ASSESSMENT OF WATER QUALITY IN IN SALINE TRACT OF PURNA VALLEY IN THE VIDARBHA REGION

ABSTRACT

Identification and management of ~~the~~ groundwater quality are of utmost importance for maintaining freshwater resources in arid and semi-arid areas, which is essential for sustainable development. The investigation was carried out to assess the quality of irrigation water in the saline tract of Purna Valley~~valley~~ in Akola and Daryapur tehsil. Forty water samples from open wells, Borewell, Farm Ponds,~~Pond~~ and Rivers~~River~~ were collected in post-monsoon~~post monsoon~~ season (winter). It was observed that~~,~~ the irrigation water in Purna Valley~~valley~~ has~~having~~ very high salinity and medium sodium hazard (C_4S_2) during the post-monsoon~~post monsoon~~ (winter) season. Amongst cations, sodium was dominant in water samples. The anionic composition was below the permissible limit, except for bicarbonates. The sodium adsorption ratio was close to the permissible limit and the Mg:Ca ratio of all water samples during the ~~post~~ post-monsoon~~monsoon~~ (winter) season was ~~–~~found to be disturbed. The adjusted sodium adsorption ratio was above the permissible limit. As per Kelley's ratio, most of the water samples were above the limit, while the samples collected from wells~~well~~, farm ponds, and rivers were within the permissible limit. The residual sodium bicarbonate of water collected from the borewell was~~were~~ above the permissible limit. Whereas, the soluble sodium percentage of ~~the~~ all irrigation water samples was~~were~~ found above the permissible limit. The magnesium adsorption of water ratio is lower than the permissible range. Hence, the borewell water was not advisable to use consistently for irrigation.

~~Key Words~~Keywords~~-~~ Saline tract, Borewell, ~~Other~~ irrigation sources, groundwater

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Introduction

Characteristics of irrigation water define its quality. It varies~~vary~~ with the source of water. There are regional differences in water characteristics, based mainly on geology and climate. There may be also great differences in quality of water depending on whether and the source of water bodies (rivers and ponds) or from groundwater aquifers with varying geology. The chemical constituents of irrigation water can affect plant growth directly through toxicity or deficiency or indirectly by altering the availability of nutrients (Ayers and Westcot, 1985).

The total geographical area of Maharashtra is 307.58 lakh ha spread over in ~~thirty six~~thirty-six districts. During the ~~year~~ season 2016-2017, the gross cropped area in the state was about 232.24 lakh ha while the net area sown was 169.10 lakh ha. The forest~~forests~~ area was about 20.1 percent~~per cent~~ of the geographical area. The irrigated area in the command area under the jurisdiction of the Water Resources Department, GoM was 39.50 lakh ha in 2017-201~~1~~8.

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In India, 51 per~~-~~cent of irrigation is provided through, while in Maharashtra the same is about 56 percent and by canal is about 23 percent (Anonymous, 2010).

Central Ground Water Board has been~~is~~ monitoring groundwater~~ground water~~ quality in Akola district for the last four decades through monitoring wells. The objectives behind the monitoring are to develop an overall picture of the ground~~-~~water quality of the district. During the year~~-~~ 2011, the Board~~ has~~ carried out groundwater~~ground water~~ quality by monitoring 27 wells. These wells mainly consist of dug wells representing shallow aquifers~~aquifer~~. The parameters analyzed include pH, Electrical Conductivity (EC), Total Alkalinity (TA), Total Hardness (TH), Nitrate (NO_3) and Fluoride (F). ~~The s~~Sample collection, preservation, storage, transportation, and analysis were carried out ~~as per~~according to the standard methods given in the ~~manual of~~ American Public Health Association Manual for the Examination of Water and Waste–water~~water~~ (APHA, 1998). The ground–water quality data thus generated was ~~first~~ checked first for completeness and then~~-~~ the data ~~the~~ validation ~~of data~~ was carried out using standard checks. Subsequent~~ly,~~ data interpretation ~~of data~~ was carried out to develop the overall picture of ground~~-~~water quality in the district in ~~the year~~ 2011. Ground~~-~~water quality was suitable~~good and suitable~~ for drinking and irrigation purposes~~purpose~~, however localized nitrate contamination was observed.

