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Characterization and quality assessment of groundwater for irrigation in the Bhopalgarh tehsil of Jodhpur district, Rajasthan, India

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Abstract
In present study, the quality of groundwater for irrigation in Bhopalgarh tehsil of Jodhpur district, Rajasthan was examined. Bhopalgarh tehsil bounded by Nagaur district to the north and east, Pipar city tehsil to the south, Jodhpur tehsil to the southwest and Bawadi tehsil to the west. Georeferenced sixty water samples of tube well/open well were collected from different villages where the waters are being used for irrigation for last few years. The water samples were analyzed for various chemical properties like EC, pH, major cations: Na^+, Ca^{2+}, Mg^{2+}, K^+ and anions: CO_3^{2-}, HCO_3^-, Cl^- and SO_4^{2-}. Subsequently, residual sodium carbonate (RSC), sodium adsorption ratio (SAR), adjusted SAR, potential salinity and Mg/Ca ratio were also calculated. The quality of irrigation water was categorized on the basis of salinity (EC), sodicity (SAR) and alkalinity (RSC) into 4 salinity (C-1 to C-4) classes, 4 sodicity (S-0 to S-3) classes and 3 alkalinity (A-1 to A-3) classes, respectively. Besides this, the quality of irrigation water was also categorized on the basis of the EC, SAR and RSC into six classes viz. good, High-SAR saline, marginally saline, marginally alkali, alkali and highly alkali. The results showed that 21.66 percent water samples were good, 15 percent water samples were marginally saline, 48.33 percent water samples were High-SAR saline, 8.33 percent water samples were marginally alkali, 3.33 percent water samples were alkali and 3.33 percent water samples were highly alkali in nature and it is found that most of the irrigation water came under high-SAR saline category.

Keywords: groundwater, salinity, sodicity, classification, irrigation

Introduction
Water is the basic and essential natural resource, needed to ensure food security in sustainable manner. Sustainable development and efficient management of water is an increasingly complex challenge in India. Increasing population, growing urbanization and rapid industrialization combined with the need for raising agricultural production generates competing claims for water. Groundwater has an important role in meeting the water requirements of agriculture, industrial and domestic sectors in India. About 85 percent of India's rural domestic water requirement, 50 percent of its urban water requirement and more than 50 percent of its irrigation requirements are being met from groundwater resources. It has become the main source of growth in irrigated area over the past three decades and now it accounts for over 60 percent of the irrigated area in the country. It is estimated that over 70 percent of India's food grain production comes from irrigated agriculture, in which groundwater plays a major role (Gandhi and Namboodiri, 2009).
The ground water available for irrigation is estimated to be 36.42 million hectare-meters. Out of this, the utilizable ground water resources for irrigation are 32.77 million hectare meters or 90 percent. Over the last two decades, 84 percent of the total addition to net irrigated area came from groundwater, only 16 percent from canals (Briscoe and Malik, 2006). Indiscriminate use of poor quality water for irrigating agricultural crops decreases the productivity because of development of salinity, sodicity and toxic effects on crop plants. The saline water negatively affects soil chemical and biological properties whereas sodic water adversely impact soil physical, chemical and biological properties, making it difficult for plant growth and ultimately reduces crop yield (Emdad *et al.*, 2006). In India, 6.73 Mha of land is affected by salinity and sodicity (Singh *et al.*, 2009). About 10 Mha of land is lost because of

salinity caused by irrigation water each year. Out of total cultivated cropped area in Rajasthan, 1.183 Mha of land is salt affected (AICRP, 2010).

Although groundwater is widely distributed and renewable resources of the earth but the quality of this is not assured. Excessive pumping, low recharge, wrong agricultural practices have led to the situation of shrinkage groundwater and groundwater becoming brackish (Venu and Rishi, 2010). Therefore, an appraisal on the nature, properties and quality of irrigation water is essential for sound irrigation so as to assess any possibility of development of secondary salinization/sodification in this region.

