International Journal of Advanced Biochemistry Research 2024; 8(4): 508-514

International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
IJABR 2024; 8(4): 508-514
www.biochemjournal.com
Received: 07-01-2024
Accepted: 16-02-2024

DV Mali
Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth Akola, Maharashtra, India

SM Jadhao
Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth Akola, Maharashtra, India

AR Salunke
Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth Akola, Maharashtra, India

PR Kadu BA Sonune
Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth Akola, Maharashtra, India

PS Solunke
Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth Akola, Maharashtra, India

Corresponding Author:
DV Mali
Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth Akola, Maharashtra, India

Appraisal of water quality of Akot and Balapur Block in Purna tract of Vidarbha region of Maharashtra

DV Mali, SM Jadhao, AR Salunke, PR Kadu BA Sonune and PS Solunke

DOI: https://doi.org/10.33545/26174693.2024.v8.i4g.999

Abstract
The present investigation entitled "Appraisal of Water Quality in Akot and Balapur tehsil in Purna Tract of Vidarbha Region" was undertaken during 2018-2020 in Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra. Fourty water samples from borewell and other sources from Akot and Balapur tehsils of Akola district of Maharashtra consisting of river, farm pond, dam were collected and analyzed for various quality parameters. The irrigation water was having high salinity and low sodium hazard (C_3S_1) during post monsoon (winter) season, amongst the cations Ca^{2+}, Mg^{2+} and K^+ was within the permissible limit in borewell and other sources of irrigation, except sodium which was above permissible limit in borewell water as well as other sources of irrigation. The all anionic composition in which HCO_3^- and Cl^- was above permissible limit and SO_4^{2-} were, below permissible limit in post monsoon season. Total dissolved solid in ground water were categorized as permissible to unsuitable. The sodium adsorption ratio was within the permissible limit in post monsoon season, Whereas the adjusted sodium adsorption ratio some samples falls above acceptable range and Mg: Ca ratio all samples during post monsoon (winter) season falls in permissible limit. As per Kelley's ratio the all samples during post monsoon season was within the permissible limit, except three samples crossed the permissible limit**.** On the basis of permeability index ground water was fall in class II which categorized as medium during post monsoon season. The residual sodium bicarbonate of all samples during post monsoon were found in above acceptable range. As per magnesium adsorption ratio all samples from both the sources found within the permissible limit during post monsoon season. Soluble sodium percentage of the all ground water samples during post monsoon season from both the sources are unsuitable for irrigation.

Keywords: Bore well, water sources, salinity, Kelley's ratio, Mg: Ca ratio

Introduction

Irrigation water is an essential and vital component of our life support system. It has become one of the important sources of water for meeting the requirements of various sectors of water use including agriculture in the country. At present, groundwater meets 65% of India's water demand and accounts for roughly half of the irrigated area. It plays a vital role in country's economic development and in ensuring its food security. In addition, ground water development for irrigation has been recognized over the last decade as having the potential to play a major role in rural poverty alleviation. The number of mechanized bore wells in India has increased from less than a million in 1960 to about 28 million in 2002 (Mukherji and Shah, 2005) [24] and every year there is an addition of 0.8 million wells

Irrigation water is an important input in agricultural productivity, and irrigated agriculture is dependent on adequate water supply of usable quality. Characteristics' of irrigation water that defines it's quality vary with source of water. The natural chemical composition of ground water is influenced predominantly by type and depth of soils and subsurface geological formations through which ground water passes. Therefore, the quality of ground water varies from place to place, with the depth of water table and from season to season and is primarily governed by the extent and composition of dissolved solids present in it.

Materials and Methods

Borewell and other sources i.e. well, farm pond, river water was identified as the potential source of irrigation water. The water samples were collected by using GPS and were analyzed for various quality parameters.

The standard procedures were applied to analyze the samples for various quality parameters. Total forty water samples were collected in post monsoon (winter) October-February, soil sample has been collected from the same field. The water samples analyzed for various quality parameters as well as soil samples for its ionic composition.

Results and Discussion

pH: The pH of the borewell water was in the range of 7.55 to 8.89 and other source was in the range of 7.41 to 8.95 (Table 1). The average value of pH of samples from both the sources were above permissible limit. The borewell water which exceeds limits of 8.0 reflects that the entire water contains higher soluble sodium and bicarbonates which interfere the hydroxyl ion concentration in water and increased pH values towards alkalinity.

