluk is one of the major mining talukas of Bellary district. It lies between $14^0\ 53^1$ to $15^0\ 18^{\ 1}$ N latitude and $76^0\ 24^1$ to $76^0\ 48^1$ E longitude. It covers an area about 1258 sq.km. The average annual maximum temperature is 41^0C and minimum is 23^0C.The study area is covered by Archean granite and peninsular gneiss. The major portion of the taluk comprises of phyllitic rocks which associated with iron and manganese ore bands. They almost standout in the form of serial hillocks and are being commercially exploited. The rock formations are joined and are traversed by doleritic Dykes. Weathering in hard rocks is limited to 5 meters from ground level where as phyllite extends upto 20 meters. Secondary porosity weathered zone, joints fresh hard rock, provide room for groundwater storage.

EXPERIMENTAL
The present study provides a detailed description of the chemical criteria of groundwater. Forty three representative samples of entire study area were collected during post monsoon, 2007 and analyzed for calcium, magnesium, sodium, potassium, iron, zinc, manganese, chloride, carbonate, bicarbonate,

fluoride, sulphate, nitrate, total hardness (TH), total alkalinity (TA), total dissolved solids (TDS), pH, electrical conductance (EC), turbidity and coliform bacteria. Further the sodium adsorption ratio (SAR), corrosivity ratio (CR), percent sodium and magnesium ratio were calculated. The techniques and methods followed for collection, preservation, analysis and interpretation are those given by Rainwater and Thatcher[3] (Table 1).

RESULTS AND DISCUSSION

Hydrogeochemistry

The results obtained from the analysis of water samples from different villages of Sandur taluk are shown in Table 1. Standard methods[4] have been employed in the analysis of the water samples. A comparison of the physico-chemical groundwater samples has been made with WHO[5], and ISI[6] drinking water standards.

pH: The pH values of groundwater samples of the study area range from 7.2-8.2 indicating slightly alkaline nature. The analysed groundwater samples are within the permissible limits of ISI[6] and WHO[5] (6.5-8.5).

Electrical Conductance (EC): A high concentration of salts in irrigation water renders the soil saline. Electrical conductance of the water samples ranged from 390 to 1600 µmhos/cm. This is within the permissible limit for all the water samples as per WHO standards.

Total Dissolved Solids (TDS): The total dissolved solids range from 280 to 820 mg/L. According to WHO specification, TDS up to 500 mg/L is highest desirable and up to 1000 mg/L is maximum permissible category, thus 51% of samples belong to maximum permissible category, and remaining 49% of samples belong to below the WHO specification.

Total Hardness: Total hardness is due to the presence of divalent cations of which Ca and Mg are the most abundant in groundwater. In the present study, the total hardness of water samples ranged from 210 to 650 mg/L. This indicates that, out of 43 samples, only 17 samples have total hardness content within ISI permissible limit (300 mg/L) while 24 samples have excessive limit (600 mg/L) and only 2 samples fall into the very hard category. The total hardness values obtained, very well correlate with TDS.

Total Alkalinity (TA): Most of the groundwaters contain substantial amounts of dissolved carbon dioxide, bicarbonates and hydroxides. These constituents are the results of dissolution of minerals in the soil and atmosphere. In the present study, alkalinity ranges between 270 to 442 mg/L. The high amount of alkalinity in the study area samples may be due to the presence of country rocks.

Chloride (Cl): The chloride content in the study area ranged between 6.5 and 268.0 mg/L. The WHO and ISI permissible limit of chloride for drinking water is 200 and 250 mg/L respectively. The chloride value of the water samples studied is well within the permissible limit of WHO and ISI for 39 samples and only two samples have high value. It may be attributed to the seepage of domestic effluents.

Fluoride (F): High concentration of fluoride, often significantly above 1.5 mg/L constitute a severe problem in large parts of the concentration of fluoride in the study area varies from 0.35 to 2.73 mg/L. The fluoride value of the water samples studied is well within the permissible limit of ISI for 33 samples, where as 10 samples have high value of fluoride (>1.2 mg/L) and not safe for drinking purpose.

