academicJournals

Vol. 5(7), pp. 418-425, July 2013
DOI: 10.5897/IJWREE2012.0375
ISSN 2141-6613 © 2013 Academic Journals
http://www.academicjournals.org/IJWREE

International Journal of Water Resources and Environmental Engineering

Full Length Research Paper

Assessment of groundwater quality for irrigation of Bhaskar Rao Kunta watershed, Nalgonda District, India

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Accepted 24 May, 2013

Semi-arid region of Bhaskar Rao Kunta watershed groundwater quality was evaluated for suitability irrigation; in this situation twenty groundwater samples were collected at identical locations from deeper bore wells. The American Public Health Association (APHA) standard methods were followed and the concentrations of physicochemical parameters of pH, electrical conductivity (EC), total hardness (TH), Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^-, SO_4^{2-}, Cl^- and NO_3^- analyzed. The results of the concentrations were interpreted and measured with different irrigation indexes like EC, sodium percent (SP), sodium adsorption ratio (SAR), residual sodium carbonate (RSC), permeability index (PI) and Kelly's ratio (KR). The interpreted results were indicated that the groundwater quality stands on EC values; 20 and 80% of the samples fall under medium to high salinity category in pre and post-monsoon seasons and stands on sodium percent (SP) values, 25 and 75% of the samples fall under excellent to good category in both seasons. The remaining indexes SAR, RSC and KR values stands on 100% of the samples and fall under the excellent and excellent to good category in both seasons. Hence, the indexes results were concluded that the quality of groundwater in general was suitable for irrigation.

Key words: Water quality, irrigation, quality indexes.

INTRODUCTION

The ground water quality study reveals that the water is suitable for drinking, agricultural and industrial purposes. Particular in arid and semi-arid areas their natural ground water resources were used as poor quality of water for irrigation. In this context irrigation water quality is important for successful crop production. The poor quality of the irrigation water may affect crop yields and soil physical conditions (Talukder et al., 1998). For example, the average yield of wheat decreased by 24% (Datta et al., 2000), rice decreased by 39% (Bai, 1988), vegetables decreased by 30% (Chang et al., 2001), and corn decreased by 21% (Lindhjem, 2007) over normal yield when poor quality water was used. The major irrigation water is judged by four important measures of salinity hazard, sodium hazard, toxicity hazard and residual sodium carbonate hazard (Michael, 1978).

In India unfortunately, salinity hazards is extensive irrigation regions problem. In addition, different crops require different irrigation water qualities. Therefore, testing the irrigation water is prior to contribute to effective management and utilization of the groundwater resources by clarifying relations among many hydrogeological considerations. In the present study, the physiochemical quality of groundwater has assessed and dissimilar index methods which were used like EC, SP, SAR, RSC, PI and KR with reference to their suitability for irrigation.

Study area

Semi-arid region of Bhaskar Rao Kunta watershed geographically lies between northern latitudes from 16° 42' 25'' to 16° 37' 58'' and eastern longitudes from 79° 28'

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15" to 79° 32' 30" of the Krishna lower basin. The watershed elevation ranges between 80 to 140 m above the mean sea level (MSL), slightly undulating terrain with slight to moderate slopes (2 to 3%) and annual normal rain fall ~ 737 mm. The average maximum and minimum temperature was 40 and 28°C respectively. The drainage system was showing dendrite to sub-dendrite pattern, governed by regional slope, homogenous lithology and relief, exhibited by 146 streams and were curved. It contributed to the flow of mostly dry season except for seasonal run-off, which could be either due to structural or topographic control (Figure 2). The study area was 40.25 km^2 out of which 71% of the land was under cultivated, in this 32% of the area was under bore well irrigation, the remaining 39% was under tank and canal irrigation, the major agricultural crops were chilli, paddy, sun flower and cotton.