Patil *et al*. (2014) [27] reported the similar results in respect of increase in pH due to concentration of sodium salts dominated with carbonate and bicarbonate in summer season. The results are also in conformity with findings placed by Abubacker *et al.* (1996) [1]. The lower value of pH during rainy season may be due to dilution of rain water Latha *et al.* (2010) [21].

Electrical conductivity (EC)

The electrical conductivity of irrigation water i.e. borewell and other sources was in the range of 1.52 to 2.83 dSm^{-1} and 1.20 to 2.62 dSm^{-1} respectively (Table 2). In most of the cases, the EC was higher than the recommended water quality guidelines for irrigation water use in agriculture, criteria given by Richards, 1954 [29] i.e. <0.25 dSm^{-1}, but when we consider the criteria given by Bhumbla and Abrol, (1972) [6] for Indian clay soil i.e. 1.5 dSm^{-1} for semi tolerant crop and 2.0 dSm^{-1} for tolerant crop it was in normal range, The grouping of water quality is adopted and recommended at national level (Minhas and Tyagi, 1998) [23], and as per the criteria given by Central Salinity Research Institute (CSSRI) Karnal, the borewell water from Purna valley was "marginally saline".

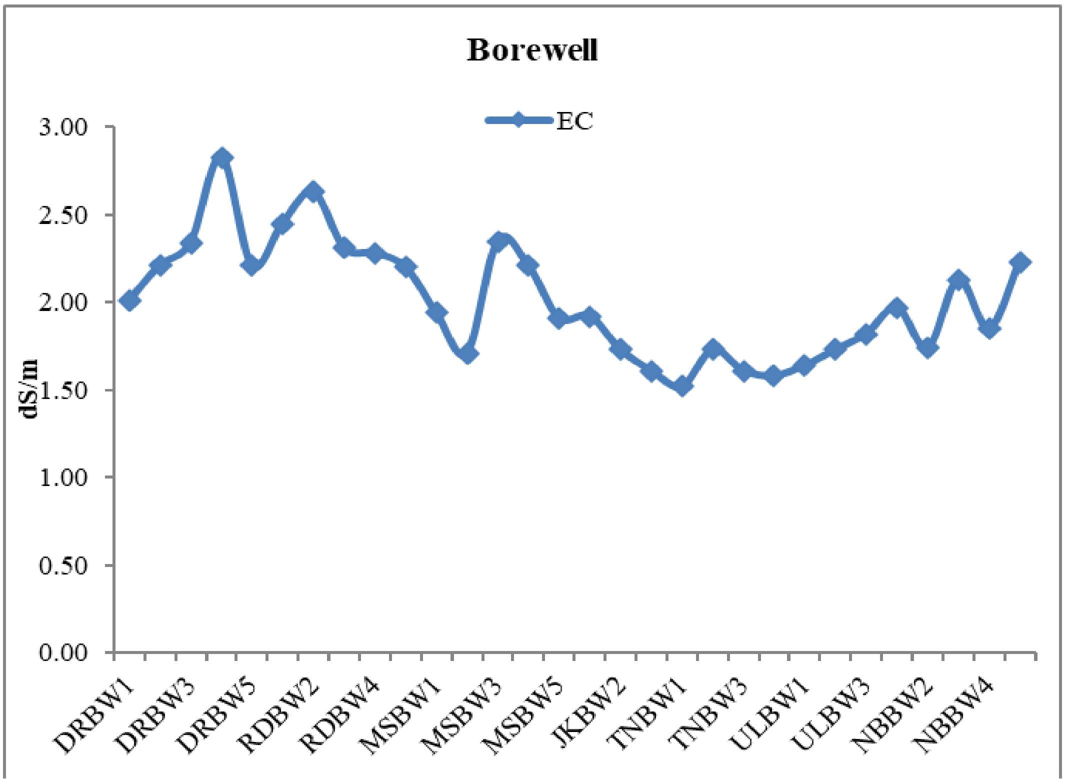
Electrical conductivity is a measurement of all soluble salt in water, the most significant water quality standard for crop productivity was the water salinity hazard. The higher the electrical conductivity lesser the water available to plant, because plant can only transpire "pure" water, therefore, irrigation water with high electrical conductivity reduce the yield potential. Similar results were observed by (Handa, 1969) [12].