Nitrate (NO_3): The WHO health-based guideline value for nitrate in drinking water is 45 mg/L. The concentration of nitrate in the present water samples varies from 14.0 to 96.0 mg/L. In the present study, out of 43 samples collected, 26 samples are well within the permissible limit of ISI and 17 samples have excessive limit.

Iron: In the present study, the iron varied from 0.09 to 1.40 mg/L. The permissible limit for iron is 0.3 to 1.0 mg/L. The concentration of iron in only 2 water samples is high whereas in the remaining samples of the study areas are well within the permissible limit.

Zinc: The concentration of zinc in water samples varied from 0.25 to 1.08 mg/L. The permissible limit of zinc is 5 mg/L. These results are well below the permissible limit.

Manganese: The manganese ranged from 0.02 to 0.60 mg/L. The permissible limit for manganese is 0.4 mg/L. The results indicated that all the samples of the study area are well within the permissible limit except Sample No.42.

Irrigational Quality of Water

To understand the suitability of water for irrigational purpose, certain ratios are of fundamental importance and are described below:

Kelley's Ratio

It has been calculated for all the 43 groundwaters of the study area and presented in Table 2. The Kelley's ratio varies from 0.16 to 1.12 epm. The ratio is less than unity in 42 samples indicating their suitable nature for irrigational uses. Sample No.23 having 1.12 epm is in marginal range for irrigation purpose.

Sodium Adsorption Ratio (SAR)

Excessive sodium in waters produces the undesirable effects of changing soil properties and reducing soil permeability[7]. Hence, the assessment of sodium concentration is necessary while considering the suitability for irrigation. SAR is an important parameter for the determination of the suitability of irrigation water because it is responsible for the sodium hazard[8].The waters were classified in relation to irrigation based on the ranges of SAR values[9]. Based on this classification, all the 43 samples of the study area fall under no problem category and are suitable for irrigation (Table 3). SAR values of the water samples vary from 3.80 to 14.30 epm (Table 2).

Soluble Sodium Percentage (SSP)

Wilcox[10] has recommended another classification for rating irrigation water on the basis of soluble sodium percentage (SSP). The values of SSP have been determined for all the water samples and presented in Table 2. The ratio of SSP values are in the range of 15.4 to 53.6 epm. In the present study, 4 samples are 'excellent', 27 samples are fall into 'good' category and remaining 12 samples fall into 'permissible' category.

Magnesium Hazards

Generally, calcium and magnesium maintain a state of equilibrium in most waters. In equilibrium more magnesium in waters will adversely affect crop yields. As the rock of the study area consists of Archean granite, schist's and peninsular gneisses, it is observed that most waters contain less Mg than Ca. In the present study all the samples contain Mg ratio less than 30 except Sample No. 19. This would not affect the crop yield. In the present study, the 'Magnesium Ratio' values vary from 5.10 to 31.12 epm (Table 2).

Corrosivity Ratio (CR)

Corrosion is an electrolytic process that takes place on the surface of the metal, which severely attacks and corrodes away the metal surfaces. Most of the problems are associated with salinity and encrustation problems. Water samples having corrosivity ratio of less than 1 are considered to be non-corrosive, while the value above 1 is corrosive. In the present study, 07 samples are considered as corrosive, while remaining 36 samples have CR values of less than 1 (Table 2).

