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Assessment of Pre-and Post-Monsoon Groundwater Resource for Irrigation in Bhopalpatnam area, Bijapur District, Chhattisgarh, India

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Abstract

The current study was conducted to determine the suitability of groundwater used for irrigation in and around the Bhopalpatnam area of Bijapur District, Chhattisgarh, during pre-and post-monsoon seasons of 2016. In this study, sixty two groundwater samples were collected from different villages and analyzed for various hydrochemical parameters like pH, EC, alkalinity, hardness , TDS, Ca, Mg, Na, K, CO_3, HCO_3, Cl, SO_4, NO_3, PO_4, Fe and F. Physico-chemical characterization of the samples revealed that groundwater from most of the sources is not fit for drinking owing to a high concentration of EC, HCO_3, NO_3, Fe and F. Irrigation indices such as sodium adsorption ratio (SAR), sodium percentage (Na %), residual sodium carbonate (RSC), permeability index (PI), Kelly's ratio (KR), magnesium hazard (MH) and EC were also calculated. The SAR values obtained for all the samples were plotted against EC values in the US salinity laboratory diagram and it was revealed that most of the samples fall under water type C3-S1 indicating high salinity and low SAR. The analysis of the various parameters indicated moderate suitability of groundwater for irrigation purpose.

Keywords: Groundwater, Irrigation, SAR, %Na, KR, PI and MH

Introduction

The present study has been carried out in Bhopalpatnam area, situated about 54 km west from Bijapur, Chhattisgarh. The study area is confined between latitudes$18^0 47'30"$ to $18^0 55'28"$ N and longitudes $80^0 20'00"$ to $80^0 31'43"$ E under survey of India Toposheet No. 65 B/5 and covers an area of 165.71 km^2 (Fig. 1). The people of the study area are economically backward, main occupation of villagers is agriculture. Physiographically, the major part of the district exhibits pediment/pediplain landforms. Most of the district area falls in Godavari, Indravati and Sabari catchments. Indravati, Godavari, Sabari rivers and their tributaries constitute the surface drainage network of the district. The area experiences a semi-arid climate with an annual mean temperature of 30^0 C. The mean annual rainfall is recorded at 745 mm, occurring generally during the southwest monsoon period (June – September). The drainage is pattern in the sudy area is dendritic to sub-dendritic. Groundwater occurs under phreatic conditions in the weathered and fractured zones. The depth to water table ranges from 5.6 to 12.1 m below the ground surface. The depth of dug wells ranges from 8 to 13 m and the diameter of the dug wells ranges from 2 to 7 m. The maximum depth of the hand pump for drinking water use is 40 m below ground level. The current study focuses on the assessment of pre- and post monsoon suitability of ground water for irrigation purposes to sustain agricultural practice in the region.

Geology of the Study Area

The study area comprises of rock formations belonging to Archaean, Neo Proterozoic and Quaternary age are exposed in the study area. The oldest rocks in the area comprises of Eastern Ghat Supergroup and Bengpal Group of Archaean age. Rock of Bengapal Group are exposed in the major part of the study area and comprises various types of gneisses and schists, amphibolites, meta-basics, metaultramafics, migmatites and different varieties of quartzites. The rocks of the area are mainly pyroxene gneisses, amphibole gneisses, mica gneisses, garnetiferous gneisses, white quartzites, magnetite quartzites, micaceous quartzites, amphibolites etc. of the Dharwarian period. The gneisses are the most prevalent rocks while amphibolites and pyroxenites occur in the form of dykes and are widely distributed in the area. The major litho-units of the study area comprise of granitic gneiss and phyllites rocks, which are overlain by red, sandy soil cover. Secondary intrusives such as dykes, pegmatite and quartz veins, which occur to a limited extent, are present in the rocks.