Geology

Geologically the study area consisted of the Kurnool group of Palnadu sub basin and partially covered by Srisailam succession of Kadapa super group (Figure 1). Srisailam sub basin was exposed with Quartzites rocks. The Quartzites rocks were inter-bedded with thin siltstone units and were usually thick bedded, dense and fine to medium grained. Palnadu sub-basin was exposed with Calcareous (chemical precipitates) sedimentary rocks like quartzites, shales and flaggy-massive limestones with covered red and red sandy soils. General sequence of sub-surface strata was encountered on the top soil, weathered/semi weathered, and shale/quartzite.

MATERIALS AND METHODS

Collection of water samples

Twenty groundwater samples were collected from deeper bore wells (average depth 60 m bgl) in pre and post monsoon seasons at identical same locations in June and December 2009 year, according to prerequisite for the analysis. Locations of sampling points were determined using a Global Positioning System (GPS) (Figure 2). Samples were collected after one hours of pumping and the screen interval of the well represents the average sample depth. The samples were collected in 1000 mL plastic bottles and field filtration was carried out through filter papers to remove suspended solids. They were then carefully sealed, labeled and taken for analyses.

Analytical procedure

Collected samples were analyzed in the laboratory to measure the concentration of the quality parameters using American Public Health Association standard methods (APHA, 1995). pH, EC, TH, Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}, CO^{-2}_{3}, HCO^{-}_{3}, NO_3, SO^{-2}_{4}, and Cl^{-} were the major ions in groundwater of the study area. Calcium and Magnesium concentrations were determined by Ethylenediaminetetraacetic acid (EDTA) titration using Eriochrome black-T as indicator. Sodium and potassium concentrations were determined by using a flame photometer. Chloride concentration was measured by silver nitrate titration. Carbonate and bicarbonate concentrations were measured by acid-base titration. Sulphate and nitrate concentrations were measured by using colorimetric-spectrophotometer. The accuracy of the analysis for major ions was cross checked from the ionic balance was within ±7% for all the samples, ions were converted from milligram per litre to milliequivalent per litre. Correlation of geochemical data has been attempted as presented in Tables 1, 2 and 3. The concentrations were interpreted and calculated with irrigation indexes using the following formula of SP, SAR, RSC, PI and KR as follows:

Sodium percentage

This was calculated employing the equation (Todd, 1995) as:

$$Na\% = \frac{(Na^{+} + K^{+}) \div (Ca^{2+} + Mg^{2+} + Na^{+} + K^{+})}{100}$$

(Concentrations are in meq/L).

Sodium absorption ration

This was calculated employing the equation (Raghunath, 1987) as:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{(Ca^{2+} + Mg^{2+})}{2}}}$$

(Concentrations are in meq/L)

Residual sodium carbonate

This was calculated employing the equation (Eaton, 1950) as:

$$RSC = [(CO_3^{2-} + HCO_3^{-}) - (Ca^{2+} + Mg^{2+})]$$

(Concentrations are in meq/L)

Permeability index

This was calculated employing the equation (Domenico, 1990) as:

$$PI = \frac{[(Na^{+} + HCO_3^{-}) \div (Ca^{2+} + Mg^{2+} + Na^{+})]}{100}$$

(Concentrations are in meq/L)

Kelly's ratio

This was calculated employing the equation (Kelly, 1963) as:

$$KR = \frac{Na^{+}}{(Ca^{2+} + Mg^{2+})}$$

(Concentrations are in meq/L)