Graphical Methods of Representing Analysis

Piper Trilinear Diagram

Piper diagram Collins[11] first proposed a graphical method of representation of chemical analysis. The method was later modified by Piper[12,13], based on the concentration of dominant cations and anions, and trilinear diagram was proposed to show the percentages at milli equivalents per liter of cations and anions in water samples. The trilinear diagram of Piper is very useful in bringing out chemical relationships among groundwaters in more definite terms (Walton, 1970). This is useful to understand the total chemical character of water samples in terms of cation-anion pairs. The piper diagram (Figure 1) consisting of 2 triangular and 1 intervening diamond-shaped fields. All 3 sides of the 2 triangular fields and the 4 sides of the diamond – shaped field are divided into 100 parts. The percentage reacting values at the 3 cation groups – Ca, Mg and (Na + K) – are plotted as a single point in the left triangular field and the 3 anion groups– (HCO_3+CO_3), SO_4 and Cl – similarly on the right triangular field. The 2 points in each triangular field show the relative concentration of several dissolved constituents of the water sample. Later a third point is plotted in the central diamond – shaped field after computing percentage reacting values for anions and cations separately. This field shows the complete chemical character of the water samples that gives the relative composition of groundwater about the cation–anion point. These 3 fields reflect the chemical character of groundwater according to the relative concentration of its constituent but not according to the absolute concentrations. In the present study, it is noted that all the samples of study area fall under area-1, only one sample (Sample No. 23) fall under area-2; 42 samples fall under area-3; 02 samples fall under area-4 ; 40 samples fall under area-5 ; 3 samples from the study area fall under area-9 ; and no samples fall under area-6,7 and 8. Few water samples of study area (6 samples) exhibit higher amount of Ca ion among the cations and bicarbonates among anions. This may be due to the dissolution of carbonates of Ca. Groundwaters of the study area are characterized by temporary hardness. Concentration of Ca in ground water samples of study area ranges from 42.1 to 299.8 mg/L.

US Salinity Laboratory (USSL) Diagram

According to a method formulated by the US Salinity Laboratory[9] , water used for irrigation can be rated based on salinity hazards and sodium or alkali hazard. Low salinity water can be used for irrigation of most crops on most soils with little likelihood that salinity will develop. According to USSL classification (Table 2), 43 samples of groundwaters of the study area, 10 samples fall into C_2S_1 (medium salinity with low sodium), 9 samples fall into C_2S_2 (medium salinity with medium sodium), 16 samples fall into C_3S_1 (high salinity with low sodium) and remaining 8 samples fall into C_3S_2 (with moderately high salinity). The waters are satisfactory for irrigational use in almost all soil types. All these waters being used for irrigation, as they facilitate good soil drainage.

Percent Sodium

Sodium concentration is important in classifying the irrigation water because sodium reacts with soil to reduce its permeability. Soils containing a large proportion of sodium with carbonate as the predominant anion are termed alkali soils; those with chloride or sulphate as the predominant anion are saline soils. The role of sodium in the classification of groundwater for irrigation was emphasized because of the fact that sodium reacts with soil and as a result clogging of particles takes place, thereby reducing the permeability[8]. Percent sodium in water is a parameter computed to evaluate the suitability for irrigation[14]. The percent sodium values of the study area samples vary from 15.30 to 52.51. It is clear from the investigation, 19 samples fall into the category of 'excellent to good', while 24 samples fall into the category of 'good to permissible'.

Coliforms

The bacteriological content is one of the most important aspects in drinking water quality. The most common and widespread health risk associated with drinking water is the bacterial contamination caused either directly or indirectly by human or animal excretia. *E.coli* a typical fecal coliform is selected as an indicator of fecal contamination. In the present study only four samples of dug wells are found to have high coliform contamination. The permissible limit of bacterial coliforms is 4/100ml as per WHO. Therefore these four samples (Sample No. 25, 29, 30 and 32) were not suitable for human consumption.