Materials and methods

The Bhopalgarh tehsil is situated in the eastern part of the Jodhpur district between latitudes of 26°28'22" and 26°42'21" N and longitudes of 73°10'30" and 73°26'40" E and occupies an area of 2,491.64 sq. km. It falls under region 2nd of the agro-ecological map (Hot arid ecoregion with desert and saline soils) and in the IIB zone, named as transitional plain of Luni Basin. Georeferenced 60 water samples of tube well/open well were collected where the waters are being used for irrigation for last few years. Water samples were collected from various villages of Bhopalgarh tehsil in January 2018. In order to get representative samples, pump was kept in operation before collecting the sample. Collected samples were stored in cleaned, rinsed and properly label bottles. Before the bottles were corked, few drops of toluene were also added to check the microbial growth. The position of sampling points was recorded by GPS at each location. The water samples were analysed for various chemical properties like EC, pH, major cations: Na^+, Ca^{2+}, Mg^{2+}, K^+ and anions: CO_3^{2-}, HCO_3^-, Cl^- and SO_4^{2-} by the procedure outlined in USDA Handbook No. 60 (Richards, 1954). Residual sodium carbonate (RSC), sodium absorption ratio (SAR), adjusted SAR and potential salinity were calculated as described the following formulas:

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

$$SAR = \frac{Na}{\sqrt{Ca + Mg/2}}$$

$$Adj.\ SAR = SAR[(1+8.4-pHc)]$$

$$Potential\ salinity = Cl^- + \frac{1}{2} SO_4^{2-}$$

Results and Discussion

pH of water varied from 7.22 to 8.45 with an average value of 7.81. The minimum (7.22) and maximum (8.45) pH value were recorded in BGW_{41} and BGW_{30} ground water sample, respectively. The spatial variability of pH of groundwater is given in Fig 1. 98.33 percent samples are safe as per Ayers and Westcot (1976) guide line. Divekar *et al.* (2005) also observed that the higher concentration of bicarbonate in water samples responsible for the development of alkalinity and thereby the higher pH values. Similar result was also reported by Kumar *et al.* (2016), More *et al*. (2017) and Selvakumar *et al.* (2017). The electrical conductivity of water varied from 0.93 to 5.81 dSm^{-1} with the mean values of 2.97 dSm^{-1}. The minimum (0.93 dSm^{-1}) value observed in BGW_{27} water sample while, the maximum value (5.81 dSm^{-1}) was recorded in BGW_{50} water sample. The spatial variability of electrical conductivity of groundwater is given in Fig 2. As per classification of irrigation water given by Gupta (1986) based on electrical conductivity, most of the water samples show low to medium EC. This is mainly due to the presence of neutral salts of chloride and sulphate in ground water samples. Similar result was also reported by Rajput and Polara (2013), Chopra *et al.* (2014) and Kumar *et al.* (2017). RSC values varied from 0 to 4.50 meL^{-1} with the mean value of 0.27 meL^{-1}. The maximum (4.50 meL^{-1}) value was observed in BGW_{33} irrigation water sample and minimum value (0 meL^{-1}) was observed in various irrigation water samples (10 samples). The most of the samples of ground irrigation water show less than 1.25 RSC. Similar results also reported by Singh *et al.* (2006), Ashraf *et al*. (2013) and Kumar *et al.* (2017). The spatial variability of RSC values of groundwater is given in Fig 3. Sodium absorption ratio varied from 3.18 to 23.79 with the mean value of 12.29. The maximum value (3.18) was found in BGW_{48} water sample while minimum value (23.79) was found in BGW_{28} water sample. The spatial varability of SAR values of groundwater is given in Fig 4. Increased in SAR values of irrigation waters with the increase in pH and EC of irrigation water might be due to dominance of soluble Na^+ over Ca^{2+}, Mg^{2+}. Similar results were also obtained by Khan and Sharma (2007), Kumar *et al.* (2017) and More *et al*. (2017). Potential salinity varied from 3.98 to 47.51 with a mean value of 21.25 meL^{-1}. The minimum (3.98 meL^{-1}) and maximum (47.51 meL^{-1}) potential salinity values found with BGW_{27} and BGW_{44} irrigation water sample, respectively. The spatial variability of Potential salinity of groundwater is given in Fig 5. Due to continuous use of irrigation waters having higher concentration of chloride and sulphate salts might have resulted in increased salinity (EC) of irrigated fields. This results in accordance with the findings of Gupta (1979) and Bali *et al.* (2015). Mg/Ca ratio varied from 0.40 to 1.60 with a mean value of 0.94. The minimum (0.40) and maximum (1.60) values of Mg/Ca ratio were found in BGW_{49} and BGW_{60} irrigation water samples, respectively. Similar results were also reported by Girdhar and Yadav (1982) and Bali *et al.* (2015). Adj. SAR varied from 7.32 to 59.09 with a mean value of 29.13. The minimum value (7.32) of Adj. SAR was found in BGW_{28} and the maximum value (59.09) of Adj. SAR was found in BGW_{46} water sample. Similar results were also reported by Sharma *et al*. (2004).