Land degradation is a widespread problem in India. ~~The e~~Estimates of land area affected by different soil degradative processes include~~includes~~ 33 M ha by water erosion, 11 M ha by wind erosion, 3 M ha by fertility decline, 8 M ha by waterlogging~~water logging~~ and 7 M ha by salinization. Salt-affected~~Salt affected~~ soils in Vidarbha occur~~occurs~~ mainly in the Purna Valley~~valley~~ which covers part of the Amravati, Akola, and Buldhana districts on both sides of the Purna River~~river~~. Around 10-45 km in width and 150 km in length. This tract spreads both sides of the Purna R~~r~~iver influencing about 892 villages, covering an area of about 4692 sq. km~~ area~~. The landform is mainly plain. The ~~soils are~~soil is fine textured with imperfect to poor drainage and ~~high water~~high-water holding capacity. The clay content ranges from 52-70%. The pHs, ECe, and ESP range~~ranges~~ from 7.7 to 9.4, 0.90 to 5.20 dSm^{-1} and 2.57 to 33.78% respectively. The soils are mostly normal at surface horizons and the problem of salinity/sodicity increases with depth (Padole *et al*., 1998). In Maharashtra, total irrigated area is 4.2 ~~m~~ M ha which accounts for~~to~~ 19.6% of the gross cultivated land. Vidarbha covers 14.1% of its land under irrigation (0.7 m ha). Amravati district of Vidarbha is spread over 12,210 sq. km, with an area of 6.9 lakh ha ~~area~~ under cultivation and 0.9 lakh ha irrigated area (14.1%).

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Purna Valley~~valley~~ is a unique tract in Vidarbha, that~~having~~ ~~combination~~ combines~~of~~ ~~three fold~~three-fold problems like ~~the native~~ natural salinity/sodicity, poor drainage,~~bility~~ and ~~poor quality~~poor-quality ground~~-~~water. The unique feature of the salt-affected~~salt affected~~ soils of Purna Valley~~valley~~ is that, though salinity is widely reported in this tract, the presence of salts on the surface is hardly seen (Anonymous, 2010). Exchangeable sodium content, poor physical condition, and nutrient deficiency are the major constraints in these soils. Despite many limitations once ameliorated using gypsum, sodic soils are used successfully for growing tolerant crops (Anonymous, 2010).

Chemical degradation of soils of the Purna Valley~~valley~~ in terms of increase in exchangeable sodium percentage (ESP) and exchangeable magnesium percentage (EMP) with depth has adversely affected the hydraulic and other properties important for crop growth. ~~The s~~Soils of the Purna valley have been extensively studied during 1990–1993 by several research~~work~~ers. ~~The salinity~~Salinity and/or sodicity problems are diagnosed in these soils, although most of the soils have good production potential. Because of~~In view of~~ the climate change during the Holocene period coupled with intensified agricultural practices, it becomes imperative to monitor ~~the~~ land degradation periodically to develop strategies for land development. In this context, it was proposed to conduct the present study by interpreting the soil datasets studied earlier. The Department of Agriculture, Government of Maharashtra has delineated a strip of 15 to 20 km (*kharpatta*) wide and 90–100 km long, along the Purna River as salt-affected. A~~It is obvious that a~~ river or any natural drainage helps in reducing salts. However, the present observation is contrary to the general understanding. According to earlier reports, the soils of the Purna V~~v~~alley are neither saline, and sodic nor saline-sodic according to the criteria suggested by the US Salinity Laboratory Staff, still, they have severe drainage problems following irrigation and/or rains, which affects the cultivation of crops in the rainy season. This condition becomes more severe if the ~~soils are~~soil is irrigated with the river or well water. Nimkar *et al*. reported the development of sodicity ~~in the surface~~ and accumulation of salts in the surface soil when well water was used for irrigation. Precise pedogenic processes responsible for sodification are not known that lead to poor drainage, nor is there any comprehensive information about the extent of this problem and the suitability of water for irrigation. Many researchers who had worked in the Purna Valley~~valley~~ and similar soils concluded that a considerable part of these soils have~~has~~ the problem of internal drainage along with the accumulation of salts in the sub-surface horizons and are prone to water-logging. The salinity and/or sodicity of these soils pose a major constraint in~~ the~~ attempting to conserve these soils. Poor drainage condition is the root

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cause of many problems. Due to poor drainage, salts have accumulated in the soils and are further aggravated by the application of poor-qualitypoor quality irrigation water. IndiscriminateIndiscriminate irrigation water useuse of irrigation water tofor getting a higher yield has led to water-logging, nutrient losses, and increased salinization of lands that once were once fertile; and this threatens the sustainability of crop yields. Groundwater in the Purna Valleyvalley occurs under the phreatic, semi-confined and confined conditions. The depth of the water table generally varies from 3 to 25 m below ground level. The average annual recharge to the groundwater is approximately 8% of the average annual rainfall. Groundwater is highly brackish. Exceptionally high salinity was of marine origin as a result ofbecause of the incursion of a stretch of seawatersea water into the Purna sub-basin. However, this water does not have a source with very high salts because the ratios of major anions and cations in this saline water are not the same as those of seawatersea water and this water is diageneticallydigenetically altered meteoric water with a long residence time, as is evident from high Na/ (Ca + Mg) ratio, negative indices of the base exchange and high SiO_2 content.