CONCLUSION

The groundwater quality of Sandur taluk in Karnataka state shows that only 77% of water samples have physico-chemical properties well within the permissible limits. The six water samples in the study area show enrichment of calcium among cations and of carbonate and bicarbonate among anions. Geochemically the behaviuor of magnesium is different from that of calcium. Magnesium ion is smaller than Na or Ca ion and therefore has a stronger charge density and greater attraction for water molecules. This enrichment is due to the dissolution of mineral dolomite [(Mg,Ca) CO_3]. The concentration of magnesium in water samples of the study area ranges from 14 to 82 mg/L. The desirable range for drinking is 30 to 100mg/L (ISI 1991). Water samples of the study area is characterized by secondary alkalinity (carbonate hardness exceeds 50%).Based on concentration of TDS, all the samples are within the permissible limit both for drinking and irrigation. According to USSL, study area of groundwater samples fall under mainly three types i.e., $C_2 S_1$, $C_2 S_2$ and $C_3 S_1$. In 8 samples it is found to be $C_3 S_2$ type with moderately high salinity. Most of the water samples are satisfactory for irrigation use in almost all soil types. The value of SAR in the study area was in excellent to good type. Out of 43 samples, 7 samples were showing corrosivity ratio higher than 1. Therefore these samples were corrosive. According to Piper's diagram, the study area is characterized by water having temporary hardness. The salinity and sodium hazards have also been evaluated by using Kelley's ratio. The ratio is less than unity in 42 samples out of 43 water samples, indicates their suitability for irrigational uses. In the study area, all the samples have less than 30% magnesium hazards indicating their suitability for irrigation purpose. The fluoride level of water samples was found to have higher values in 10 samples as prescribed permissible limit (1.2 mg/L) by WHO and may not be safe for drinking purpose. The presence of E.coli in four samples of groundwater indicates potentially dangerous situation, and require immediate attention. The results also suggested that the contamination problem in 23% of water samples is alarming. Thus, proper remedial measures such as periodical quality monitoring of water and appropriate water treatment would be beneficial to avoid water pollution in the study area.

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Table-1: Result analysis of the samples collected in the study area, Sandur Taluk Karnataka