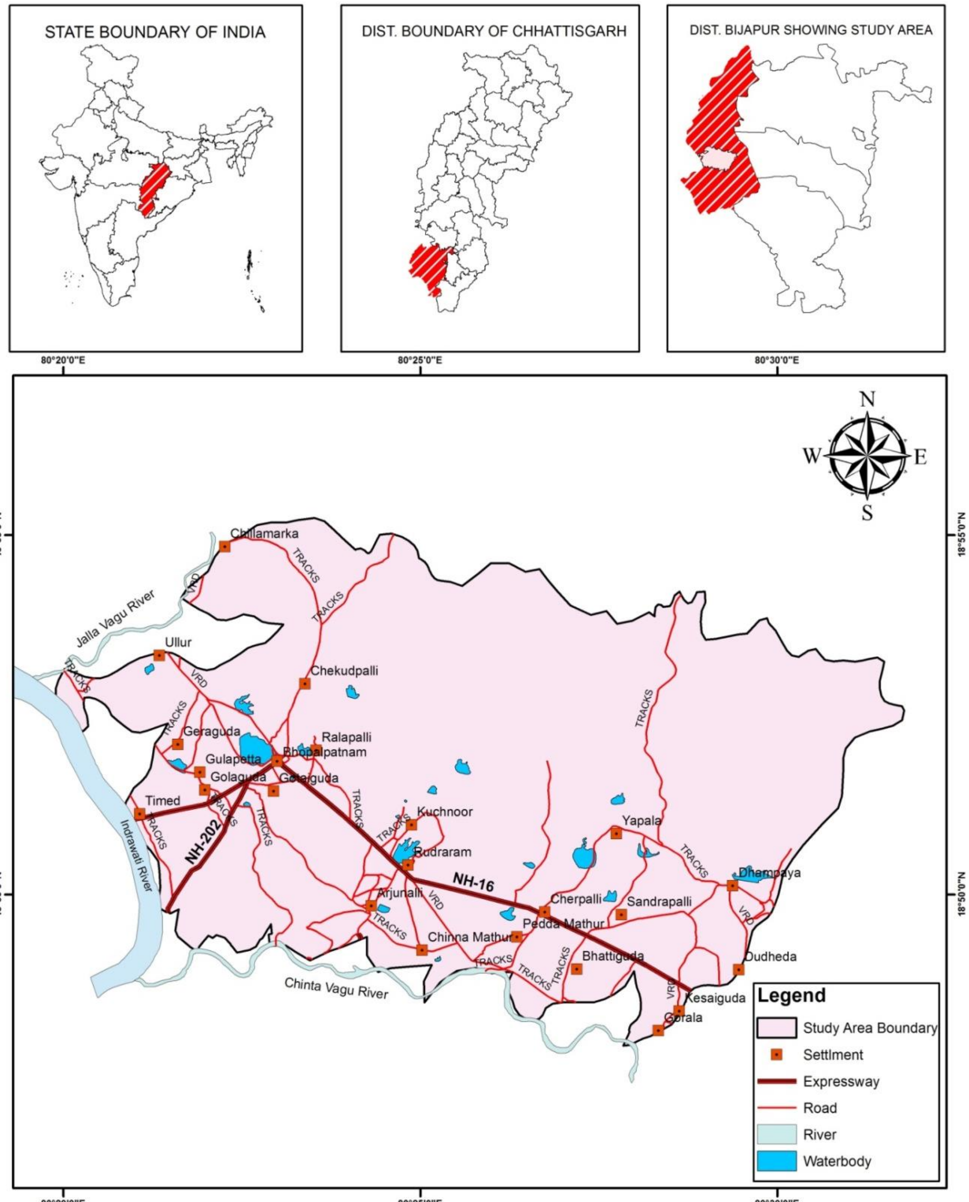

Fig.1. Location map of the study area Bhopalpatnam, district-Bijapur

Materials and Methods

In order to assess water quality of the study area, 62 groundwater samples were collected to cover the entire study area in the pre-and post-monsoon period during May and November 2016. The groundwater samples were collected in pre-washed polythene, narrow mouth bottles from study area and the bottles were rinsed twice before sampling. Based on this study, representative wells were selected. The location map is presented as Figure 1. The water samples from the bore wells were collected after pumping out water for about 10 minutes remove stagnant water from the well. Samples were immediately transferred to pre-cleaned polythene bottles with 500 ml. capacity. Collected samples were taken to the laboratory for analysis. Analysis of groundwater samples for evaluation of chemical parameters were done as per Standard Methods (APHA,

1995) procedure, from CGCOST central laboratory Raipur (CG).

The Chemical parameters calculated were pH (hydrogen ion concentration), EC (electrical conductivity), TDS (total dissolved solid), TH (total hardness) and concentrations of all major cations like Ca (calcium), Mg (magnesium), Na (sodium) and K (potassium) and anions like Cl, (chloride), HCO_3 (bicarbonate), F (fluoride), SO_4 (sulfate) and NO_3 (nitrate N). The pH and electrical conductivity respectively were measured by using pH meter and conductivity meter. CO_3 and HCO_3 concentrations were determined using acid titration method; Alkalinity and Phosphate were determined by titration method, Cl concentration by the $AgNO_3$ titration method, SO_4 concentration by the $BaCl_3$ method using spectrophotometer and NO_3 concentration by the titration method. Na and K were analyzed using Micro Processor Flame Photometer, Ca and F were analyzed by Cary,100 Bio, UV-visible spectrophotometer, Mg and Fe were analyzed by using Atomic Absorption Spectrometer (AAS) and TDS of the groundwater was determined by the following equation:

Results and Discussion

The statistical analyses of the parameters concentration are shown in Table 1. There is a significant variation in the concentration of most of the parameters from well to well as reflected in the high median and standard deviation values (Table 1). The pH value mean for pre-and post-monsoon seasons was slightly higher than 7.0 which indicate alkaline conditions. Bicarbonate (HCO_3) prevails and carbonate (CO_3) concentration becomes negligible under these pH conditions (Table 1). For example, TDS, which is an important water quality parameter that reflects the concentration of all dissolved ions, ranged from 149.12 to 1868.80 mg/l and 137.60 to 2291.20 mg/l pre-and post-monsoon seasons respectively. These results indicate that groundwater suitability for irrigation may vary from well to well. SAR, % Na, RSC, KR, PI and MH as calculated from Equations 1–6 (given in the following sections) and salinity (EC) are used for assessment of water for irrigation suitability due to the significant effect of these parameters on crop and soil physical properties.

TDS in mg/l= EC*0.64.

Table 1. Statistical analyses results of the major ions concentration in groundwater samples.

S.No.	Parameters	Pre-monsoon					Post-monsoon				
		Minimum	Maximum	Mean	Median	SD	Minimum	Maximum	Mean	Median	SD
1	pH	6.40	7.83	7.11	7.18	0.29	6.50	7.30	7.10	7.10	0.13
2	EC (µS/cm)	233.00	2920.00	1019.82	962.00	431.38	215.00	3580.00	1029.10	985.00	455.63
3	Alka (mg/l)	120.00	560.00	362.58	365.00	96.07	150.00	600.00	374.50	366.00	85.54
4	Hard (mg/l)	110.00	800.00	357.58	340.00	131.93	88.00	1640.00	374.19	330.00	207.77
5	TDS (mg/l)	149.12	1868.80	651.80	615.68	275.76	137.60	2291.20	658.01	625.40	291.57
6	Ca (mg/l)	29.06	347.21	89.85	79.41	43.65	25.04	305.05	91.25	89.29	38.02
7	Mg (mg/l)	1.02	159.23	45.15	35.72	33.61	11.20	89.21	52.78	53.11	19.51
8	Na (mg/l)	0.02	189.23	59.47	59.22	34.45	1.09	110.08	54.29	48.65	29.20
9	K (mg/l)	0.34	46.40	3.10	2.40	5.76	0.52	30.12	3.07	2.64	3.72
10	CO_3 (mg/l)	18.00	48.00	32.82	33.90	7.87	20.08	59.50	36.25	35.78	8.09
11	HCO_3 (mg/l)	14.89	450.18	255.57	252.54	81.31	12.55	415.50	252.24	257.25	76.10
12	Cl (mg/l)	60.00	370.00	123.87	100.00	55.85	80.00	380.00	134.03	120.00	51.61
13	SO_4 (mg/l)	1.20	765.92	53.74	22.28	103.02	0.09	788.61	57.55	35.56	104.52
14	NO_3 (mg/l)	30.00	65.00	50.24	50.00	7.43	0.27	87.02	38.85	32.70	25.57
15	PO_4 (mg/l)	0.00	1.00	0.15	0.00	0.27	0.00	0.90	0.08	0.00	0.19
16	Fe (mg/l)	0.00	5.13	0.50	0.08	0.98	0.00	3.99	0.43	0.22	0.58
17	F (mg/l)	0.00	2.56	1.06	0.90	0.68	0.19	3.99	1.96	2.01	0.88

The groundwater of the study area is used also for the agricultural purpose. The suitability of groundwater for irrigation purpose depends upon the mineral constituents present in the water. Irrigation water of good quality is essential to maintain the soil crop productivity at a higher level. Water used for irrigation always contains measurable quantities of dissolved substances, which are generally called as the salts. The salts should contain small amounts of dissolved solids originating from dissolution or weathering of the rocks. EC and Na play a vital role in suitability of water for irrigation. Higher salt content in irrigation water causes an increase in soil solution osmotic pressure (Throne and Peterson 1954), which makes difficult for the plant root to extract water for osmosis. The various salts present in the irrigation water not only affect the plant growth directly, but also affect the soil structure, permeability and aeration which indirectly affect the plant growth (Mohan and others 2000). Hence the groundwater in the study area needs to be analyzed for its suitability for irrigation purpose. The chemical parameters which are used for assessing the suitability of water for irrigation are sodium content which are expressed by using EC, Sodium Absorption ratio (SAR), Percentage of Sodium (%Na), Residual Sodium Carbonate (RSC), Kelly's ratio (KR), Permeability Index (PI) and Magnesium hazard (Table 2).

Table 2. Calculation of SAR, %Na, RSC, KR, PI and MH for groundwater in pre-and post-monsoon seasons.