Table 1: Chemical properties of irrigation water of Bhopalgarh tehsil

S.NO.	Sample code	pH	EC (dSm^{-1})	RSC (meL^{-1})	SAR	Potential salinity (meL^{-1})	Adj.SAR	Mg/Ca Ratio
1	2	3	4	5	6	7	8	9
1	BGW_1	7.49	4.01	0.00	10.43	33.10	25.03	0.88
2	BGW_2	7.89	1.45	3.30	8.77	8.14	18.41	0.88
3	BGW_3	7.93	3.53	1.50	15.46	25.16	37.10	1.00
4	BGW_4	7.90	3.32	2.60	15.87	23.09	38.08	1.03
5	BGW_5	7.63	3.37	0.40	13.49	23.97	33.73	0.94
6	BGW_6	8.10	2.92	2.30	16.95	20.54	35.59	1.15
7	BGW_7	7.95	4.36	1.20	16.70	32.84	41.75	0.97

8	BGW_8	7.58	3.57	0.00	11.09	27.35	27.73	1.08
9	BGW_9	7.73	3.58	0.90	14.03	26.23	35.07	0.78
10	BGW_{10}	7.72	3.72	0.80	13.87	26.11	34.68	0.82
11	BGW_{11}	7.70	3.02	0.80	14.78	24.88	33.99	1.14
12	BGW_{12}	8.10	2.66	2.60	12.01	17.37	28.81	1.03
13	BGW_{13}	8.12	2.70	4.20	17.37	17.70	38.21	1.11
14	BGW_{14}	7.93	2.76	1.20	12.30	19.27	27.06	0.66
15	BGW_{15}	8.35	1.94	3.30	12.20	12.45	26.83	1.46
16	BGW_{16}	8.06	1.46	2.00	10.00	9.78	20.00	1.28
17	BGW_{17}	7.43	1.76	0.20	6.64	10.62	15.27	0.76
18	BGW_{18}	7.69	1.13	0.40	4.01	5.67	8.82	0.50
19	BGW_{19}	8.10	1.06	2.00	6.81	5.59	13.62	1.15
20	BGW_{20}	7.85	1.39	1.00	6.16	7.33	12.93	0.83
21	BGW_{21}	7.63	1.25	0.30	4.07	6.41	9.37	0.89
22	BGW_{22}	7.50	1.68	1.50	7.31	9.39	16.09	0.50
23	BGW_{23}	7.55	3.20	0.00	10.51	19.93	27.32	0.89
24	BGW_{24}	7.73	1.30	0.70	4.78	6.87	11.00	0.57
25	BGW_{25}	7.92	0.97	1.50	6.39	5.34	11.50	1.08
26	BGW_{26}	8.34	0.98	3.40	7.40	4.30	13.32	1.50
27	BGW_{27}	7.99	0.93	1.60	3.68	3.98	8.09	1.22
28	BGW_{28}	7.72	1.02	0.80	3.18	4.16	7.32	1.04
29	BGW_{29}	8.00	1.50	4.40	8.50	6.16	19.54	1.25
30	BGW_{30}	8.45	1.53	4.20	9.07	6.56	19.94	1.42
31	BGW_{31}	7.31	3.62	0.00	8.93	29.70	23.22	1.04
32	BGW_{32}	8.22	2.53	1.60	10.50	14.99	25.20	1.13
33	BGW_{33}	7.93	2.31	4.50	14.74	13.78	30.96	0.59
34	BGW_{34}	8.07	2.34	2.80	10.80	13.54	25.92	1.07
35	BGW_{35}	7.83	1.35	1.40	8.64	9.40	16.41	0.66
36	BGW_{36}	8.10	1.28	3.20	5.66	5.23	13.01	1.09
37	BGW_{37}	7.44	1.94	0.20	7.62	12.54	19.05	0.81
38	BGW_{38}	7.72	2.48	0.70	12.77	18.54	26.82	0.45
39	BGW_{39}	7.62	3.26	0.00	13.55	26.92	32.51	0.63
40	BGW_{40}	7.33	3.60	0.00	9.08	29.31	23.62	0.77
41	BGW_{41}	7.22	3.62	0.00	11.03	27.80	27.58	1.03
42	BGW_{42}	7.73	3.60	0.50	12.81	25.68	32.03	0.84
43	BGW_{43}	7.40	5.50	0.00	12.59	46.95	33.99	0.95
44	BGW_{44}	7.42	5.56	0.00	12.22	47.51	33.00	0.95
45	BGW_{45}	7.89	5.02	0.70	20.30	37.70	48.72	0.53
46	BGW_{46}	7.88	4.96	1.50	19.70	38.12	59.09	0.58
47	BGW_{47}	7.90	5.16	1.80	20.75	39.66	51.87	0.54
48	BGW_{48}	8.10	3.74	2.00	23.79	28.97	49.95	1.10
49	BGW_{49}	7.71	3.63	0.80	18.08	28.29	41.58	0.40
50	BGW_{50}	7.76	5.81	0.50	19.52	44.17	50.75	0.80
51	BGW_{51}	7.70	3.10	0.70	16.16	24.48	35.54	0.89
52	BGW_{52}	7.89	3.92	1.10	19.34	29.21	44.48	0.78
53	BGW_{53}	7.49	3.60	0.00	10.48	28.40	26.20	1.22
54	BGW_{54}	7.72	3.57	0.80	15.13	27.46	36.30	0.84
55	BGW_{55}	7.84	4.20	1.00	15.62	29.36	39.06	1.04
56	BGW_{56}	8.12	4.26	2.00	17.95	31.67	44.89	1.05
57	BGW_{57}	8.14	4.67	2.00	19.15	33.16	47.88	1.11
58	BGW_{58}	7.70	4.53	0.60	17.73	33.44	42.55	1.05
59	BGW_{59}	7.73	3.17	0.40	14.49	22.90	33.32	0.87
60	BGW_{60}	7.82	3.53	1.00	14.49	25.90	36.22	1.60
Mean		7.81	2.97	0.27	12.29	21.25	29.13	0.94
Maximum		8.45	5.81	4.50	23.79	47.51	59.09	1.60
Minimum		7.22	0.93	0.00	3.18	3.98	7.32	0.40