Sample No.	Turbidity (NTU)	pH	EC (μ mhos/cm)	TH (mg/L)	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Na^{+} (mg/L)	K^{+} (mg/L)	Cl^{-} (mg/L)	CO_3^{2-} (mg/L)	HCO_3^{-} (mg/L)	F^{-} (mg/L)	SO_4^{-2} mg/L)	TA (mg/L)	TDS (mg/L)	Fe^{2+} (mg/L)	NO_3^{-} (mg/L)	Zn^{2+} (mg/L)	Mn^{2+} (mg/L)	Bacteria (MPN/100ml)
1	2.0	7.4	970	523	160.5	22.0	42.0	4.1	90.0	0.0	168	1.82	70.0	388	610	0.09	67.0	0.66	0.03	-
2	1.0	7.7	990	343	102.6	16.0	58.0	3.2	210.0	9.0	238	1.91	21.0	379	680	0.09	69.0	0.50	0.09	-
3	1.0	7.8	880	352	136.3	24.0	39.0	2.0	60.5	0.0	270	1.67	14.0	402	535	0.09	86.0	0.64	0.04	-
4	2.0	7.8	1000	255	83.7	27.0	76.0	1.8	82.5	10.0	202	2.73	12.0	399	705	0.00	85.0	0.78	0.04	-
5	1.0	7.6	700	365	114.2	29.0	78.0	9.8	81.5	21.0	210	1.71	30.0	382	660	0.18	42.0	0.25	0.06	-
6	1.0	7.5	480	255	68.1	14.0	59.0	3.6	15.5	13.0	200	2.61	10.0	426	380	0.00	28.2	0.96	0.03	-
7	1.0	7.2	480	232	72.1	22.0	62.0	2.0	21.0	0.0	134	2.60	12.0	431	360	0.00	37.0	0.69	0.02	2
8	1.0	7.8	970	330	109.0	42.0	124.0	1.8	98.0	0.0	268	0.74	25.0	384	640	0.00	63.0	0.73	0.05	-
9	1.0	7.6	1100	475	191.2	40.0	58.0	2.6	75.0	0.0	234	1.20	30.3	346	672	0.27	85.0	0.87	0.44	-
10	1.0	7.6	800	225	80.6	26.0	84.0	8.2	76.9	10.0	189	1.18	45.0	332	336	0.09	85.0	0.79	0.04	-
11	1.0	7.6	430	255	77.0	27.0	48.0	2.8	37.5	0.0	160	1.19	12.0	435	315	0.27	71.0	0.90	0.04	-
12	1.0	7.8	975	323	134.7	24.0	42.0	1.0	168.0	0.0	228	1.20	43.0	372	680	0.46	71.0	0.54	0.07	-
13	1.0	7.8	1050	544	213.0	18.0	59.0	2.4	64.0	0.0	230	0.35	30.0	310	740	0.09	91.0	1.09	0.08	-
14	1.0	7.5	805	285	299.8	20.0	58.0	1.2	268.0	6.0	196	1.11	10.0	412	440	0.00	87.0	0.60	0.05	-
15	1.0	7.8	1040	610	227.3	38.0	96.0	2.2	162.5	10.0	246	0.70	49.0	371	740	0.00	81.0	0.55	0.06	-
16	1.0	7.2	630	250	87.8	32.0	60.0	1.8	31.0	5.0	156	1.04	29.0	442	380	0.00	46.0	0.69	0.08	-
17	1.0	7.6	660	335	132.0	46.0	108.0	9.6	16.5	9.0	230	0.50	28.0	328	480	0.00	27.0	0.97	0.05	-
18	2.0	7.8	690	440	47.3	19.0	48.0	3.2	19.5	0.0	286	1.16	24.0	351	410	0.00	45.0	0.76	0.04	-
19	2.0	7.3	530	210	42.1	68.0	96.0	12.4	14.5	0.0	138	1.15	29.0	349	340	1.40	55.0	0.64	0.05	-
20	2.0	7.4	390	230	96.0	32.0	104.0	3.4	13.5	0.0	180	1.12	22.0	362	280	0.18	40.0	0.75	0.04	-
21	2.0	7.2	480	228	78.2	24.0	68.0	3.1	11.5	0.0	110	1.19	13.0	375	410	0.18	14.0	0.53	0.02	1
22	1.0	7.1	875	478	232.0	16.0	42.0	3.0	52.0	11.0	206	0.60	65.0	331	630	0.09	50.0	0.77	0.04	-
23	3.0	8.0	735	460	53.0	32.0	96.0	1.8	55.0	0.0	308	1.02	62.0	318	620	0.36	84.9	0.56	0.03	-
24	1.0	7.9	1086	280	204.4	48.0	106.0	2.8	162.0	10.0	300	1.20	41.0	378	410	0.00	96.0	0.48	0.04	-
25	2.0	7.9	1070	472	176.0	51.0	92.0	3.4	62.0	10.0	283	0.92	90.0	319	720	0.00	42.0	0.50	0.04	55