Table 1: pH of irrigation water

Source	pH			
	Range		Average	CV
	Min	Max		
Borewell	7.55	8.89	8.18	0.04
Other	7.41	8.95	7.88	0.06

Table 2: Electrical Conductivity (dSm^{-1}) of irrigation water

Source	Electrical conductivity (dSm^{-1})			
	Range		Average	CV
	Min	Max		
Borewell	1.52	2.83	2.01	0.16
Other	1.2	2.62	1.80	0.24



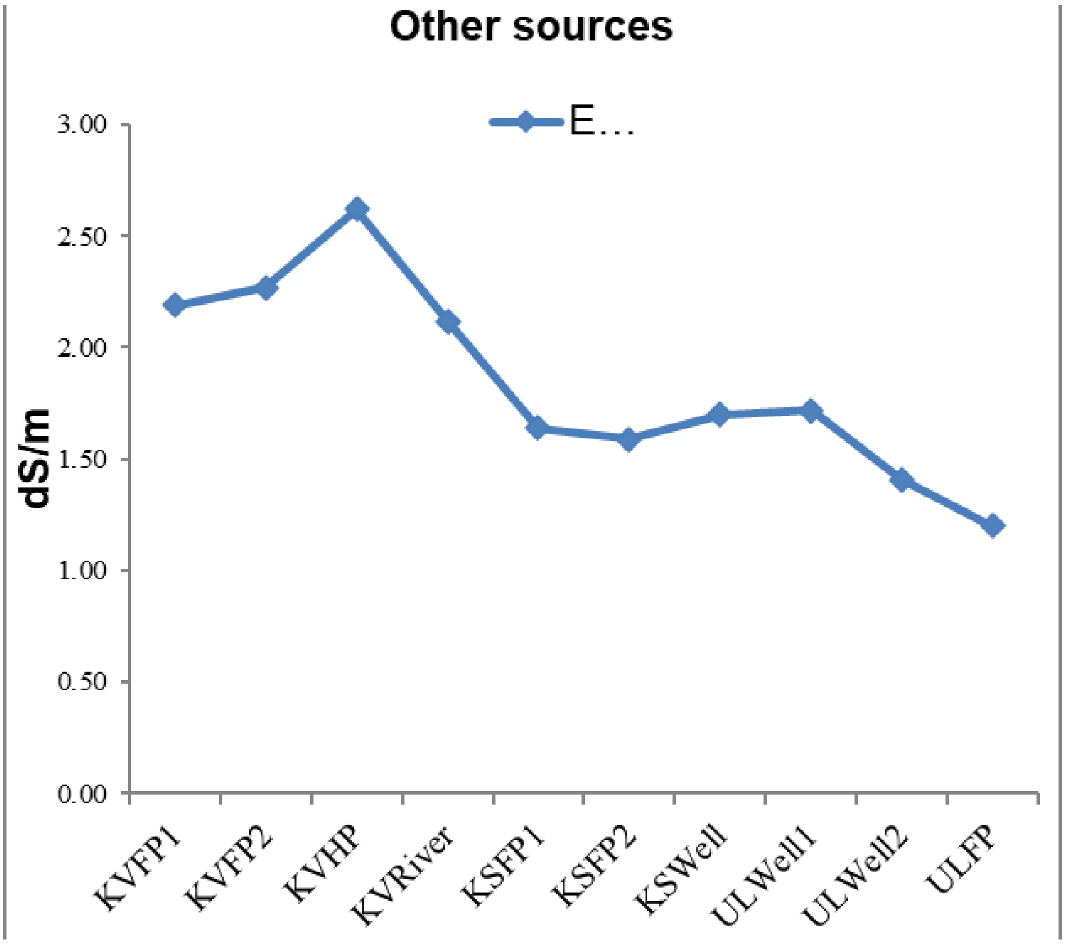


Fig 1: Electrical conductivity of water

Cation content in various ground water sources

The calcium content in borewell water was 4.21 to 7.33 meL^{-1} which was within the normal range of 0-20 meL^{-1} however the calcium content from other sources of irrigation was 3.79 to 6.41 meL^{-1} which was comparatively lower than borewell water. The concentration of magnesium was in the range of 2.78 to 4.89 meL^{-1} in borewell water and 2.56 to 4.79 meL^{-1} in other sources during post monsoon season which was within permissible limit (0-5 meL^{-1}). The sodium concentration in borewell water was in between 7.92 to 11.95 meL^{-1} and from other sources was in the range of 6.23 to 10.62 meL^{-1} respectively, which can cause dispersion in soil. The sodium content of borewell water and other sources was higher during post monsoon season which clearly indicates that it was above the permissible limit of sodium content in irrigation water i.e.<3 meL^{-1}. The Potassium concentration was very low in the borewell water and it was in between 0.10 to 0.21 meL^{-1} whereas in other sources of irrigation it ranges between 0.12 to 0.21 meL^{-1} respectively. This content of potassium in irrigation water was found below the permissible limit i.e. < 2 meL^{-1}. The potassium is cation which was found in water due to the presence of potassium chloride (Table 3).