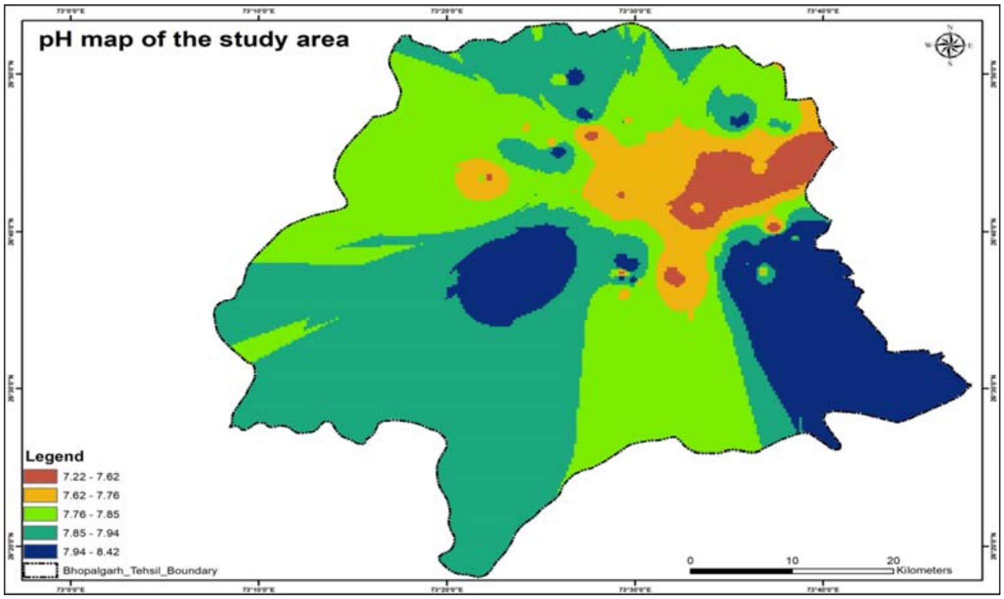

Fig 1: Spatial variability of pH of groundwater used for irrigation in Bhopalgarh tehsil.