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Hence, considering the boundaries for crop diversification, higher yield, and soil improvement are very narrow in Purna Valleyvalley. Therefore, considering the possibility of supplemental irrigation and to exploring e the initiatives for crop divergence, the available water resources can be trapped and they can be judiciously used to maximizefor maximization of crop yield.

Materials and Methods

Study Area

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The PurnaThe Purna Rriver has a drainage area of 2431 km^2 and itits travels 180 km before joining with Arabian Seasea. Navsari Citycity is located in southern Gujarat and is is situatedlocated on the bank of the Purna Riverriver, within a few kilometerskilometres of the river's delta, which is west of the city and empties into the Gulf of Khambhat. Its immediate banks are mostly liable to flooding. This enormous catchment area is often tagged as a sub-basin of the Godavari Rriver and along with its tributaries, it forms a dendritic drainage pattern. (Fig. 1). It is located at It lies between 20°42'26.02" andto 77°00’10" North latitudes and East longitudes and falls in the survey of India Toposheet 55-A, 55-C, 55-D, and 55-P. The district covers a total geographical area of 9670 sq. km. While Daryapur is the adjoining tehsil to Akola lies in the Amravati district and falls in the Survey of India

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Toposheet.-. It is at an altitude of 925 ft (287m) to 1036.745 ft (316m) above sea level. The area is covered by mainly two formations i.e. Deccan Basalt and recent Alluvium. The alluviumAlluvium consists ofis consisting of bouldersboulder, sand, silt, and clay. The clayey and silty alluvium deposited all along the river Purna on both the Northern & Southern sidesside of the Saline tract. It covers about 330 villages i.e. about 1/3 villages of the district. The Alluvial Tract lying between Satpura hills & saline tract is covered by the Boulder Alluvium & sweet water (Alluvial) zone. The total area covered by alluvium is 1864 sq. km. The Igneous and Weathered formations comprise 90 % of the aerial distribution of rock types in the catchments, which consist of Hard compact massive Basalt., Vesicular Zeolitic Basalt, Fractured and jointed basalt,. and– Weathered Basalt.

Sampling and analytical methods

FortyFourty ground-water samples were collected from wellswell, borewellsbore well, Farm ponds,pond and riversriver from villages Vviz. Ghusar, Apatapa, Ambikapur, Siloda, Ugava, Katyar, Mhaisang, Ganori, Gandhigram from Akola and Ramgad, Karatkhed, Chandikapur, Khalar, Ramtirth, Dongargaon from Daryapur tehsil of Amravarti District in Purna Vvalley accordingly analyzed for various parameters at Department of Soil Science and Agricultural Chemistry, Dr. P.D.K.V., Akola during 2019-2020.

The high- d.densityensity PVC bottles were used for sampling. They wereand thoroughly cleaned by rinsing with 8N HNO. and deionized waterrvater followed by repeatedreieated washing with waterwaer sarnple as suggested by De (1989). BeforeBefori sampling from a well, water was pouredpurnped out sufficiently so that the sample represents the ground wrvater from which the well is fed (Raghunath, 1990). The bottles were kept air-tightair tight andancl labeled properly for identification. Aeration during sampling was avoided by stoppingstoppering the bottle quickly. The samples were brought to the laboratory by using an icebox, and stored at 4 °C until the physiochemical parameters were analyzed. The in situin-situ parameters pH, temperature (degrees Celsius), and electrical conductivity were measured immediately while sampling using a field kit. Furthermore, the samples were filtered through 0.45-µm-size fiberglassfiber glass filters to remove suspended particles in the laboratory and then analyzed by using standard methods The EC and pH were determinedwere determine as per methods described by Richards (1954). Ionic TDS was simplysirnply determined by multiplyingrnultiplying the measured EC values (in iS/cm) by 0.64 as there exists an approximate relation between EC and TDS