Table -1 continued

Sample No.	Turbidity (NTU)	pH	EC (µ mhos/cm)	TH (mg/L)	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Na (mg/L)	K^+ (mg/L)	Cl^- (mg/L)	CO_3^{2-} (mg/L)	HCO_3^- (mg/L)	F^- (mg/L)	SO_4^{2-} (mg/L)	TA (mg/L)	TDS (mg/L)	Fe^{2+} (mg/L)	NO_3^- (mg/L)	Zn^{2+} (mg/L)	Mn^{2+} (mg/L)	Bacteria (MPN/100ml)
26	1.0	7.4	1500	235	112.4	82.0	108.0	8.2	206.0	0.0	142	1.48	50.0	351	480	0.00	18.0	0.77	0.04	-
27	1.0	7.9	1600	545	256.5	43.0	84.0	8.1	80.0	11.0	306	0.82	58.0	340	820	1.13	47.0	0.68	0.05	-
28	1.0	7.4	1550	373	136.3	29.0	71.0	2.3	168.5	0.0	260	1.13	70.0	382	780	0.00	36.0	0.76	0.04	-
29	1.0	8.0	1040	548	174.3	62.0	84.0	4.2	241.0	10.0	326	1.14	61.0	410	730	0.00	28.0	0.82	0.06	66
30	1.0	7.9	1100	650	116.2	68.0	77.0	1.4	150.0	0.0	296	1.18	54.0	438	820	0.00	20.0	0.79	0.07	59
31	2.0	7.2	520	243	78.2	41.0	86.0	2.0	6.5	10.0	168	1.19	6.0	412	310	0.09	19.0	0.58	0.07	-
32	1.0	7.3	600	245	79.4	18.0	62.0	0.3	13.0	16.0	182	1.06	16.0	342	360	0.19	33.0	1.02	0.06	32
33	1.0	7.6	485	282	113.4	26.0	64.0	2.0	13.0	0.0	190	0.79	29.0	372	315	0.36	56.0	0.76	0.03	-
34	1.0	7.4	440	210	118.2	32.0	106.0	0.8	27.0	0.0	110	0.94	12.0	336	318	0.00	31.0	0.68	0.05	-
35	1.0	7.5	510	226	89.0	20.0	54.0	2.0	60.0	0.0	176	2.36	10.0	341	280	0.00	64.0	0.96	0.03	-
36	2.0	7.7	660	340	111.4	19.0	63.0	3.2	41.0	10.0	228	1.17	30.0	386	450	0.36	46.0	0.54	0.42	-
37	1.0	7.6	820	418	216.2	16.0	74.0	7.0	183.5	10.0	218	1.08	25.0	370	540	0.00	33.0	0.82	0.05	-
38	1.0	7.6	555	305	97.8	20.0	48.0	1.0	13.5	0.0	172	1.89	6.0	410	340	0.00	18.0	0.59	0.06	2
39	1.0	7.8	1100	376	180.0	36.0	53.0	2.2	62.5	6.0	220	1.02	32.0	431	660	0.09	45.0	0.65	0.02	-
40	1.0	7.3	1080	408	128.3	42.0	98.0	7.6	83.5	10.0	126	1.04	12.0	381	740	0.18	39.0	0.78	0.03	-
41	1.0	8.0	1400	544	172.3	76.0	108.0	0.8	141.0	0.0	334	0.80	54.0	358	800	0.00	35.0	0.55	0.04	-
42	1.0	7.3	660	268	93.0	62.0	85.0	1.2	18.0	0.0	110	1.69	10.2	391	320	0.09	27.0	0.75	0.62	-
43	2.0	7.6	970	385	100.2	24.0	38.0	1.0	63.5	8.0	206	1.10	30.2	270	420	0.09	27.0	0.83	0.04	-
Min.	1.0	7.1	390	210	42.1	14.0	38.0	0.3	6.5	0.0	110.0	0.35	6.0	270	280	0.00	14.0	0.25	0.02	1.0
Max.	3.0	8.0	1600	650	299.8	82.0	124.0	12.4	268.0	21.0	334.0	2.73	90.0	442	820	1.40	96.0	1.09	0.62	66.0
SD	0.5	0.3	314	122	60.0	17.5	23.0	2.9	70.0	5.7	60.7	0.54	20.9	39	177	0.33	23.9	0.17	0.12	29.3

Table-2: Irrigational specification values of groundwater samples of Sandur taluk

S No.	Sample Location	SAR	Mg Hazards	Kelley's Ratio	SSP	Percent Sodium	CR	USSL Salinity
1	Sandur I	4.4	9.6	0.2	21.0	18.3	1.18	C_3S_1
2	Sandur II	7.5	8.9	0.5	34.0	32.2	1.20	C_3S_1
3	Lakshmipura	4.3	11.9	0.3	20.4	19.4	0.36	C_3S_1
4	Krishnanagar	10.2	14.3	0.7	41.3	40.3	0.60	C_3S_2
5	Bujanganagar	9.2	12.5	0.5	38.0	33.8	0.63	C_2S_2
6	Tharanagar	9.2	9.7	0.7	42.6	40.8	0.15	C_2S_1
7	Sushilanagar	9.0	14.0	0.7	40.5	39.2	0.31	C_2S_1
8	Thallur	14.3	15.1	0.8	45.4	44.8	0.61	C_3S_2
9	Oddu	5.4	13.7	0.3	20.8	19.9	0.59	C_3S_1
10	Toranagallu	11.5	13.0	0.8	46.4	42.3	0.63	C_3S_2
11	Dharoji	6.7	17.4	0.5	32.8	31.0	0.40	C_2S_1
12	Jaihindnagar	4.7	11.9	0.3	21.3	20.8	1.23	C_3S_1
13	Mallapura	5.8	6.2	0.3	21.0	20.2	0.52	C_3S_1
14	Vidugatti	4.6	5.3	0.2	15.6	15.3	1.87	C_3S_1
15	Bandri	8.3	10.5	0.4	27.0	26.4	1.11	C_3S_2
16	Chikkakariyanahalli	7.8	17.6	0.5	34.0	33.0	0.45	C_2S_1
17	Hirekariyanahalli	11.5	15.6	0.6	39.8	36.5	0.22	C_2S_2
18	Kalingeri	8.3	16.2	0.7	43.6	40.9	0.18	C_2S_1
19	Sovenahalli	13.0	31.1	0.9	49.6	43.9	0.35	C_2S_2
20	Hagrahara	13.0	13.6	0.8	45.6	44.2	0.23	C_2S_2
21	Choranur	9.5	13.8	0.7	41.0	39.2	0.26	C_2S_2