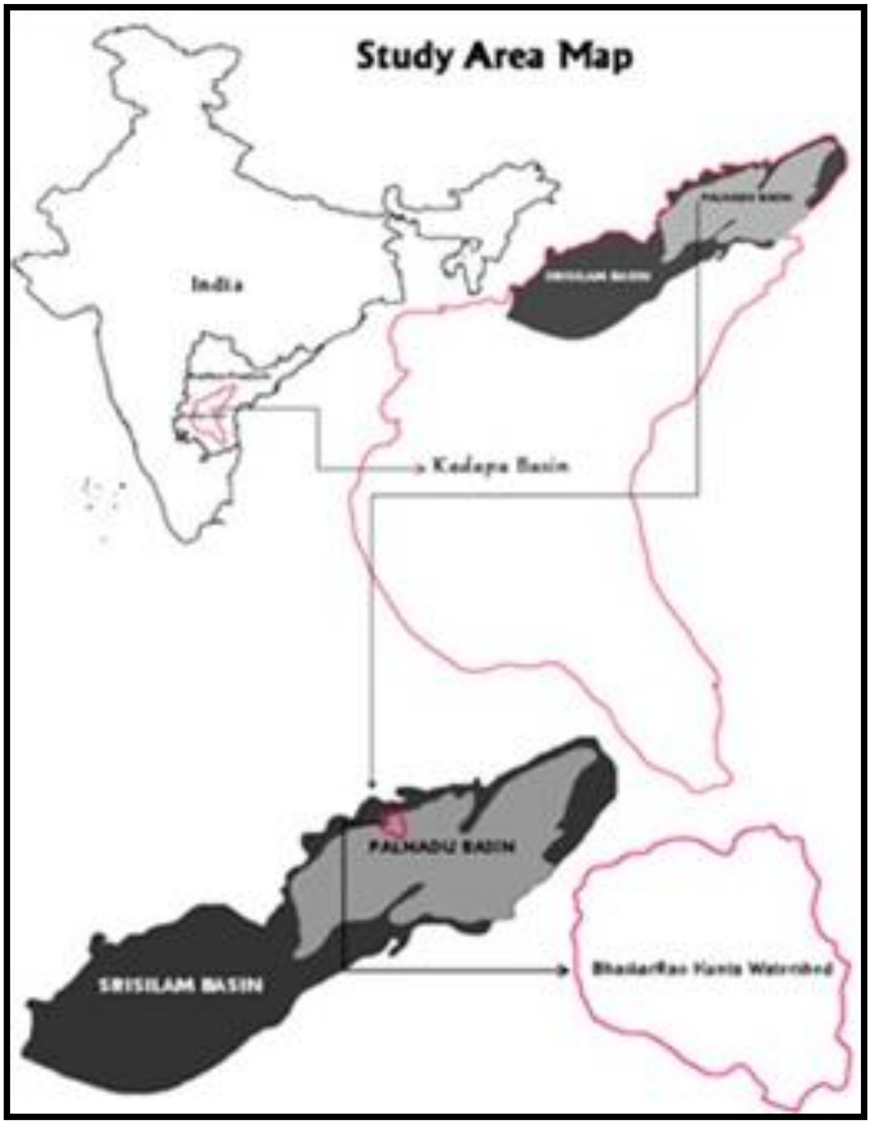

Figure 1. Map showing location of the study area.

RESULTS AND DISCUSSION

The results are obtained from hydrogeochemical analysis of water samples of study area as presented in Table 1. The calculated parameter results were presented in Table 2 and summary statistics of different indexes of groundwater quality are presented in Table 3.

Electrical conductivity

It was a measurement of all soluble salts in samples, the most significant water quality standard on crop productivity which was the water salinity hazard. The primary effect of high EC water on crop productivity was the failure of the plant to compete with ions in the soil solution for water. The higher the Ec, the lesser the water available to plants, even though the soil may show wet, because plants can only transpire "pure" water; useable plant water in the soil solution decreases significantly as Ec increases. The amount of water transpired through a crop was directly related to yield; therefore, irrigation water with high EC reduces yield potential. In the study area, the classification for EC is given (Handa, 1969) in Table 4. It indicated that overall the water quality was medium to high EC category.