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For most_—natural water in the range of 100 to5000 iS/cm leading to the equivalencies 1 me1- of cations = 100 iS/cmrn and 1 mel-r= 1.56 iS/cm (Todd, 1980).' $Na^{+}$and K^{+}were determineddetermineel by flame photometry (Jaqkson, 1967); Ca^{2+} $Mg^{2+}$and B by visible spectrophotometry (Jackson, 1967 and Page et al., 1989); $Cl^{-}$and HCO_3^{-};- the by titration method (Jackson, 1967)._The sodium adsorption ratio (SAR) was by the equation using the values obtained for_,Ca^{2+}, Mg^{2+} in mel-r (Richards, 1954).; the soluble sodium percentage (SSP) was determined by the equation using the values obtained for Na^{+},K^{+}, Ca^{2+},_It Mg^{2+} in molel'r (Todd, 1980); the residual sodium carbonate (RSC) was determineddeterrnined by the equation using the values obtained for CO., HCO. Irl melr (Eaton, 1950). The Kelly's ratio was determineddeterrnined by the equation using the values obtained for Na^{+}, Ca^{2+} and Mg^{2+} in mel' I (Kelly, 1 953). Adj.R Na^{+} was detenninneddetermined by the equation using the values obtained for Na , Ca^{2+} and Mg^{2+} in mel'r (Suarez, 1981). The permeability index was calculated according to Doneen (1964) by using values obtained for HCO'-,_Na^{+}, Ca^{2+} and Mg^{2+}. The residual sodium bicarbonate was caiculated according to Gupta and Gupta (1987). The alkalineChloro Alkaline Indices ratio was determined by the equation using the values obtained for Na^{+}, K^{+}, and Cl in mel

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Results and Discussion

Cation

The calcium content in bore-well water was 4.6 to 6.9 meL^{-1} in analyzed samples from villages, which was within the normal range of 0-20 meL^{-1} however, the calcium content from other sources of irrigation was 4.3 to 5.6 meL^{-1}. The concentration of magnesium was 3.0 to 5.4 meL^{-1} in borewell water and the magnesium content in other sources of irrigation was in the range of 2.9 to 4.1 meL^{-1}. Some villages were beyond the permissible limit (0-5 meL^{-1}) in respect of water collected from borewell water except in other sources of irrigation where it was within safe limit which indicates that the higher concentration of magnesium in irrigation water can increase the soil pH. TheWhile the sodium concentration in bore-well water was in between 10.18 to 16.35 meL^{-1} and from other sourcess was in the range ofranged from 8.21 to 13.8 meL^{-1}. The sodium content in borewell water was lower than that of otherother sources sources of irrigation. The sodium content was more than the permissible limit, which may cause dispersion in the soil.

The potassium concentration was very low in the bore–well water above the permissible limit and it was in between 0.09 to 0.22 meL^{-1} whereas, in other sources of irrigation it ranges between 0.09 to 0.18 meL^{-1}. These results were supported by the findings of Muhamtnad et.al (2013), Kamlesh Kumar et al. (2015), and Jadhao et al., (2016) who reported that the concentration of potassium in water is very low to low-. In a nutshellnut 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 causescause for the development of native natural sodicity in Purna Valleyvalley soil. (Babhulkar et al, (2009). ; Jadhao et al., (2016). Whereas The irrigation water that has high sodium content can bring about a displacement of exchangeable cationscation $Ca^{2+}$and Mg^{2+} from the clay minerals of the soil, followed by the replacement of the cations by sodium (Islam and Shamsad, (2009). ; Jadhao et al., (2016).

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Anions

The bicarbonate concentration in borewell water was in the range of 8.6 to 15.3 meL^{-1} while, the bicarbonate concentration in water from other sources of irrigation was in the range of 7.7 to 12.3 meL^{-1}. Most of the values withinin respect toof bicarbonates of water samplessample from both sources fall into "slight to moderate" and "severe" degreesdegree of restriction to use (UCCC, 1974). The bicarbonate content can bring about a change in soluble sodium percentage in irrigation water which, regulates the sodium hazards (Adhikary and Biswas, 2011).; Jadhao et al., (2016). The chloride content in irrigation water from borewell was varied from 3.6 to 14.4 meL^{-1} and from other sources was varied 2.6 to 12.2 meL^{-1}. The values of chloride values exceeds the permissible limit of 4 meL^{-1} which indicatesing the impact of settlement and anthropogenic effect (. Adhikary and Biswas, , (2011;) Jadhao et al., (2016). AAalso reported that the chloride content normally increased –as the mineral content increasedincrease and may reducereduced phosphorus availability to plants.