Table- 2: continued

S No.	Sample Location	SAR	Mg Hazards	Kelley's Ratio	SSP	Percent Sodium	CR	USSL Salinity
22	Bommagatta	3.8	5.5	0.2	15.4	14.3	0.65	C_3S_1
23	Teliyappanahalli	14.7	17.5	1.1	53.6	52.2	0.45	C_2S_2
24	Jagenahalli	4.5	15.6	0.2	17.6	16.7	0.94	C_3S_1
25	Swamyhalli	8.7	15.8	0.4	29.6	28.5	0.62	C_3S_2
26	Thonasigeri	10.9	26.4	0.6	37.4	34.8	2.40	C_3S_2
27	Narayanapura	13.7	10.9	0.3	23.5	21.5	0.54	C_3S_2
28	Devigeri	7.8	12.2	0.4	30.7	29.8	1.19	C_3S_2
29	Karthikeshwara	7.7	19.1	0.4	27.2	25.9	1.19	C_3S_1
30	Rajapura	8.0	25.9	0.4	29.9	29.3	0.90	C_3S_1
31	Hubbalagundi	11.1	19.7	0.7	42.5	41.5	0.08	C_2S_2
32	Mailapuram	8.9	11.3	0.6	39.0	38.8	0.16	C_2S_1
33	Donimalai	7.7	12.7	0.5	32.1	31.2	0.25	C_2S_1
34	Linganahalli	13.2	10.1	0.7	41.6	41.2	0.45	C_2S_2
35	Anthapura	7.3	12.1	0.5	34.0	32.7	0.54	C_2S_1
36	Chikkanthapura	7.8	9.7	0.5	33.7	32.0	0.37	C_2S_1
37	Thumati	6.9	8.1	0.3	28.9	23.6	1.24	C_3S_1
38	Vitlapura	6.3	12.0	0.4	15.6	28.8	0.14	C_2S_1
39	Mettriki	4.9	13.3	0.2	20.4	19.5	0.53	C_3S_1
40	Gundahalli	10.6	15.2	0.6	38.4	35.5	0.90	C_3S_2
41	Lakkalahalli	9.7	21.3	0.4	30.5	30.2	0.76	C_3S_2
42	Gollalingamanahalli	9.7	25.7	0.6	35.7	35.2	0.32	C_2S_2
43	Yerrammanahalli	4.8	14.7	0.3	23.9	23.2	0.56	C_3S_1

Table-3: Frequency distribution of SAR, SSP, Mg Hazards, Kelley's Ratio and USSL Classification

S.No.	Water Quality Parameters	Range	Water Classes	No. of Samples
1	SAR	< 10	Excellent	31
		10 - 18	Good	12
		18 - 26	Fair	--
		> 26	Poor	--
2	SSP	< 20	Excellent	4
		20 - 40	Good	27
		40 - 60	Permissible	12
		60 - 80	Doubtful	--
		> 80	Unsuitable	--
3	Mg Hazards	< 50 %	Suitable	43
		50 - 65	Marginal	--
		> 65	Unsuitable	--
4	Kelley's Ratio	< 1	Suitable	42
		1 - 2	Marginal	1
		> 2	Unsuitable	--
5	USSL Diagram	C_2S_1	Good	10
		C_2S_2	Moderate	9
		C_3S_1	Good	14
		C_3S_2	Moderate	10