In a nut shell it can be concluded that the sodium was the dominant cation in irrigation water followed by calcium, magnesium and potassium. The dominancy of Na^+ over $Ca^{2+}$and Mg^{2+} may be one of the geological causes for development of native sodicity in Purna valley soil. Babhulkar *et al*. (2009) [4].

The irrigation water that has high sodium (Na^+) content can bring about a displacement of exchangeable cation $Ca^{2+}$and $Mg^{2+}$from the clay minerals of the soil, followed by the replacement of the cations by sodium (Islam and Shamsad, 2009) [13].

Table 3: Cation content in irrigation water (meL^{-1})

Source	Ca (meL^{-1})				Mg (meL^{-1})				Na (meL^{-1})				K (meL^{-1})			
	Range		Average	CV	Range		Average	CV	Range		Average	CV	Range		Average	CV
	Min	Max			Min	Max			Min	Max			Min	Max		
Borewell	4.21	7.33	5.82	0.11	2.78	4.89	3.83	0.12	7.92	11.95	9.61	0.10	0.10	0.21	0.13	0.20
Other	3.79	6.41	5.34	0.15	2.56	4.39	3.64	0.17	6.23	10.62	8.85	0.15	0.12	0.21	0.17	0.17

Anion content in ground water

The bicarbonate concentration in borewell water was in the range of 8.72 to 13.73 meL^{-1} while in other sources it was in the range of 8.41 to 12.13 meL^{-1} in post monsoon season. Most of the values in respect of bicarbonates of water sample from both sources fall into "slight to moderate" and "severe" degree of restriction to use (UCCC, 1974). The bicarbonate content can bring about a change insoluble sodium percentage in irrigation water, which regulates the sodium hazards (Adhikari and Biswas, 2011) [2], whereas the chloride content in irrigation water from borewell was varied from 3.29 to 9.45 meL^{-1} and from other sources was varied from 3.11 to 9.12 meL^{-1}, which exceeds the permissible limit of 4 meL^{-1} indicates the impact of settlement and anthropogenic effect. lslam *et al.* (1999) [14], reported that the chloride content normally increases as the mineral content increase and may reduce phosphorus availability to plants. The concentration of sulphate was in between 1.53 to 4.03 meL^{-1} from borewell and 0.97 to 3.62 meL^{-1} from other sources of irrigation, which was within the permissible limit given by Richards (1954) [29]. Sulphate is relatively common in irrigation water and has no major effect on the soil, other than contributing to the total salt content. Irrigation water high in sulphate ion reduced phosphorus availability to plants Khalil *et al.* (2010) [20], Table 4.

Table 4: Anion content in irrigation water (meL^{-1})

Source	HCO_3 (meL^{-1})				Cl^- (meL^{-1})				SO_4^{2-} (meL^{-1})			
	Range		Average	CV	Range		Average	CV	Range		Average	CV
	Min	Max			Min	Max			Min	Max		
Borewell	8.72	13.73	10.76	0.12	3.29	9.45	6.03	0.30	1.53	4.03	2.58	0.29
Other	8.41	12.13	10.13	0.13	3.11	9.12	5.92	0.38	0.97	3.62	2.26	0.35

Nitrate- nitrogen content in irrigation water

The Nitrate-nitrogen content in borewell water was in the range of 1.52 to 7.43 mgL^{-1} whereas from other sources it was in the range of 1.43 to 5.67 mgL^{-1} respectively (Table,5). Nitrates enter in an aquatic body from various sources such as erosion of natural resources or soil, as well as application of fertilizer into the soil and through rainfall and sewage. Hence content of NO_3-N is based on the geography and cropping system in particular area (Kapoor, 2011) [16]. In concern to the Purna valley, the native salinity method of fertilization and content of salt and minerals in various water sources contributed in enhancing the content of NO_3-N in water (Bamniya, 2011) [16].