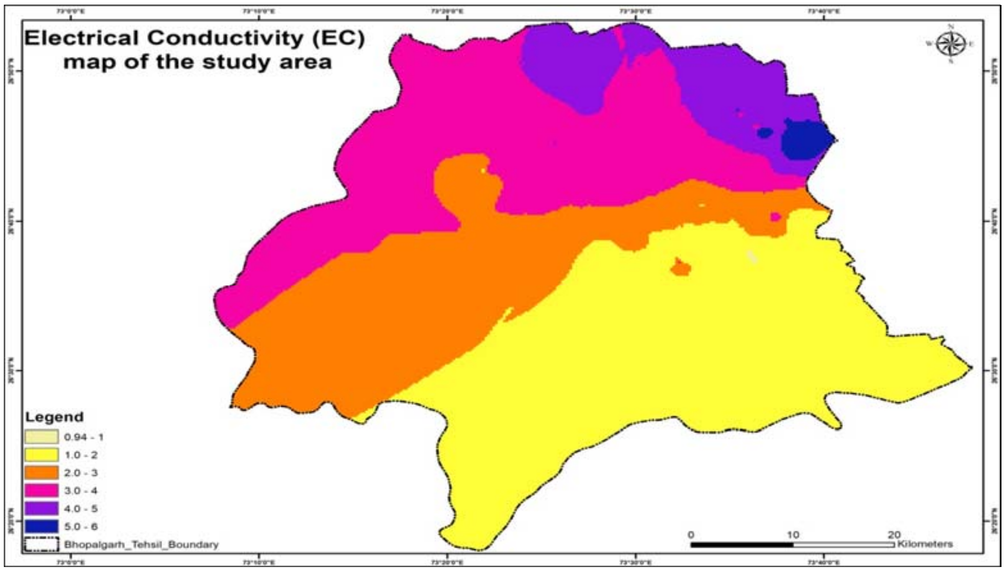

Fig 2: Spatial variability of EC of groundwater used for irrigation in Bhopalgarh tehsil.

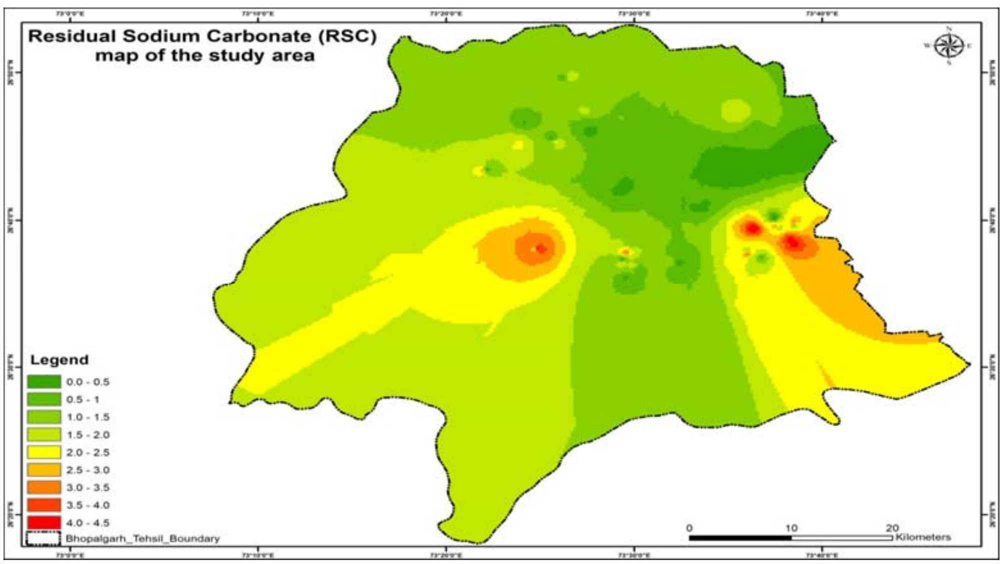

Fig 3: Spatial variability of RSC of groundwater used for irrigation in Bhopalgarh tehsil.

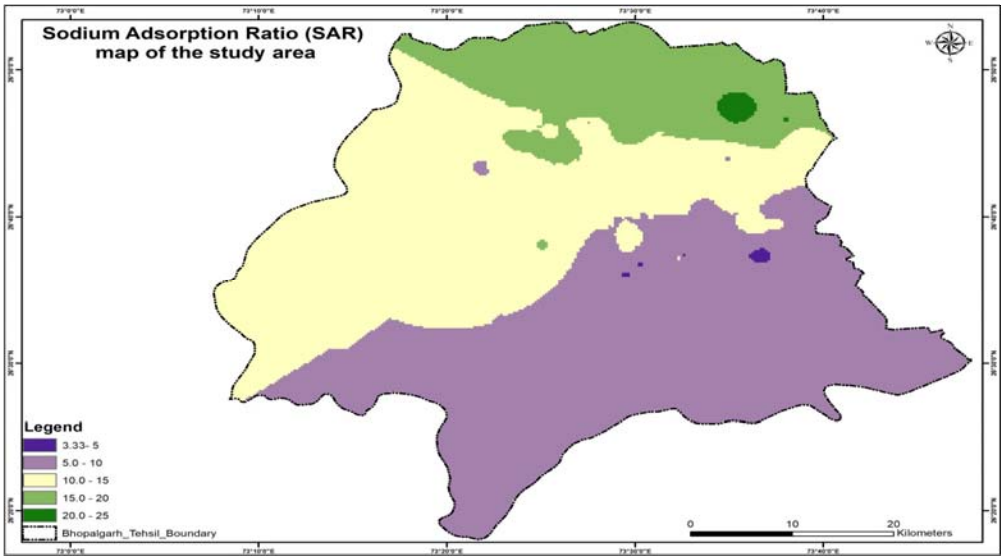

Fig 4: Spatial variability of SAR of groundwater used for irrigation in Bhopalgarh tehsil.