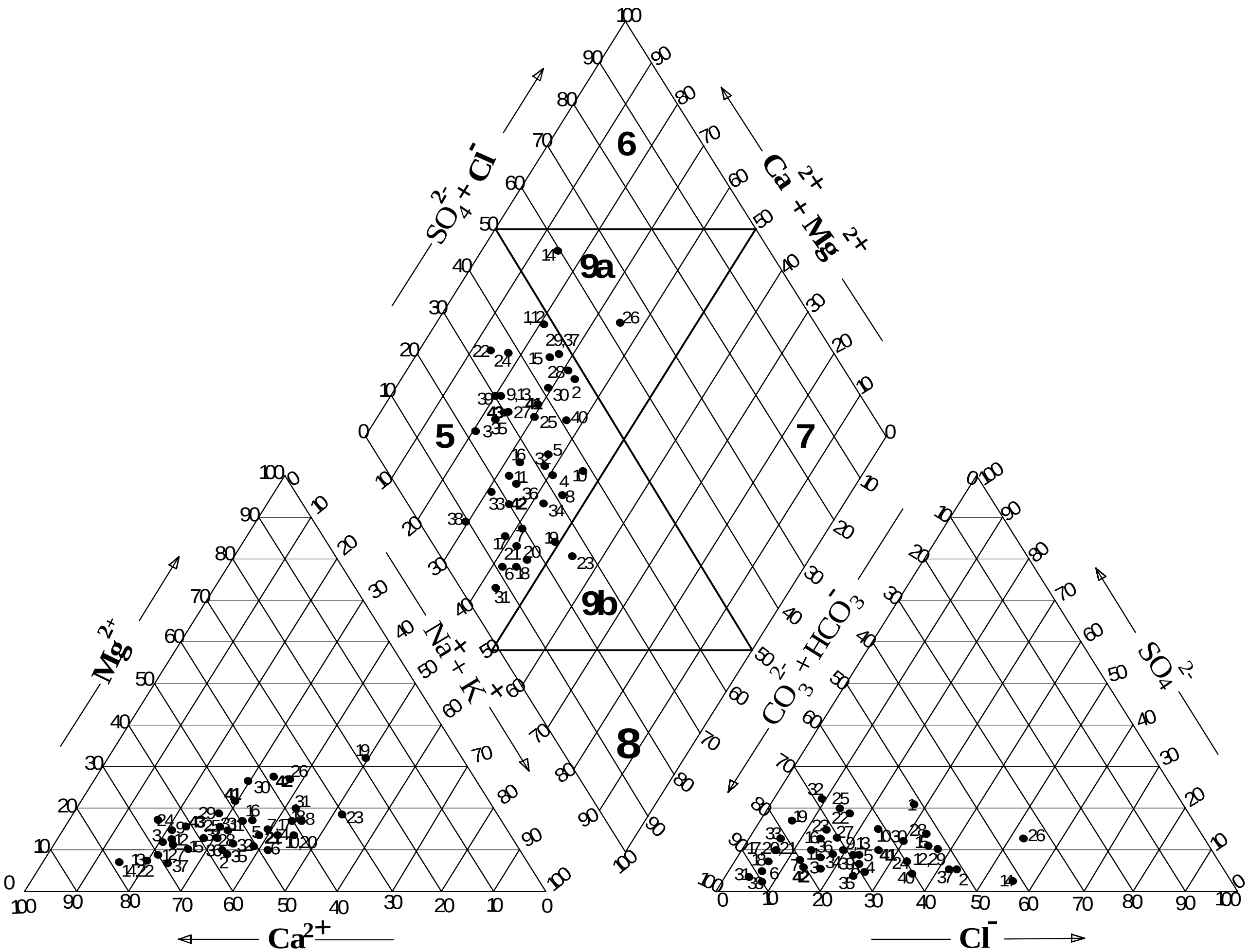

Figure 1. Piper trilinear diagram of borewell samples of Sandur taluk