Table 5: Nitrate- nitrogen content in irrigation water (mgL^{-1})

Source	NO_3-N (mgL^{-1})			
	Range		Average	C.V.
	Min	Max		
Borewell	1.52	7.43	4.87	0.37
Other	1.43	5.67	3.61	0.45

Derived parameters

Total Dissolved Salts (TDS)

Total dissolved solids generally reflect the amount of dissolved mineral content in water and controls its suitability for use. High concentration of total dissolved solids causes adverse effects. The total dissolved solids from borewell irrigation water was in the range of 973 to 1811 mgL^{-1} whereas the total dissolved solids of water samples collected from other sources of irrigation is in the range of 768 to 1677 mgL^{-1} (Table,6). The total dissolved solids in water is having greater effects while irrigating the fields because many of the toxic salt material may be imbedded in the water which may be harmful to the plants (Matthess, 1982). As per the total dissolved solid content in irrigation water the water can be categorized as " moderate" and "severe" for irrigation purpose.

Table 6: TDS of irrigation water (mgL^{-1}).

Source	TDS (mgL^{-1})			
	Range		Average	CV
	Min	Max		
Borewell	973	1811	1288	106
Other	768	1677	1157	158

SAR, Adj. SAR and Adjusted RNa of irrigation water

Sodium Adsorption Ratio (SAR): The sodium adsorption ratio was in the range of 3.66 to 5.39 $mmol^{1/2} L^{-1/2}$ and other sources of irrigation ranges from 3.50 to 4.62 $mmol^{1/2} L^{-1/2}$ As per the criteria given by Richards (1954) [29] sodium adsorption ratio in the villages were within the permissible limit and irrigation water samples fall under low to medium sodium hazards class. Accumulation of salts in lower layer was observed due to transportation of dissolved salts from upper horizons with percolating water. Excess use of borewell water for irrigation was believed to be one of the major causes of water logging and salinization as most of the salts like Na leached to impounded deep water.

High sodium adsorption ratio in any irrigation water implies hazards of sodium (Alkali) replacing Ca^{2+} and Mg^{2+} of the soil through cation exchange process, a situation eventually damaging of soil structure like permeability which ultimately affect the fertility of soil and reduce crop yield (Gupta, 2005) [11].

Adjusted Sodium Adsorption Ratio (Adj. SAR)

The adjusted sodium adsorption ratio of borewell water was in the range of 2.32 to 7.93 whereas the Adjusted SAR from other sources of irrigation was 2.07 to 7.24 respectively as shown in Table 8. The coefficient of variance of Adj. SAR of borewell water was lower than other sources of irrigation which indicate there is variation of adjusted SAR in water sample. The adj.SAR is basically used for assessment of alkalinity hazard in irrigation water.

The presence of bicarbonate and carbonate ions in the irrigation water increases the permeability hazard as quantified by sodium adsorption ratio (Bauder, 2011) [5]. The result showed that the concern due to sodium hazard of the water became more emphatic because in all water samples adj.SAR is higher than SAR. (Nagaraju *et al.* (2014) [25].

Adjusted RNa

The Adj. RNa of borewell water was in the range of 4.25 to 5.75 and that of other sources having range of 3.22 to 5.31, The Adjusted RNa, can be used to predict more correctly potential infiltration problem due to relatively high sodium (or low calcium) in irrigation supplies and can be substituted for sodium adsorption ratio which is concern to the standards for Adjusted RNa given by (Ayers, 1985) [3]. The concept regarding sodium hazards from irrigation water developed by Bower and Massland (1963) is being used to predict the effect of sodium hazard on soil properties which in turn affect plant growth and yield.

Table 7: Sodium Adsorption Ratio, Adjusted SAR and Adjusted RNa of irrigation water

Source	SAR				Adjusted SAR				Adjusted RNa			
	Range		Average	CV	Range		Average	CV	Range		Average	CV
	Min	Max			Min	Max			Min	Max		
Borewell	3.66	5.39	4.37	0.09	2.32	7.93	5.27	0.28	4.25	5.75	4.95	0.10
Other	3.50	4.62	4.14	0.08	2.07	7.24	6.14	0.26	3.22	5.31	4.57	0.13

Magnesium Calcium Ratio (Mg: Ca) and Kelley's Ratio (KR) of irrigation water

Magnesium Calcium Ratio (Mg: Ca)

The magnesium calcium ratio in borewell was ranged between 0.49 to 1.05 however it was in the range of 0.64 to 0.83 in other sources respectively which was within acceptable range.