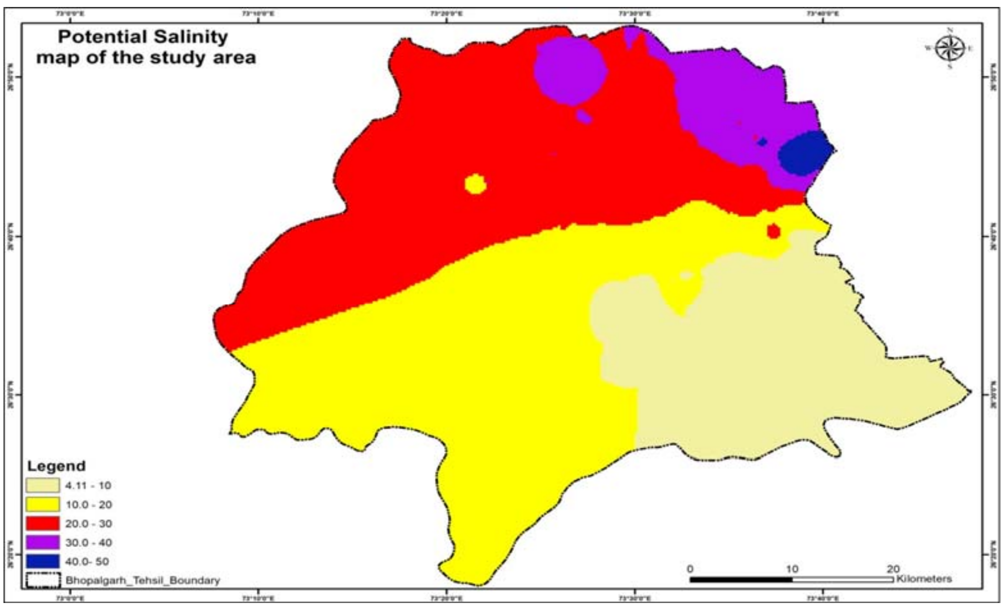

Fig 4: Spatial variability of potential salinity of groundwater used for irrigation in Bhopalgarh tehsil.

Soluble cation Ca^{2+} varied from 0.80 to 9.40 meL^{-1} with the mean value of 3.54 meL^{-1}. Soluble cation Mg^{2+} varied from 1.20 to 9.00 meL^{-1} with the mean value of 3.18 meL^{-1}. The presence of Ca^{2+} in groundwater might be attributed to calcium-rich minerals such as amphiboles, pyroxenes and feldspars and the Mg^{2+} in groundwater might be due to olivine mineral and the ion exchange is with the ions in minerals. Soluble cation Na^{+} varied from 5.08 to 45.36 meL^{-1} with the mean value of 22.44 meL^{-1}. In general, sodium was found dominant cation followed by magnesium and calcium. The presence of Na^{+} in groundwater primarily results from the chemical decomposition of feldspars, feldspathoids and some iron, magnesium minerals. Soluble cation K^{+} varied from 0.07 to 0.88 meL^{-1} with the mean value of 0.16 meL^{-1}. Soluble anion CO_3^{2-} varied from 0.40 to 1.50 meL^{-1} and HCO_3^{-} varied from 3.60 to 10 meL^{-1} with the mean value of 0.65 meL^{-1} and 6.35 meL^{-1}, respectively. The reason for carbonate (CO_3^{2-}) and bicarbonate (HCO_3^{-}) concentrations in groundwater can be ascribed to carbonate weathering as well as from the dissolution of carbonic acid in the aquifers. Soluble anion SO_4^{-2} varied from 0.37 to 9.85 meL^{-1} with the mean value of 3.47 meL^{-1}. Soluble anion Cl^{-} varied from 3.50 to 45 meL^{-1} with the mean value of 19.51 meL^{-1}. Chloride was observed as dominant anion in irrigation water of Bhopalgarh tehsil of Jodhpur district followed by bicarbonate and carbonate. The results are in accordance with the findings of Singh *et al*. (2006), Narsimha *et al*. (2013), Kumar *et al.* (2016), Kumar *et al*. (2017) and Selvakumar *et al.* (2017).