Sample ID	Pre-monsoon, 2016						Post-monsoon, 2016					
	SAR meq/l	%Na meq/l	RSC meq/l	KR meq/l	PI meq/l	MH meq/l	SAR meq/l	%Na meq/l	RSC meq/l	KR meq/l	PI meq/l	MH meq/l
TIM-1-1	0.88	21.05	-0.25	0.26	49.12	36.95	0.91	21.29	-1.07	0.26	47.15	36.73
TIM-1-3	0.64	12.95	-3.69	0.15	31.75	65.06	1.03	22.28	-2.76	0.28	42.68	61.81
GOL-2-5	0.87	15.32	-6.80	0.18	29.39	33.84	1.51	25.42	-5.93	0.33	38.32	56.50
GOL-2-6	0.00	6.86	-9.23	0.00	20.25	58.52	0.02	6.41	-5.95	0.00	23.79	61.51
GUL-3-7	0.00	1.01	-1.59	0.00	29.44	51.07	0.03	1.75	-3.58	0.01	23.99	47.58
GUL-3-9	0.10	3.20	-0.74	0.03	35.92	51.30	0.27	7.35	-2.42	0.08	33.13	49.85
GER-4-10	0.01	0.51	-22.35	0.00	5.45	29.96	0.12	2.15	-18.59	0.02	6.98	29.92
GER-4-11	2.26	35.13	-0.54	0.53	54.47	53.57	1.89	30.05	-2.43	0.42	46.84	56.13
GER-4-12	1.86	28.26	-4.65	0.39	42.73	71.61	1.78	28.40	-4.41	0.39	42.89	50.41
GER-4-13	1.65	29.31	-0.80	0.41	50.85	63.53	1.28	21.58	-4.62	0.27	38.31	49.46
ULL-5-15	1.52	23.48	-8.03	0.30	34.98	61.17	1.40	25.18	-4.23	0.33	40.87	51.70
ULL-5-16	2.34	36.08	-1.26	0.56	54.26	63.00	1.67	26.74	-4.41	0.36	41.56	56.54
CHI-6-17	0.96	19.10	-1.82	0.23	41.73	57.01	0.83	15.33	-4.12	0.18	33.32	48.97
CHI-6-19	0.66	17.33	-2.42	0.19	38.21	46.95	0.63	15.24	-2.94	0.17	35.17	35.01
CHE-7-20	0.21	6.84	-4.15	0.07	15.44	72.87	0.26	12.65	-0.78	0.12	30.90	42.44
CHE-7-21	0.98	18.88	-3.86	0.22	36.15	58.54	0.95	18.99	-3.34	0.22	36.97	31.81
BHO-8-24	2.43	37.14	0.25	0.59	57.22	64.85	1.75	27.29	-3.85	0.37	42.96	44.90
BHO-8-26	1.45	29.83	-0.60	0.41	52.43	50.02	1.14	20.19	-5.87	0.25	34.30	48.07
BHO-8-28	4.63	56.75	-0.42	1.30	71.67	40.26	2.00	29.79	-4.92	0.42	43.85	51.16
BHO-8-29	2.33	38.42	-2.57	0.62	54.39	21.39	1.78	31.54	-3.43	0.45	46.73	21.99
BHO-8-32	1.67	31.85	-1.74	0.46	51.31	58.50	1.13	21.36	-3.76	0.27	38.77	50.93
GOT-9-33	1.05	21.38	-3.71	0.26	39.08	48.54	0.94	19.55	-3.99	0.24	37.23	43.29
GOT-9-35	0.55	12.02	-3.47	0.13	33.59	40.17	0.58	11.90	-5.11	0.13	29.16	40.76
BHO-8-36	1.70	24.96	-8.11	0.33	36.39	51.31	1.66	25.44	-6.57	0.34	38.41	49.27
BHO-8-37	1.74	28.38	-3.93	0.39	43.98	59.96	1.54	24.02	-6.72	0.31	37.19	46.43
RAL-10-38	1.57	29.28	-1.21	0.41	50.36	55.90	1.19	23.47	-2.88	0.30	42.09	55.70
RAL-10-39	1.23	23.35	-4.00	0.29	39.93	33.12	1.08	18.97	-5.79	0.23	33.90	47.59
KUC-11-43	2.04	35.40	0.67	0.54	58.67	60.20	1.90	31.75	-2.22	0.46	49.67	67.04
KUC-11-44	1.50	27.97	-1.92	0.38	47.51	57.55	1.62	27.19	-4.36	0.37	42.38	62.95
RUD-12-45	1.03	25.22	1.25	0.32	57.35	45.52	2.22	38.77	-1.27	0.62	57.32	45.56
RUD-12-46	2.40	36.15	-2.49	0.56	52.71	76.43	1.84	29.48	-2.20	0.40	47.04	63.99