The high magnesium calcium ratio increases the exchangeable magnesium on soil exchange complex and build up magnesium calcium ratio in the soil which increases with increase in the magnesium calcium ratio in the irrigation water. Proportion of magnesium over calcium in ground water enhances sodification of soils at given adsorption ratio and electrical conductivity. The crop yield is affected adversely as magnesium calcium ratio in the irrigation water when it exceeds 2.0. Similar results were reported by Girdhar and Yadav (2004) [10] and Kanaskar (2007) [17]. High Mg^{2+}/Ca^{2+} ratio can increase precipitation of calcium, phosphates and carbonates which are less soluble than their magnesium counterparts.

Mg hazard in irrigation water is expressed in the ratio of Ca^{2+}/Mg^{2+} less than one. However, the water samples in the present study showed the mean value less than one. So the water samples collected during this study showed the less Mg hazard. A similar result of the Ca^{2+}/Mg^{2+} ratios was also reported by Kharde (1992) [19].

Kelley's Ratio (KR)

In the present study values of Kelley's ratio of borewell water was in the range of 0.81 to 1.28 and that of irrigation water collected from other sources was in the range of 0.77 to 1.05 displayed in Table 9.

The level of Na^+ measured against Ca^{2+} and Mg^{2+} is known as Kelley's ratio, and it is used to rate irrigation waters (Kelley, 1940; Paliwal, 1967) [18, 26]. Kelley's ratio describes the concentration of Na in irrigation water and further it can explain the workability of application Na of irrigation water in field. Based on Kelley ratio, the water can be classified in suitable and not suitable for irrigation. When Kelly's ratio is more than 1 it indicated excess level of sodium in irrigation water while when it will be less than 1 it can be recommended for irrigation.

Table 8: Magnesium: Calcium Ratio (Mg:Ca) and Kelley's Ratio (KR) of irrigation water

Source	Mg/Ca Ratio				Kelley's Ratio			
	Range		Average	CV	Range		Average	CV
	Min	Max			Min	Max		
Borewell	0.49	1.05	0.67	0.20	0.81	1.28	0.99	0.08
Other	0.64	0.83	0.68	0.09	0.77	1.05	0.96	0.05

Magnesium Adsorption Ratio (MAR)

The magnesium adsorption ratio of collected from borewell water was in the range of 32.87 to 51.27 and from other sources was in the range of 39.04 to 41.76. The MAR is the excess amount of magnesium over calcium. Generally, the source of magnesium in groundwater is due to ion exchange of minerals from rocks and soils by water (Mukherji *et al.* 2005) [24]. The high MAR (>50) results in increase soil alkalinity and affects the crop yield.

Magnesium content in bore well water and other sources is considered as one of the most important qualitative criteria in determining the quality of water for irrigation. Generally, calcium and magnesium maintain a state of equilibrium in most waters. More magnesium in water will adversely affect crop yield as the soil become more saline Joshi *et al.* (2009) [15].

Table 9: Magnesium Adsorption Ratio (MAR) of irrigation water

Source	Magnesium Adsorption Ratio			
	Range		Average	CV
	Min	Max		
Borewell	32.98	51.27	39.87	0.11
Other	39.04	41.76	40.13	0.02

Residual sodium carbonate (RSC) and Residual Sodium Bicarbonate (RSBC) of irrigation water

Residual sodium carbonate (RSC)

The residual sodium carbonate content of borewell was in the range of 0.08 to 3.12 meL^{-1} which was classified under high as per criteria of suitability of irrigation water given by Richards (1954) [29]. Whereas the RSC of water collected from other sources of irrigation was in the range of 0.18 to 2.98 meL^{-1}. Water contain appreciable quantity of carbonate, bicarbonate, calcium and magnesium which precipitate dawn the concentration of soil solution increase through evapotranspiration (Eaton, 1950) [9].

Residual Sodium Bicarbonate (RSBC)

The residual sodium bicarbonate in the collected water samples was recorded in the range of 3.34 meL^{-1} to 7.59 meL^{-1} in borewell and 3.49 meL^{-1} to 6.89 meL^{-1} in other sources in Table 10. As per the criteria, both the sources of water was above permissible limit or unsafe for irrigation. The residual sodium bicarbonate values are less than 3.0 meL^{-1} and are therefore considered as safe for irrigation purpose.

The RSBC values classified into three group safe marginal and unsafe (Wilcox, 1955) [32]. So as per the results the irrigation water collected from bore well were unsafe.