Table 2: Ionic composition of irrigation water of Bhopalgarh tehsil

S.NO.	Sample code	Cations (meL^{-1})				Anions (meL^{-1})			
		Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	CO_3^{2-}	HCO_3^-	SO_4^{2-}
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	BGW_1	26.79	0.22	7.00	6.20	31.00	0.40	5.00	4.21
2	BGW_2	11.09	0.18	1.70	1.50	7.80	0.50	6.00	0.67
3	BGW_3	28.50	0.12	3.40	3.40	22.00	1.20	7.10	6.32
4	BGW_4	27.25	0.12	2.90	3.00	20.40	1.00	7.50	5.37
5	BGW_5	25.60	0.15	3.70	3.50	22.00	0.60	7.00	3.95
6	BGW_6	24.85	0.13	2.00	2.30	18.00	0.40	6.20	5.08
7	BGW_7	34.02	0.16	4.20	4.10	31.20	1.50	8.00	3.28
8	BGW_8	24.55	0.16	4.70	5.10	25.40	0.40	5.20	3.91
9	BGW_9	26.80	0.16	4.10	3.20	25.20	1.20	7.00	2.06
10	BGW_{10}	26.50	0.22	4.00	3.30	25.30	1.00	7.10	1.62
11	BGW_{11}	25.60	0.16	2.80	3.20	24.00	0.80	6.00	1.76
12	BGW_{12}	20.62	0.11	2.90	3.00	15.60	1.00	7.50	3.53
13	BGW_{13}	23.30	0.11	1.70	1.90	15.40	0.80	7.00	4.61
14	BGW_{14}	20.40	0.14	3.30	2.20	18.40	0.80	5.90	1.74
15	BGW_{15}	16.59	0.11	1.50	2.20	10.70	0.80	6.20	3.50
16	BGW_{16}	12.65	0.11	1.40	1.80	8.40	0.40	4.80	2.76
17	BGW_{17}	11.50	0.13	3.40	2.60	9.40	0.40	5.80	2.43
18	BGW_{18}	6.21	0.12	3.20	1.60	5.00	0.40	4.80	1.33
19	BGW_{19}	8.06	0.12	1.30	1.50	4.60	0.40	4.40	1.98
20	BGW_{20}	9.13	0.13	2.40	2.00	6.00	0.40	5.00	2.66
21	BGW_{21}	6.63	0.09	2.80	2.50	6.00	0.40	5.20	0.82
22	BGW_{22}	10.60	0.28	2.80	1.40	9.00	0.40	5.30	0.78
23	BGW_{23}	22.66	0.09	4.90	4.40	15.00	0.80	7.20	9.85
24	BGW_{24}	7.93	0.11	3.50	2.00	5.60	0.80	5.40	2.54
25	BGW_{25}	7.14	0.14	1.20	1.30	4.50	0.40	3.60	1.68
26	BGW_{26}	7.40	0.20	0.80	1.20	4.00	0.40	5.00	0.60
27	BGW_{27}	5.20	0.17	1.80	2.20	3.80	0.40	5.20	0.37
28	BGW_{28}	5.08	0.14	2.50	2.60	3.50	0.40	5.50	1.32
29	BGW_{29}	11.40	0.11	1.60	2.00	4.80	0.40	7.60	2.71
30	BGW_{30}	11.82	0.11	1.40	2.00	5.00	0.40	7.20	3.13
31	BGW_{31}	22.86	0.25	6.40	6.70	28.40	0.40	5.20	2.61
32	BGW_{32}	18.78	0.20	3.00	3.40	12.20	0.40	7.60	5.58
33	BGW_{33}	19.50	0.16	2.20	1.30	11.60	0.80	7.20	4.36
34	BGW_{34}	18.07	0.20	2.70	2.90	10.80	0.80	7.60	5.47
35	BGW_{35}	10.58	0.22	1.80	1.20	9.00	0.40	4.00	0.80
36	BGW_{36}	8.39	0.08	2.10	2.30	4.80	0.40	7.20	0.87
37	BGW_{37}	13.20	0.28	3.30	2.70	11.40	0.40	5.80	2.28
38	BGW_{38}	19.16	0.23	3.10	1.40	18.00	0.40	4.80	1.09
39	BGW_{39}	25.70	0.24	4.40	2.80	25.90	0.40	5.20	2.04
40	BGW_{40}	22.98	0.23	7.20	5.60	26.80	0.40	4.20	5.01
41	BGW_{41}	25.40	0.20	5.20	5.40	25.00	0.80	5.60	5.60
42	BGW_{42}	26.10	0.16	4.50	3.80	24.80	0.80	8.00	1.76
43	BGW_{43}	37.34	0.16	9.00	8.60	44.40	0.40	5.60	5.10
44	BGW_{44}	37.07	0.15	9.40	9.00	45.00	0.40	5.60	5.02
45	BGW_{45}	40.60	0.10	5.20	2.80	35.00	0.40	8.30	5.40
46	BGW_{46}	39.64	0.09	5.10	3.00	36.80	1.20	8.40	2.63
47	BGW_{47}	42.01	0.10	5.30	2.90	37.60	1.40	8.60	4.11
48	BGW_{48}	33.64	0.11	1.90	2.10	25.80	0.40	5.60	6.35
49	BGW_{49}	30.25	0.12	4.00	1.60	26.20	0.80	5.60	4.17
50	BGW_{50}	45.36	0.11	6.00	4.80	42.06	1.30	10.00	4.21
51	BGW_{51}	26.30	0.17	2.80	2.50	22.00	1.20	4.80	4.97
52	BGW_{52}	32.65	0.16	3.20	2.50	26.31	0.40	6.40	5.80
53	BGW_{53}	24.69	0.22	5.00	6.10	26.00	0.40	5.20	4.81
54	BGW_{54}	28.30	0.21	3.80	3.20	26.40	0.80	7.00	2.11
55	BGW_{55}	32.40	0.11	4.20	4.40	26.00	1.20	8.40	6.71
56	BGW_{56}	35.00	0.11	3.70	3.90	29.24	1.00	8.60	4.87
57	BGW_{57}	36.84	0.88	3.50	3.90	30.00	0.60	8.80	6.32
58	BGW_{58}	35.01	0.08	3.80	4.00	32.00	0.40	8.00	2.89
59	BGW_{59}	25.09	0.11	3.20	2.80	20.60	0.40	6.00	4.60
60	BGW_{60}	27.68	0.12	2.80	4.50	24.00	1.00	7.30	3.80
Mean		22.44	0.16	3.54	3.18	19.51	0.65	6.35	3.47
Maximum		45.36	0.88	9.40	9.00	45	1.50	10.00	9.85
Minimum		5.08	0.07	0.80	1.20	3.5	0.40	3.60	0.37