Sodium percentage

Sodium hazard was an important factor in irrigation water quality. The use of high percentage sodium of water for

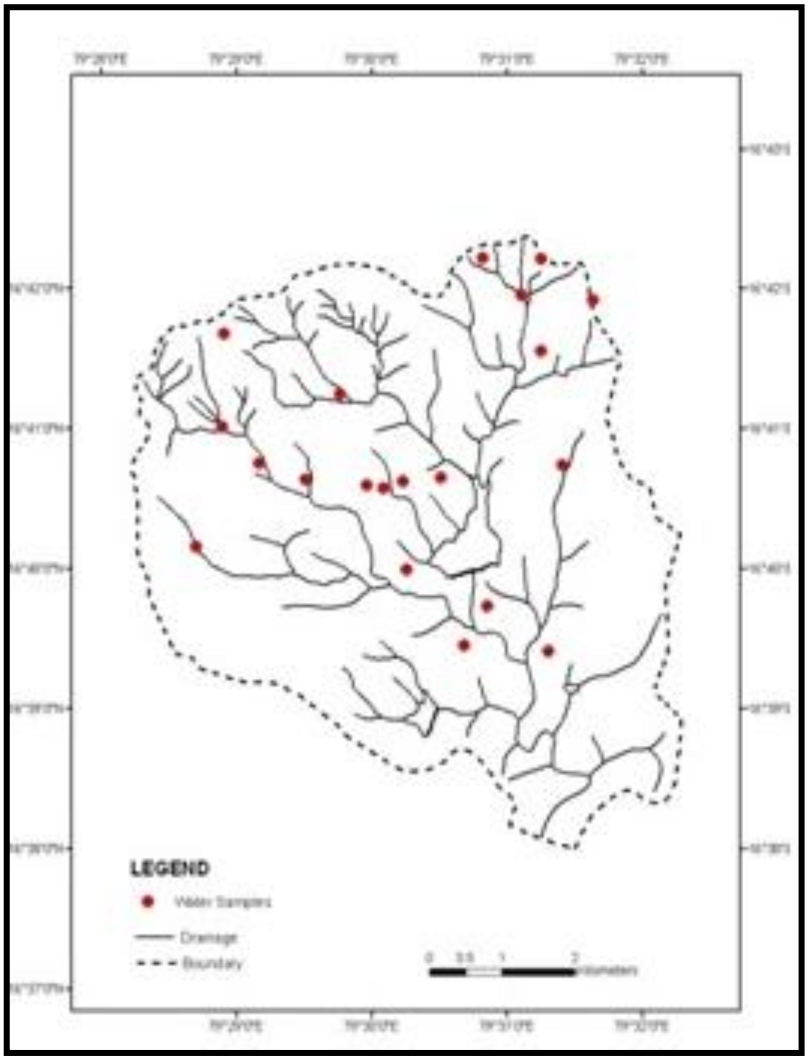

Figure 2. Groundwater Samples Locations Map.

irrigation was stunts, the plant growth and sodium reacts with soil to reduce its permeability (Joshi et al., 2009). The finer the soil texture and the greater the organic matter content, the greater the impact of sodium on water infiltration and aeration. The classification for SP was given (Wilcox, 1955) in Table 5. It is indicating the overall ground water quality of the samples which are falling under excellent to good category in pre and post-monsoon seasons.

Sodium adsorption ratio

It was a significant parameter for the determination of suitability of irrigation water; excess sodium in water produces the undesirable effects of changing soil properties and reducing soil permeability (Biswas et al., 2002). The measure to which irrigation water tend to penetrate into cation-exchange reactions in soil can be indicated by the sodium adsorption ratio, sodium replacing adsorbed calcium and magnesium was a hazard as it causes damage to the soil structure, it becomes compact and impervious. In the study area all the groundwater samples have SAR values within the excellent class and acceptable for irrigation. The classification for SAR as is given (Richards, 1954) in Table 6.

Residual sodium carbonate

The concentration of bicarbonate and carbonate also influences the suitability of water for irrigation purpose. One of the empirical approaches was based on the assumption that calcium and magnesium precipitate as carbonate, considering this hypothesis (Eaton, 1950)

Table 1. Results of hydrogeochemial analysis of groundwater samples.