The concentration of bicarbonate influences the suitability of water for irrigation purpose. The water with high residual sodium bicarbonate has high pH. Therefore, land irrigated with such water becomes infertile owing to deposition of sodium carbonate (Eaton, 1950) [9].

Table 10: Residual Sodium Bicarbonate (RSBC) and Residual Sodium Carbonate (RSC)

Source	RSBC (meL^{-1})				RSC (meL^{-1})			
	Range		Average	CV	Range		Average	CV
	Min	Max			Min	Max		
Borewell	3.34	7.59	4.94	0.20	0.08	3.12	1.10	0.79
Other	3.49	6.89	4.78	0.22	0.18	2.98	1.04	0.86

Permeability Index (PI) Soluble Sodium Percentage (SSP) and Chloro Alkaline Indices - Ion (CAI-I) of irrigation water

Permeability Index (PI)

The permeability index of borewell and other sources of irrigation water respectively. In the present study the minimum and maximum permeability of borewell was in range between 62.27 to 70.48% and PI of other sources 64.01 to 73.80% hence, as per the permeability index the collected water samples were suitable for irrigation from other sources of irrigation. The soil permeability is affected by long term use of irrigation water and sodium, calcium, magnesium content in the soil (Raju, 2007) [28]. According to Doneen (1964) [8], The permeability Index can be categorized in three classes: class I (> 75%, suitable), class II (25–75%, good) and class III (< 25%, unsuitable). Water under class I and class II are recommended for irrigation.

Soluble sodium percentage (SSP)

The soluble sodium percentage of studied borewell water was in the range of 44.83 to 55.36% and that of water samples from other sources ranges from 47.60 to 51.85%. The data generated in respect of water sample collected from borewell having high alkali hazard and was classified in unfair Class Ill (Wilcox, 1955) [32]. Soluble sodium percentage is an important factor for studying sodium hazard. It also used for adjudging the quality of water for agricultural purpose, Joshi *et al.* (2009) [15]. The use of high percentage sodium water for irrigation purpose stunting in of the plant growth. Sodium reacts with soil and reduces its permeability (Todd and John Wiley, 1980). Soluble sodium percentage another important criteria for soil physical properties and can affect plant growth (Wilcox 1955) [32].

Chloro alkaline indices - ion (CAI - I)

The analytical data regarding CAI-I shown negative values which proves the base exchange reaction indicates that exchange between sodium and potassium in water with calcium and magnesium in the rock by a type of base exchange reactions (Raju *et al.* 2007) [28].

Table 11: Permeability Index (PI), Soluble sodium Percentage (SSP) and Chloro Alkaline Indices-Ion (CAI-I) of irrigation water

Source	PI (%)				SSP (%)				CAI – I			
	Range		Average	CV	Range		Average	CV	Range		Average	CV
	Min	Max			Min	Max			Min	Max		
Borewell	62.27	70.48	66.84	0.02	44.83	55.36	49.80	0.04	-1.90	-0.05	-0.70	-0.59
Other	64.01	73.80	67.43	0.04	47.60	51.85	49.89	0.02	-1.12	-0.12	-0.61	-0.60

Conclusion

From the study it can be concluded that the irrigation water collected from various water sources during post monsoon season falls in high salinity and low sodium hazards class. Therefore, the water collected from other sources than borewell are advisable for irrigation but the irrigation water collected from borewell water is also advisable for irrigation with cautions i.e. by adopting proper management practices.