According to classification (Gupta *et al.* 1994) of irrigation water based on EC, SAR and RSC the irrigation water were classified into six categories. 21.66 percent water samples were good, 15 percent water samples were marginally saline, 48.33 percent water samples were High-SAR saline, 8.33 percent water samples were marginally alkali, 3.33 percent water samples were alkali and 3.33 percent water samples were highly alkali in nature. Most of the irrigation water came under high-SAR saline category.

Table 3: Samples under different categories of water qualities of Bhopalgarh tehsil and recommended practices (Gupta *et al.* 1994).

S. No.	Water quality	No. of Samples	percent of samples
1	2	3	4
1.	Good (EC<2 dSm^{-1}, SAR<10 and RSC<2.5 meL^{-1})	13	21.66
2.	Marginally saline (EC2-4 dSm^{-1}, SAR<10 and RSC<2.5 meL^{-1})	9	15
3.	Saline (EC>4 dSm^{-1}, SAR<10 and RSC<2.5 meL^{-1})	-	-
4.	High-SAR saline (EC>4 dSm^{-1}, SAR>10 and RSC<2.5 meL^{-1})	29	48.33
5.	Marginally alkali (EC<4 dSm^{-1}, SAR<10 and RSC 2.5-4.0 meL^{-1})	5	8.33
6.	Alkali (EC<4 dSm^{-1}, SAR<10 and RSC>4 meL^{-1})	2	3.33
7.	Highly alkali (EC variable, SAR>10 and RSC>4 meL^{-1})	2	3.33

Conclusion

It is concluded that good quality and marginally saline waters can be successfully used for crop production without any hazardous effect on soil and plant. Alkali waters can be used with special management practices depending upon soil type, crop to be grown and rain fall of the region. Waters classified as highly alkali and high SAR saline are generally unfit for crops can be used in conjunction with canal water by cyclic mode or applying gypsum as amendment to neutralize the RSC of the irrigation waters. As the soils of Bhopalgarh tehsil are light textured, this water can also be used without appreciable sodium hazard.

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