RUD-12-49	1.85	33.21	-0.83	0.48	54.17	34.31	1.51	25.05	-5.42	0.32	39.50	44.59
RUD-12-50	0.90	14.57	-9.28	0.17	26.69	47.22	0.88	15.95	-5.32	0.18	31.88	45.55
RUD-12-51	0.77	18.56	-2.40	0.22	39.53	34.38	0.75	17.86	-2.72	0.21	38.05	47.98
RUD-12-52	1.91	36.13	-0.70	0.55	58.46	34.72	1.59	28.29	-4.14	0.39	42.95	59.03
RUD-12-53	1.56	30.45	-1.66	0.43	51.01	33.48	1.63	33.49	-0.66	0.49	56.61	40.23
RUD-12-54	1.95	34.41	-0.91	0.52	54.97	33.37	1.90	32.27	-3.63	0.47	47.56	40.68
ARJ-13-55	1.55	31.71	-1.76	0.46	52.76	21.93	0.29	7.33	-4.67	0.07	24.25	81.94
ARJ-13-57	1.48	25.99	-3.68	0.35	43.25	34.98	1.69	30.58	-1.09	0.44	50.23	20.18
CHI-14-59	0.94	20.71	-1.27	0.26	45.46	12.47	0.83	17.15	-1.58	0.20	39.85	39.86
CHI-14-60	0.62	14.08	-2.20	0.16	37.69	27.37	0.81	16.81	-2.49	0.20	38.65	40.16
PED-15-61	1.68	33.61	-1.22	0.50	55.97	4.26	1.43	26.81	-2.88	0.36	45.18	48.04
PED-15-63	2.63	45.24	1.14	0.81	69.51	23.36	2.59	43.35	1.48	0.75	67.35	49.80
PED-15-64	1.64	37.99	0.35	0.59	66.30	8.59	1.22	28.00	-0.43	0.37	54.92	35.10
CHE-16-66	0.54	13.61	-3.06	0.16	34.55	50.30	0.44	9.38	-6.29	0.10	24.81	71.57
CHE-16-67	1.54	31.95	-0.84	0.46	56.95	27.32	1.07	22.26	-1.77	0.28	45.51	49.63
CHE-16-69	0.77	18.55	-1.35	0.22	45.09	34.85	0.57	11.82	-4.49	0.13	31.15	61.86
YAP-17-71	0.34	6.37	-8.16	0.06	21.24	69.79	0.72	13.53	-4.85	0.15	30.79	46.25
YAP-17-72	1.90	37.97	-0.15	0.60	62.57	30.75	0.71	15.16	-4.10	0.17	33.93	75.98
SAN-18-73	1.54	41.74	2.69	0.69	85.70	4.72	2.49	43.27	0.67	0.75	66.45	63.59
SAN-18-75	0.61	15.50	-1.73	0.17	42.05	39.11	0.94	20.26	-1.79	0.24	42.98	50.65
BHA-19-77	1.09	27.07	-0.05	0.36	58.16	17.26	1.29	29.84	1.28	0.41	62.93	56.90
BHA-19-79	0.87	20.51	-1.29	0.26	46.11	11.52	0.72	15.52	-1.99	0.18	38.82	36.54
GOR-20-81	1.53	33.49	-1.04	0.50	57.71	1.77	1.04	20.88	-3.69	0.25	38.50	39.26
GOR-20-83	1.85	38.77	0.49	0.62	67.37	26.26	1.05	20.96	-3.11	0.26	39.50	53.29
DHA-21-84	1.37	18.79	-11.21	0.22	30.00	70.68	1.53	25.07	-3.93	0.32	41.72	54.00
DHA-21-86	1.01	15.10	-10.87	0.17	26.62	58.62	0.83	15.00	-4.59	0.17	32.87	55.42
DHA-21-87	0.99	21.28	-3.31	0.26	40.30	11.03	0.24	6.73	-2.82	0.06	29.78	27.47
DUD-22-89	1.61	32.57	-1.55	0.47	54.08	42.42	0.66	17.32	0.14	0.19	48.75	39.40
DUD-22-92	1.94	38.49	-0.22	0.61	61.72	24.54	0.42	10.04	-2.16	0.10	33.65	57.65
KES-23-93	1.04	25.83	-1.83	0.34	48.02	24.03	0.42	11.79	-2.81	0.13	32.03	31.59
KES-23-95	1.24	21.66	-8.66	0.26	31.42	34.23	1.13	21.22	-5.92	0.25	35.51	42.18
Mini	0.00	0.51	-22.35	0.00	5.45	1.77	0.02	1.75	-18.59	0.00	6.98	20.18
Max	4.63	56.75	2.69	1.30	85.70	76.43	2.59	43.36	1.48	0.75	67.35	81.94
Average	1.35	25.31	-2.91	0.36	45.84	41.42	1.13	21.20	-3.55	0.28	39.85	48.59
SD	0.77	11.38	3.94	0.22	14.48	19.12	0.60	9.09	2.72	0.16	10.31	11.98