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Whereas tThe –concentration of sulphate was in between 2.1 to 14.6 meL^{-1} from the bore well and 1.2 to 10.2 meL^{-1} from other sources of irrigation, which was within the higher-than-permissiblehigher than permissible limit given by Richards (1954). 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 ionsion reduced phosphorus availability to plants (Khalil *et al.* 2010;) and Jadhao et al., (2016)

Sodium adsorption ratio (SAR)

Sodium adsorption ratio was in the range of 4.19 to 7.83 mmol$^{1/2}$L$^{-1/2}$ and other sources of irrigation ranges from 3.91 to 7.17 mmol$^{1/2}$L$^{-1/2}$. As per the criteria given by Richards (1954) sodium adsorption ratio in the villages waswere within the permissible limit and irrigation water samples fall under the low to medium sodium hazards class i.e. S_1 class and slightly useful for irrigation. A high~~High~~ sodium adsorption ratio in any irrigation water implies hazards of sodium (Alkali) replacing Ca^{2+} and Mg^{2+} of the soil through the cation exchange process, a situation that eventually damages~~damaging of~~ soil structure like permeability which ultimately affects~~affect~~ the fertility of the soil and reduces~~reduce~~ crop yield (Gupta, ~~(~~2005~~)~~; ~~and~~ Jadhao et al., ~~(~~2016)~~.~~.

Residual Sodium Carbonate (RSC)

The residual sodium carbonate content of borewell water ~~and it~~ was in the range of 0.3 to 3.6 meL^{-1} which was classified ~~under~~ high as per the criteria of the suitability of irrigation water given by Richards (1954). Whereas the RSC of water collected from other sources of irrigation was in the range of 0.2 to 2.6 meL^{-1} which is unsuitable for irrigation above 2.5. Water contains appreciable quantities~~quantity~~ of carbonate, bicarbonate, calcium, and magnesium which precipitate down when the ~~the~~ concentration ~~of~~ in soil solution increases~~increase~~ through evapotranspiration (Eaton, ~~(~~195 and~~0)~~, Jadhao et al., ~~(~~2016).

Magnesium: Calcium Ratio (Mg: Ca)

The data showed that ~~the values of the~~ Mg^{2+}/Ca^{2+} ranged between 0.65 to 0.79 with an average value of 0.72, indicating~~e~~ that this~~these~~ water ~~samples~~ was~~ere~~ ~~in~~ suitable ~~category~~ for irrigation purpose. The high magnesium-~~:~~ calcium ratio increases the exchangeable magnesium on the soil exchange complex and builds~~build~~ up the magnesium-calcium ratio in the soil which increases with its increase ~~in the magnesium calcium ratio~~ in the ground~~-~~water. The proportion~~Proportion~~ of magnesium over calcium in ground~~-~~water enhances the sodification of soils at a given sodium adsorption ratio and electrical conductivity. The crop yield is affected adversely as magnesium-calcium ratio in the ground water when it exceeds 2.0. Similar results were reported by (~~Girdhar~~ Girdhur and Yadav, ~~(~~2004; ~~)~~ ~~and~~ Kanaskar, ~~(~~2007). A high~~High~~ Mg^{2+}/Ca^{2+} ratio can increase the precipitation of calcium ~~,~~ phosphates, and carbonates which are less soluble than their magnesium counterparts (Fatemi,~~(~~ 2015, and~~)~~ Jadhao et al., ~~(~~2016).~~.~~

Adjusted Sodium Absorption Ratio (SAR)

The adjusted sodium adsorption ratio of borewell water was in the range of 4.72 to 9.46 whereas, the Adjusted SAR from other sources of irrigation was 4.83 to 9.41. ~~—~~ The coefficient of variance of Adj. SAR of borewell water was lower than other sources of irrigation water which indicates~~indicate~~ ~~there is~~ the variation of adjusted SAR in the water samples. The presence of bicarbonate and carbonate ions in the ground~~-~~water increases the permeability hazard as quantified by the sodium adsorption ratio (Bauder *et.al*. 2011). ~~The~~ ~~a~~Adj. SAR measures the water sodium level against calcium and magnesium~~,~~ while adjusting the effect of bicarbonates and carbonate ions~~ion~~, these ions cause~~causes~~ the calcium ions to precipitate ~~and~~ resulting in high sodicity. (Ayers, ~~(~~1985;~~)~~ ~~and~~ Jadhao et al., ~~(~~2016).

Adj. R_{Na}

The Adj. R_{Na} of borewell water was in the range of 6.52 to 8.37 and that of other sources having range of 5.36 to 7.77. The Adj. R_{Na} can be used to predict more correctly potential infiltration problems~~problem~~ due to relatively high sodium (or low calcium) in-ground~~in ground~~ supplies and can be substituted for sodium adsorption ratio which is a concern to the standards for Adj. R_{Na}. 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.