S.No	Location		Pre-monsoon										Post-monsoon									
	Longitude	Latitude	pH	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	HCO^{-}_3	SO^{-}_4	Cl^{-}	NO^{-}_3	TH	pH	Ca^{+2}	Mg^{+2}	Na^{+2}	K^{-}	HCO^{-}_3	SO^{-}_4	Cl^{-}	NO_3^{-}	TH
1	79.48184	16.69462	8.3	96	72	72	0.8	199	23	57	25	407	7.9	103	78	75	0.8	206	27	61	29	418
2	79.52091	16.69261	8.5	79	83	120	1.0	231	39	37	26	446	8.4	82	89	122	1.0	241	41	39	28	450
3	79.51853	16.69924	8.1	88	87	80	1.0	219	33	95	25	495	8.1	92	89	81	0.9	226	34	97	29	500
4	79.50391	16.67703	7.8	127	88	110	1.0	192	28	115	26	423	7.6	132	89	109	0.9	195	29	120	26	425
5	79.50153	16.67625	8.1	97	65	103	0.8	184	31	50	23	422	8.0	101	68	106	0.7	189	32	51	24	425
6	79.49611	16.68746	7.7	140	94	81	1.0	237	23	110	40	523	7.4	144	97	86	1.1	244	25	113	41	525
7	79.49947	16.67665	8.0	116	100	70	0.8	217	19	60	29	396	7.9	118	103	74	0.8	220	19	61	30	400
8	79.49188	16.67732	8.1	118	72	81	0.8	241	31	95	30	446	7.9	122	73	82	0.7	247	32	96	32	450
9	79.52731	16.69863	7.9	108	53	89	0.7	165	23	93	29	323	7.8	112	53	91	0.6	168	26	96	31	325
10	79.51375	16.70373	8.5	86	91	81	0.6	195	27	47	21	397	8.1	89	92	82	0.5	198	29	48	22	400
11	79.52091	16.70356	8.1	91	67	75	1.0	221	43	38	35	370	7.9	92	69	74	1.0	229	46	39	39	375
12	79.47841	16.66934	8.1	95	102	102	0.9	179	25	30	40	573	7.9	96	107	106	0.9	183	26	31	41	575
13	79.48162	16.68361	8.4	73	56	63	0.7	177	19	35	38	349	8.2	72	58	66	0.7	183	19	36	39	350
14	79.48616	16.67927	8.8	130	76	71	0.8	196	39	73	24	447	8.1	131	76	72	0.7	198	41	76	26	450
15	79.52356	16.67901	8.5	85	69	106	1.0	260	36	46	17	347	8.3	88	71	110	0.9	262	38	47	18	350
16	79.51143	16.65753	7.9	114	70	80	1.0	244	37	102	49	396	7.9	116	73	83	0.9	250	39	109	51	400
17	79.51427	16.66217	8.5	151	91	77	1.0	236	35	54	20	520	7.8	152	93	78	1.1	241	37	59	21	525
18	79.50864	16.67751	8.3	124	95	80	0.9	191	24	97	31	542	7.9	128	96	81	0.7	189	25	99	32	550
19	79.50442	16.66661	8.7	97	97	91	1.0	211	27	98	41	497	8.2	101	98	93	1.0	214	29	106	43	500
20	79.52186	16.65682	9.0	119	88	91	1.5	237	38	83	34	536	8.0	127	94	97	1.0	243	42	87	40	550
Mean			8.3	107	81	86	0.9	212	30	71	30	443	8.0	110	83	88	0.8	216	32	74	32	447
Minimum			7.7	73	53	63	0.6	165	19	30	17	323	7.4	72	53	66	0.5	168	19	31	18	325
Maximum			9.0	151	102	120	1.5	260	43	115	49	573	8.4	152	107	122	1.1	262	46	120	51	575

Units are expressed in EC (µS/cm); except all are in mg/L.

proposed by the concept of residual sodium carbonate (RSC) for the measurement of high carbonate waters. The classification for RSC is given (Richards, 1954) in Table 7. In the present study area, RSC values are withinthe falling safe category in pre and post monsoon seasons respectively, hence, all water samples are considered safe for irrigation.