Salinity Hazard (EC)

The most influencing water quality for crop production is salinity hazard which is expressed as electrical conductivity (EC), reflected by an increase in TDS value of groundwater. Electrical Conductivity is a measure of the degree of the mineralization of the water, which is dependent on rock water interaction and thereby the residence time of the water in the rock (Eaton, 1950). EC of the irrigation water becomes one of the important parameters to evaluate the overall chemical quality of groundwater. Based on the classification of EC (Wilcox 1955), waters are classified as Excellent, Good, Permissible, Doubtful and unsuitable. The standard classification of water quality is given in (Table 3).

Table 3. Irrigation water quality based on Electrical Conductivity (Wilcox 1955)

Classification of Water	Range of EC in µS/cm	No. of samples		Percentage of Samples	
		Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
Excellent (C1)	<250	1	1	1.61%	1.61%
Good (C2)	250-750	15	16	24.19%	25.80%
Permissible (C3)	750-2000	45	44	72.58%	70.96%
Doubtful (C4)	2000-3000	1	Nil	1.61%	Nil
Unsuitable (C5)	>3000	Nil	1	Nil	1.61%

As groundwater moves and stays for a longer time along its flow path the increase in total dissolved concentration and major ions normally occurs. It has been noticed in many groundwater investigations that the groundwater in recharge area is characterized by a relatively low EC than the groundwater in the discharge area it is higher (Freeze and Cheery, 1979). Hence, irrigation water with high EC will affect the root zone and water flow, due to high osmotic pressure. From the classification of EC most of the water falls under permissible category to be used for irrigation purpose in pre-monsoon and post-monsoon seasons 2016.

Sodium Absorption Ratio (SAR)

The measurement of the sodium content relative to the calcium and magnesium in soil and water medium which influences the properties of the soil and the growth of the plant is sodium absorption ratio (SAR). Sodium ions have a tendency to get adsorbed on the soil colloids. Excess sodium in water produces the undesirable effects of changing soil properties and reducing soil permeability and soil structure (Kelly, 1957). SAR is an important parameter for the determination of the suitability of irrigation water because it is responsible for the sodium hazard (Todd, 1980). Hence, the assessment of sodium concentration is necessary while considering the suitability for irrigation. The SAR can be found out by the relation given by Karnath (1987) as follows:

$$SAR = \frac{Na+}{\sqrt{(Ca2+ + Mg2+)/2}} \quad \text{......... (1)}$$

Table 4. Alkalinity Hazard Classification of Groundwater (Richards 1954)

SAR	Alkalinity Hazard	Water Class	Samples number		Percent of samples	
			Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
<10	S1	Excellent	62	62	100%	100%
10-18	S2	Good	Nil	Nil	Nil	Nil
18-26	S3	Doubtful	Nil	Nil	Nil	Nil
>26	S4	Unsuitable	Nil	Nil	Nil	Nil

All the values are expressed in meql/litre. According to Richards (1954), water with SAR values less than 10 is excellent, 10-18 is good, 18-26 is doubtful and greater than 26 is unsuitable is given in the (Table 4).According to the above classification, the SAR values in the study area range from 0.00 to 4.63 meq/l pre-monsoon and 0.02 to 2.59 meq/l post-monsoon (Table 2), and the samples of the study area have been classified as there is no danger of sodium consideration in soil as per SAR. From this classification around 100% of water is under the excellent category of water (S1) of both the pre and post monsoon seasons.

Sodium percentage (%Na)

Sodium concentration is important in classifying the irrigation water because sodium reacts with the soil to reduce its permeability content (Kaur & Singh 2011). Percent sodium in water is a parameter computed to evaluate the suitability of water quality for irrigation (Wilcox 1948). The %Na is computed with respect to relative proportions of cations present in water, where the concentrations are expressed in meq/l using the formula:

$$(\%)\ Na^{+} = \frac{(Na+ + K+)}{(Ca2+ + Mg2+ Na+ + K+)} \times 100 \quad \text{...... (2)}$$