Kelley's Ratio (KR)

The sodium~~Sodium~~ problem in irrigation water could very conveniently be worked out based on~~on the basis of~~ the values of Kelley's ratio (Kelly, 1953). Kelley's ratio of more than 1 indicates an excess level of sodium in water. ~~In the present study~~ In the present study, values of Kelley's ratio of borewell water were~~was~~ in the range of 0.8 to 1.8 and that of irrigation water collected from other sources was in the range of 0.9 to 1.8 this ratio ~~clearly~~ indicates~~indicate~~ that out of forty~~fourty~~ samples, ~~–~~twenty-seven~~twenty seven~~ samples~~sample~~ are unfit and thirteen samples~~sample~~ for suitable for irrigation.

Permeability Index (PI)

In the present study, the ~~the minimum and~~ maximum permeability of bore~~-~~well water was 62.0 to 78.4% and PI of other sources 66.2 to 78.6% 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~~long term~~ use of irrigation water and sodium, calcium, and magnesium content in the soil (Raju et. al., 2007). The water is classified in class I and class II according to Doneen's criteria (1964). Permeability Index can be categorized into~~in~~ three classes: class I (>75%, suitable), class II (25–75%, good), ~~–~~and class III (<25%, unsuitable). Water under Class~~class~~ I and Class~~class~~ II is recommended for irrigation (Doneen, 1964; ~~and~~ Raghunath, 1990).

Chloro Alkaline Indices-Ion (CAI - I)

The water sample collected from various villages from Akola and Daryapur tehsils showedshown negative values of CAI-I 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 reactionreactions Raju *et al*. (2007) and Jadhao et al (2016).

Residual Sodium Bicarbonate (RSBC)

The residual sodium bicarbonate in collected borewell water samples was recorded and in the range of 3.9 to 8.7 meL^{-1} while, samples from other sources rangedranges between 3.2 to 6.7 meL$^{-1.}$ As per the criteria, all water samples werewas above permissible limitslimit and unsafe for irrigation. The residual sodium bicarbonate values were greater than 3.0 meL^{-1} and are therefore considered as unsafe for irrigation purpose.

Magnesium Adsorption Ratio (MAR)

The magnesium adsorption ratio of irrigation water collected from borewells waswere in the range of 37.73 to 44.34 and from other sources waswere in the range of 39.18 to 48.19. Indicatinginging that all collected water samples were below the acceptable range i.e. below 50. Magnesium content in well waterwell water is considered as one of the most important qualitative criteria in for determining the quality of water quality 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 becomesbecome more saline (Joshi *et al*, 2009).

Soluble Sodium Percentage (SSP)

The soluble sodium percentage values of studied borewell water samples was in rangedrange fromof 46.6 to 65.5% and that of water samples from other sources rangedds from 48.6 to 65.3% based onOn the basis of soluble sodium percentage, the irrigation water samples were above the permissible limit.

Conclusion

From this study, it can be concluded that the irrigation water collected from various water sources in Akola and Daryapur tehsils during the post-monsoonpost monsoon season is categorized under high salinity and medium sodium hazard class i.e.C_4S_2. Therefore, while irrigating the crops, it is advocated to prefer other sources of irrigation. However, under unavoidable circumstances, the borewell water can be blendedbe blend with other sources.

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Table 1(a):Cationic concentration in water samples of borewell