References

1. Abubacker MV, Kannan V, Sridharan M, Chandramohan M, Rajavelu S. Physio-chemical and biological studies on Uyyakondan canal water of River Cauvery. Pollution Research. 1996;15(3):257-259.
2. Adhikari PP, Biswas H. Geospatial assessment of ground water quality in Datia district of Bundelkhand. Indian Journal of Soil Conservation. 2011;39(2):108-116.
3. Ayers RS, Westcot DW. Water quality for agriculture. FAO irrigation and drain. 1985; Paper No 29(1):1-109.
4. Babhulkar VP, Balpande SS, Kadu PR, Mande MGM. Soil and water characteristics and their relationships in Purna valley tract of Vidarbha region. Journal of Soils and Crops. 2009;19(2):329-332.
5. Bauder TA, Waskom RM, Sutherland PL, Davis JG. Irrigation water quality criteria. 2011;5(11):506.
6. Bhumbla DR, Abrol IP. Is your water suitable for irrigation? Indian Farming. 1972;22:15-17.
7. Bower CA, Massland. Proc Soil Soc Am. 1963;pp 21-20.
8. Doneen LD. Notes on water quality in agriculture. Water Science and Engineering Paper 4001, Department of Water Science and Engineering, University of California. 1964.
9. Eaton FM. Significance of carbonates in irrigation water. Soil Science. 1950;69:123-133.
10. Girdhar IK, Yadav JSP. Influence of Mg rich irrigation waters on soil sodicity development and on plant growth. UP Council of Agricultural Research, Lucknow. 2004;1:88-89.
11. Gupta PK. Methods in Environmental Analysis: Water, Soil and Air. Agrobios (India), Jodhpur. 2005;pp 1-127.
12. Handa BK. Description and classification of media for hydrogeochemical investigation. Symposium on Groundwater Studies in Arid and Semi-arid Regions. 1969.
13. Islam MS, Shamsad SBKM. Assessment of Irrigation Water Quality of Bogra District in Bangladesh. Bangladesh Journal of Agricultural Research. 2009;34(4):597-608.
14. Islam MS, Hassan MQ, Shamsad SZKM. Ground water quality and hydrochemistry of Kushtia District, Bangladesh. Journal of Asiatic Society Bangladesh Science. 1999;25(1):1-11.
15. Joshi DM, Kumar A, Agarwal N. Assessment of the irrigation water quality of river Ganga in Haridwar district India. Journal of Chemistry. 2009;2(2):285-292.
16. Kapoor K, Bamniya BR. Water eutrophication and algal bloom. In: Kumar A, ed. Ecology and Conservation of Lakes, Reservoirs and Rivers. ABD Publications, Jaipur. 2011;42-57.
17. Kanaskar SR. Effect of irrigation on physical and chemical properties of Vertisols in Upper Wardha command area. M.Sc. Thesis, Dr. PDKV, Akola. 2007.
18. Kelley WP. Permissible composition and concentration of irrigation waters. Proceedings of the American Society of Civil Engineers. 1940;66.
19. Kharde BB. Characterization of well waters of Nevasa tahsil, district Ahmednagar. M.Sc. (Agri.) Thesis submitted to M.P.K.V., Rahuri (M.S.). 1992.

20. Khalil AA, Arther V. Irrigation Water Quality Guideline' reclaimed water project, Jordan Valley Authority and German Technical Corporation. 2010.
21. Latha N, Ramachandra Mohan M. Water quality of the lake Kommaghatta, Bangalore. Environment and Ecology. 2010;28(3A):1901-1905.
22. Matthess G. The Properties of Ground Water. John Wiley and Sons, New York, USA; c1982. p. 397.
23. Minhas PS, Tyagi NK. Guidelines for irrigation with saline and alkali waters. Central Soil Salinity Research Institute, Karnal, Technical Bulletin. 1998;1/g8:36.
24. Mukherji A, Shah T. Ground water socio-ecology and governance; A review of institutions and policies in selected countries. Hydrology Journal. 2005;13:328-345.
25. Nagaraju K, Sunil Kumar K, Thejaswi A. Assessment of groundwater quality for irrigation: a case study from Bandalamottu lead mining area, Guntur District, Andhra Pradesh, South India. Applied Water Science. 2014;4:385–396.
26. Paliwal KV. Effect of gypsum application on the quality of irrigation waters. The Madras Agricultural Journal. 1967;59:646–647.
27. Patil SS, Khandare RN, Gajare AS. Assessment of quality of ground water for irrigation in Ahmedpur tehsil of Latur district, Maharashtra. Asian Journal of Soil Science. 2014;9(1):73-77.
28. Raju NJ. Hydrogeochemical parameters for assessment of groundwater quality in upper Gunjanaeru River basin, Cuddapah district, Andhra Pradesh, South India. Environmental Geology. 2007;52:631-645.
29. Richards LA. Diagnosis and improvement of saline and alkali soils. Handbook No. 60, Oxford and IBH Publishing Co., Calcutta. USA; c1954. p. 160.
30. Todd DK. Ground Water Hydrology. 2nd ed. John Wiley and Sons Inc., New York, USA; c1980. p. 10-138.
31. UCCC (University of California Committee of Consultants). Guidelines for Interpretations of water Quality for Irrigation. Technical Bulletin, University of California Committee of Consultants, California, USA; c1974. p. 20-28.
32. Wilcox LV. Classification and Use of Irrigation Waters. US Department of Agriculture, Circular 969, Washington D.C. USA; c1955. p. 19.