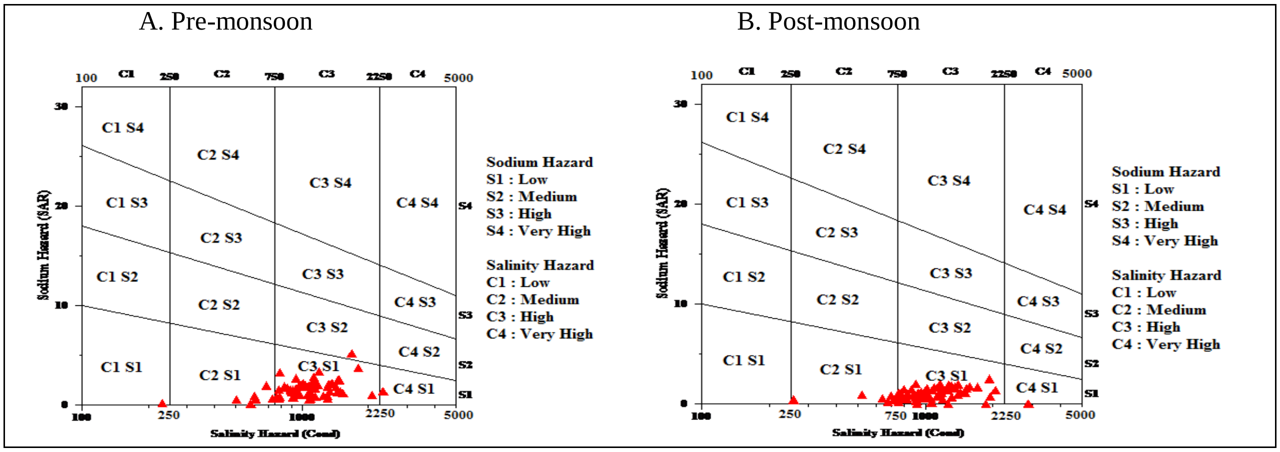

Fig. 2. Salinity and sodium hazard of irrigation water in US salinity diagram (after Wilcox 1955) for A. (pre-monsoon) and B. (post-monsoon) seasons, 2016.

Table 5. Classification of groundwater based on % Na (Wilcox 1955).

%Na	Quality of water	Samples number		Percentage of samples	
		Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
<20	Excellent	20	26	32.25%	41.93%
20-40	Good	39	34	62.90%	54.83%
40-60	Permissible	03	02	4.83%	3.22%
60-80	Doubtful	Nil	Nil	Nil	Nil
>80	Unsuitable	Nil	Nil	Nil	Nil

All the values are expressed in terms of meq/litre. Wilcox (1955) classified the irrigation water based on percentage of Na as excellent (<20), good (20-40), permissible (40-60), doubtful (60-80) and unsuitable (>80). The classification of groundwater based on Wilcox 1955 is given in (Table 5). Table 5 shows most of the analysed groundwater samples collected during the pre-monsoon and post-monsoon periods fall under the category of excellent to good quality. A few samples fall under permissible category. The results of the analysis are plotted in the Wilcox's diagram (Wilcox 1955) for the classification of groundwater for irrigation (Figure 2).

Residual sodium carbonate (RSC)

The quantity of bicarbonate and carbonate in excess of alkaline earth metal cations, (Ca^{2+} + Mg^{2+}) also influences the suitability of water for irrigation purposes (Karanth 1989). The bicarbonate and carbonate in the irrigation water tend to precipitate calcium and magnesium ions in the soil resulting in an increase in the proportion of the sodium ions. For this reason, RSC was considered as an indicative of the sodicity hazard of water. The RSC values were computed, where ions are expressed in meq/l using the following formula.

$$RSC = (CO_3^{2-} + HCO_3^{-}) - (Ca^{2+} + Mg^{2+}) \quad \ldots\ldots\ldots (3)$$

All the values are expressed in terms of meq/liter. A high value of RSC in water leads to an increase in the adsorption of sodium on soil (Eaton 1950).

Table 6. Suitability of irrigation water based on residual sodium carbonate

RSC (meq/l)	Suitability for irrigation	Samples number		Percentage of samples	
		Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
<1.25	Safe	61	60	98.38%	96.77%
1.25-2.5	Moderate	Nil	2	Nil	3.22%
>2.5	Unsuitable	Nil	Nil	Nil	Nil

Irrigation waters having RSC values greater than 5 meq/l have been considered harmful to the growth of plants, while waters with RSC values above 2.5 meq/l are unsuitable for irrigation. An RSC value between 1.25 and 2.5 meq/l is considered as the marginal quality and value < 1.25 meq/l as the safe limit for irrigation. The variation in RSC values of the study area during pre- and post-monsoon seasons is given in Table 6. However, with respect to RSC all samples fall within the safe quality category for irrigation. From the Table 6, it is found that well nos 43 and 52 are moderate for post-monsoon seasons. The calculated RSC values are 98.38% for pre-and 96.77 for post-monsoon seasons of the analyzed groundwater samples which are below 2.5 meq/l, indicating that in general groundwater is suitable to marginally suitable for irrigation purposes.

Kelly's ratio

Based on Kelly's ratio waters are also classified for irrigation. Sodium measured against calcium and magnesium was considered by Kelly (1957) to calculate this parameter. The concentration of Na^+ in irrigation water is considered to be one of the prime factors in making the water unsuitable, if Kelly's ratio is >1.