Village name	Sample No.	Ca	Mg	Na	K
		($meqL^{-1}$)			
Apatapa	APBW1	6.1	4.4	11.30	0.23
Ambikapur	AMBW1	4.7	3.2	13.48	0.18
Ambikapur	AMBW2	5.1	3.5	12.81	0.20
Katyar	KTBW1	5.5	4	10.86	0.18
Katyar	KTBW2	5.3	3.7	12.22	0.22
Katyar	KTBW3	5	3.5	14.17	0.13
Mhaisang	MHBW1	6.2	4.4	10.18	0.16
Mhaisang	MHBW2	5.6	4	10.60	0.13
Karatkhed	KRBW1	6.2	4.5	10.42	0.18
Ramtirth	RTBW1	6.5	5.1	10.36	0.13
Ramtirth	RTBW2	6.7	5.2	10.24	0.17
Ramagad	RGBW1	5.5	3.9	12.39	0.14
Ramagad	RGBW2	5.1	3.6	13.30	0.13
Siloda	SLBW1	5.7	4.1	11.65	0.12
Ugava	UGBW1	6.7	5.1	10.34	0.16
Ugava	UGBW2	6.4	4.8	10.26	0.11
Ugava	UGBW3	6.4	4.7	10.32	0.12
Dongargaon	DGBW1	4.6	3	13.57	0.18
Dongargaon	DGBW2	4.7	3.2	12.96	0.09
Ganori	GNBW1	6.6	5.2	10.45	0.13
Chandikapur	CDBW1	6.9	5.4	16.30	0.10
Chandikapur	CDBW2	6.6	5.1	10.58	0.11
Chandikapur	CDBW3	6.7	5.3	10.68	0.10
Chandikapur	CDBW4	6.6	5.2	10.52	0.11
Chandikapur	CDBW5	6.4	5.1	10.34	0.12
Khalar	KHBW1	4.9	3.8	16.35	0.18
Khalar	KHBW2	5.2	3.7	15.65	0.11
Khalar	KHBW3	6.6	4	10.35	0.15
Khalar	KHBW4	6.3	3.9	10.65	0.09
Khalar	KHBW5	5.8	4.2	10.55	0.16
	Max	**6.9**	**5.4**	**16.35**	**0.22**
	Min	**4.6**	**3**	**10.18**	**0.09**
	Mean	**5.88**	**4.29**	**11.79**	**0.14**
	CV	**0.1235**	**0.1683**	**0.1606**	**0.2605**

Table 1(b): Cationic concentration in water samples of other sources

Village name	Sample No.	Ca ($meqL^{-1}$)	Mg($meqL^{-1}$)	Na($meqL^{-1}$)	K($meqL^{-1}$)
Ghusar	GHFP1	4.7	3.1	13.10	0.19
Ghusar	GHFP2	4.4	3	13.80	0.18
Ghusar	GHHP1	5.6	4.1	12.20	0.19
Ambikapur	AMDam	4.6	3	11.50	0.16
Mhaisang	MHRiver	4.5	2.9	8.70	0.12
Ramagad	RGFP1	4.6	3	9.22	0.15
Ramagad	RGFP2	4.7	3.1	9.68	0.16
Ugava	UGRiver	4.3	4	8.56	0.09
Gandhigram	GGRiver	5.2	3.6	8.21	0.13
Dongargaon	DGWell	4.4	3	10.34	0.11
	Max	**5.6**	**4.1**	**13.8**	**0.18**
	Min	**4.3**	**2.9**	**8.21**	**0.09**
	Mean	**4.7**	**3.28**	**10.53**	**0.14**

	CV	0.0856	0.1369	0.1902	0.0335

Table 2(a): Anionic concentration in water samples of borewells

Village name	Sample No.	HCO_3 (meqL^{-1})	Cl (meqL^{-1})	SO_4(meqL^{-1})
Apatapa	APBW1	11.8	11.5	13.6
Ambikapur	AMBW1	8.6	4.8	3.2
Ambikapur	AMBW2	9.8	4.9	2.1
Katyar	KTBW1	10.6	10.6	10.4
Katyar	KTBW2	10.2	11.7	9.2
Katyar	KTBW3	10.1	9.2	4.2
Mhaisang	MHBW1	12.3	10.2	6.4
Mhaisang	MHBW2	12.2	10.2	4.2
Karatkhed	KRBW1	12.4	10.2	14.6
Ramtirth	RTBW1	12.5	10.4	4.4
Ramtirth	RTBW2	12.3	8.2	6.6
Ramagad	RGBW1	10.2	6.6	3.2
Ramagad	RGBW2	9.2	10.4	4.6
Siloda	SLBW1	10.6	8.2	5.6
Ugava	UGBW1	12.1	7.8	4.4
Ugava	UGBW2	12.7	6.6	4.6
Ugava	UGBW3	12.4	9.2	6.6
Dongargaon	DGBW1	9.2	3.6	3.2
Dongargaon	DGBW2	8.6	4.3	2.6
Ganori	GNBW1	12.7	6.6	10.6
Chandikapur	CDBW1	14.6	14.4	8.6
Chandikapur	CDBW2	15.3	6.4	6.6
Chandikapur	CDBW3	13.2	10.2	9.6
Chandikapur	CDBW4	12.3	6.6	8.2
Chandikapur	CDBW5	13.8	7.3	9.4
Khalar	KHBW1	10.3	7.9	5.8
Khalar	KHBW2	10.6	9.1	6.2
Khalar	KHBW3	11.2	9	4.8
Khalar	KHBW4	10.6	8.2	4.4
Khalar	KHBW5	11.1	6.1	3.2
	Mean	**11.45**	**8.34**	**6.37**
	CV	**0.1460**	**0.2931**	**0.4995**