Permeability index

The soil permeability is affected by long term use of irrigation water. A criterion for assessing the suitability of water for irrigation was based on PI water and can be classified as class I, Class II and Class III orders. Class I and Class II water was categorized as good for irrigation with 75% or more maximum permeability. Class III water was unsuitable with 25% of maximum permeability (Doneen, 1964; Raghunath, 1987). In the present study area the minimum and maximum permeability is 38 and 61%, 37 and 60% in pre and post monsoon seasons respectively in Table 3; hence, the groundwater quality was suitable for irrigation.

Table 2. Calculated parameters indexes for irrigation quality.

S.No	Location		Pre-monsoon						Post-monsoon					
	Longitude	Latitude	EC (µS/cm)	SP (%)	SAR	RSC (meq/L)	PI (%)	KR (meq/L)	EC (µS/cm)	SP (%)	SAR	RSC (meq/L)	PI (%)	KR (meq/L)
1	79.48184	16.69462	859	23	1.35	-7.45	46	0.29	862	22	1.36	-8.18	45	0.28
2	79.52091	16.69261	795	33	2.25	-6.99	56	0.48	798	32	2.22	-7.47	55	0.46
3	79.51853	16.69924	840	23	1.45	-7.96	47	0.30	855	23	1.44	-8.22	47	0.30
4	79.50391	16.67703	1300	26	1.84	-10.44	43	0.35	1304	26	1.80	-10.71	43	0.34
5	79.50153	16.67625	751	31	1.98	-7.18	51	0.44	758	30	2.00	-7.54	51	0.43
6	79.49611	16.68746	1349	19	1.30	-10.84	41	0.24	1355	20	1.36	-11.17	41	0.25
7	79.49947	16.67665	873	18	1.15	-10.45	39	0.22	876	18	1.20	-10.76	39	0.22
8	79.49188	16.67732	965	23	1.45	-7.86	49	0.30	967	23	1.45	-8.05	49	0.29
9	79.52731	16.69863	689	29	1.75	-7.04	48	0.40	698	29	1.77	-7.20	48	0.40
10	79.51375	16.70373	781	23	1.45	-8.58	44	0.30	782	23	1.46	-8.76	44	0.30
11	79.52091	16.70356	829	25	1.46	-6.43	52	0.32	830	24	1.42	-6.52	52	0.31
12	79.47841	16.66934	661	25	1.73	-10.20	42	0.34	662	25	1.77	-10.60	42	0.34
13	79.48162	16.68361	650	25	1.35	-5.34	51	0.33	650	26	1.40	-5.37	52	0.34
14	79.48616	16.67927	852	20	1.22	-9.52	40	0.24	849	20	1.24	-9.54	40	0.24
15	79.52356	16.67901	1001	32	2.07	-5.66	61	0.46	1008	32	2.12	-5.93	60	0.47
16	79.51143	16.65753	1421	23	1.45	-7.45	50	0.30	1428	24	1.49	-7.70	50	0.31
17	79.51427	16.66217	1453	18	1.22	-11.15	39	0.22	1460	18	1.23	-11.29	39	0.22
18	79.50864	16.67751	1027	20	1.32	-10.87	38	0.25	1031	20	1.32	-11.19	37	0.25
19	79.50442	16.66661	901	24	1.56	-9.36	44	0.31	910	24	1.58	-9.61	44	0.31
20	79.52186	16.65682	1497	23	1.54	-9.29	46	0.30	1526	23	1.59	-10.10	45	0.30

Table 3. Summary statistics of different indexes of groundwater quality.