As per the Kelly's ratio

$$\{KR= \frac{Na+}{Ca2+ + Mg2+} meq/l\} \quad \text{…. (4)}$$

Where, the groundwater is categorized into suitable, if KR is <1, marginal, when KR is 1-2 and unsuitable if KR is >2 (Table 7).

Table 7. Classification of groundwater (Kelly 1951)

Range of Kelly'sratio	Category	Number of samples		Percentage of samples	
		Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
<1	Suitable	61	62	98.38%	100%
1-2	Marginal	1	Nil	Nil	Nil
>2	Unsuitable	Nil	Nil	Nil	Nil

A Kelly's ratio of more than one indicates an excess level of sodium in waters. Therefore, water with the Kelly's ratio less than one is suitable for irrigation, while those with a ratio more than two are unsuitable for irrigation. Kelly' ratio of groundwater of the study area varies from 0.00 to1.30 meq/l with an average 0.36meq/l during the pre-monsoon while in the post-monsoon it varies from 0.00 to 0.75 meq/l with an average of 0.28 meq/l (Table 2). Therefore, according to the Kelly's ratio, all the water samples are in the category of suitable for irrigation except only one sample in pre-monsoon season. The majority of groundwater samples of the current study are suitable 98.38% in pre-monsoon and 100% in post-monsoon seasons for irrigation.

Permeability index (PI)

The soil permeability is affected by long term use of irrigation water as it is influenced by sodium, calcium, magnesium and bicarbonate content of the soil. Doneen (1964), WHO (1989) gave a criterion for assessing the suitability of groundwater for irrigation based on the permeability index (PI). The PI is formulated is as:

$$PI = \frac{(Na+K)+\sqrt{HCO3}}{Ca+Mg+Na+K} \times 100, \quad \text{…….. (5)}$$

Table 8. Classification of Permeability Index.

Class	Order %	Samples numbers		Percentage of Samples	
		Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
I	>75%	01	Nil	1.61%	Nil
II	25-75%	57	57	91.93%	91.93%
III	<75%	61	62	98.38%	100%

where all the ions concentrations are in meq/l.

Accordingly, the permeability index is classified under class 1 (>75%), class 11(25-75%) and class 111(<75%) orders. Class 1 and class 11 waters are categorised as good quality for irrigation with 75% or more of maximum permeability (Table 8). Class 111 waters are unsuitable with 25% of maximum permeability. In the study area, the PI during the pre-monsoon varies from 5.45 to 85.70 with an average of 45.84, while PI values vary from 6.98 to 67.35 with an average value 39.85 during the post-monsoon seasons (Table 2). According to Doneen classification, 1.61% of the samples are acceptable for irrigation purpose of pre-monsoon and none for post-monsoon (Table 8).

Magnesium hazard MH)

Generally calcium and magnesium maintain a state of equilibrium in groundwater. Excess magnesium in water affects the soil quality converting it to alkaline and decreases crop yield. Szabolcs and Darab (1964) proposed magnesium hazard (MH) value for irrigation water as given below.

$$MH = Mg/ (Ca + Mg) \times 100 \quad \ldots\ldots (6)$$

where all ionic concentrations are expressed in milliequivalent/litre. The magnesium hazard (MH) value in the groundwater samples varies between 1.77 to 76.43% with the average value 41.42% during pre-monsoon and varies between 20.18 to 81.94% with average value 48.59% during post-monsoon period (Table 2).

Table 9. Magnesium Hazard Ratio (MH) of GW samples in the study area.

Range	Class	No. of samples		Percentage of no. of samples	
		Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
<50	Suitable	37	37	59.67%	59.67%
>50	Unsuitable	25	25	40.32%	40.32%

MH > 50 is considered harmful and unsuitable for irrigation purpose. In the analyzed waters, 40.32% and 40.32% of the groundwater samples having magnesium hazard (MH) > 50% during pre-and post-monsoon seasons respectively (Table 9).

Conclusion

Evaluation of groundwater quality for irrigation purposes is of paramount importance in semi-arid and arid regions of the world, particularly in the developing countries like India owing to burgeoning population, expansion of irrigated farming and mushroom growth of industrial clusters. Results of the current study revealed that water samples from two wells are not suitable for irrigation based on SAR and %Na, and all other groundwater samples are suitable for irrigation based on RSC. US salinity laboratory diagram, however, showed that the majority of the groundwater samples fall in the high or very high salinity zone which indicates that special requirements should be met before the water from these wells can safely be used for irrigation. This includes cultivation of salt-tolerant crops or fruits, good drainage soil, application of leaching requirements, and using improved irrigation systems. Since groundwater is a precious resource, therefore, there is a need to preserve and protect this valuable resource by following preventive measures to control the contamination.

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