Parameter	Pre-monsoon				Post-monsoon			
	Mean	Minimum	Maximum	SD	Mean	Minimum	Maximum	SD
EC (µS/cm)	975	650	1497	285	980	650	1526	285
SP (%)	24	18	33	4	24	18	32	4
SAR	1.56	1.15	2.25	0.31	1.57	1.20	2.22	0.30
RSC (meq/L)	-8.56	-11.15	-5.34	1.84	-8.83	-11.29	-5.37	1.89
PI (%)	46	38	61	6	46	37	60	6
KR (meq/L)	0.32	0.22	0.48	0.08	0.32	0.22	0.47	0.07

Table 4. Irrigation water quality based on Ec values.

EC (µS/cm)	Class	Samples falling in dissimilar seasons			
		Pre-monsoon		Post-monsoon	
		%	No. of samples and Samples No's	%	No. of samples and Sample's No's
0-250	Low	Nil		Nil	
251-750	Medium	20	4 (5,9,12,13)	20	4 (5,9,12,13)
751-2250	High	80	16 (except 5, 9,12,13)	80	16 (except 5, 9,12,13)
2251-6000	Very high	Nil		Nil	

Kelly's ratio

Based on Kelly's ratios (Kelly, 1963) ground water was classified for irrigation, Kelly's ratio was more than 1 indicating an excess level of sodium in water; therefore the water Kelly's ratio of less than 1 was suitable for irrigation. In the study KR values fall within the safe category in pre and post monsoon seasons in Table 8;

Table 5. Classification of water based on SP values.

SP (%)	Class	Samples falling in dissimilar seasons			
		Pre-monsoon		Post-monsoon	
		%	No. of samples and Samples No.	%	No. of samples and Samples No.
< 20	Excellent	25	5 (6,7,14,17,18)	25	5 (6,7,14,17,18)
20-40	Good	75	15 (except 6,7,14,17,18)	75	15 (except 6,7,14,17,18)
40-60	Permissible	Nil		Nil	
60-80	Doubtful	Nil		Nil	
> 80	Unsuitable	Nil		Nil	

Table 6. Classification of water based on SAR values.

SAR (value)	Class	Samples falling in dissimilar seasons			
		Pre-monsoon		Post-monsoon	
		%	No.of samples and Samples No.	%	No.of samples and Samples No.
<10	Excellent	100	All samples	100	All samples
10-18	Good	Nil		Nil	
18-26	Fair	Nil		Nil	
>26	Poor	Nil		Nil	

Table 7. Classification of water based on RSC values.

RSC (meq/L)	Class	Samples falling in dissimilar seasons			
		Pre-monsoon		Post-monsoon	
		%	No. of samples and Samples No.	%	No. of samples and Samples No.
<1.25	Safe	100	All samples	100	All samples
1.25-2.5	Marginal	Nil		Nil	
>2.5	Unsuitable	Nil		Nil	

Table 8. Classification of water based on KR values.

KR meq/L	Class	Samples falling in dissimilar seasons			
		Pre-monsoon		Post-monsoon	
		%	No. of samples and Samples No.	%	No. of samples and Samples No.
<1	Safe	100	All samples	100	All samples
>1	Unsuitable	Nil		Nil	

hence, the groundwater quality suitable for irrigation.

Conclusions

Evaluation of groundwater quality for irrigation were carried out using different index methods like SP, SAR, RSC, PI, KR and EC; among these, majority of index results were similar to SP, SAR, RSC, PI, and KR implying that the 100% of the groundwater samples fall under excellent and were excellent to good category in pre and post monsoon seasons. But, only based on EC, 80% of the samples fall under the high salinity category (751 to 2250 µS/cm); it is suitable for horticultural crops. Therefore, the results were concluded, that the study area groundwater quality was in general suitable for irrigation. Observed from the analyzed results of groundwater quality was diminutive and changed due to monsoon impacts of a lesser amount of rain fall, runoff, infiltration and rock water interaction (geogenic reaction) in the study area.

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