Table 2(b): Anionic concentration in water samples of other sources of irrigation

Village name	Sample No.	HCO_3(meqL^{-1})	Cl(meqL^{-1})	SO_4(meqL^{-1})
Ghusar	GHFP1	9.2	8	1.2
Ghusar	GHFP2	8.3	8.2	1.6
Ghusar	GHHP1	12.3	12.2	10.2
Ambikapur	AMDam	7.8	4.6	2.2
Mhaisang	MHRiver	9.6	7.8	3.2
Ramagad	RGFP1	7.9	3.6	2.4
Ramagad	RGFP2	8	3.4	1.2
Ugava	UGRiver	9.8	5.6	3.2
Gandhigram	GGRiver	9.4	4.2	3.8
Dongargaon	DGWell	7.7	2.6	1.2
	Mean	**9**	**6.02**	**3.02**
	CV	**0.1567**	**0.4951**	**0.8914**

Table 3(a): Sodium absorption ratio, Adjusted SAR and Adjusted R_{Na} of water samples collected borewell

Village name	Sample No.	SAR	AdjSAR	Adj R_{Na}
Apatapa	APBW1	4.93	9.46	6.34
Ambikapur	AMBW1	6.78	8.95	8.50
Ambikapur	AMBW2	6.17	5.99	7.78
Katyar	KTBW1	4.98	5.53	6.30
Katyar	KTBW2	5.76	4.72	7.28
Katyar	KTBW3	6.87	8.17	8.52
Mhaisang	MHBW1	4.42	7.20	5.69
Mhaisang	MHBW2	4.83	7.45	6.03
Karatkhed	KRBW1	4.50	7.52	5.77
Ramtirth	RTBW1	4.30	6.58	5.52
Ramtirth	RTBW2	4.19	4.78	5.45
Ramagad	RGBW1	5.71	4.85	7.30
Ramagad	RGBW2	6.37	6.95	8.09
Siloda	SLBW1	5.26	7.94	6.74
Ugava	UGBW1	4.25	5.15	5.56
Ugava	UGBW2	4.33	7.63	5.57
Ugava	UGBW3	4.38	5.56	5.66
Dongargaon	DGBW1	6.96	7.44	8.58
Dongargaon	DGBW2	6.52	8.93	8.17
Ganori	GNBW1	4.30	5.33	5.53
Chandikapur	CDBW1	6.57	8.54	8.40
Chandikapur	CDBW2	4.37	7.21	5.49
Chandikapur	CDBW3	4.36	6.01	5.60
Chandikapur	CDBW4	4.33	5.76	5.59
Chandikapur	CDBW5	4.31	6.03	5.42
Khalar	KHBW1	7.83	8.54	9.51
Khalar	KHBW2	7.41	7.34	9.23
Khalar	KHBW3	4.49	6.15	6.13
Khalar	KHBW4	4.71	6.03	6.37
Khalar	KHBW5	4.71	6.13	6.03
	Mean	**5.30**	**6.80**	**6.67**
	CV	0.2122	0.1986	0.1955

Table 3(b): Sodium Absorption ratio, Adjusted SAR and Adjusted R_{Na} of water samples collected from other sources of irrigation

Village name	Sample No.	SAR	AdjSAR	Adj R_{Na}
Ghusar	GHFP1	6.63	9.41	8.23
Ghusar	GHFP2	7.17	6.74	8.82
Ghusar	GHHP1	5.53	5.87	6.87
Ambikapur	AMDam	5.89	7.07	7.50
Mhaisang	MHRiver	4.52	8.36	5.48
Ramagad	RGFP1	4.72	7.56	6.00
Ramagad	RGFP2	4.90	6.37	6.24
Ugava	UGRiver	4.20	5.21	4.83
Gandhigram	GGRiver	3.91	5.20	4.99
Dongargaon	DGWell	5.37	4.83	6.70
	Mean	**5.28**	**6.66**	**6.53**
	CV	**0.1985**	**0.2223**	**0.1918**

Table 4(a): Magnesium: Calcium Ratio (Mg:Ca), Kelley's Ratio (KR) and Magnesium Absorption Ratio (MAR) of water samples of borewell

Village name	Sample No.	Mg/Ca Ratio	Kelly's Ratio	MAR
Apatapa	APBW1	0.72	1.07	41.90
Ambikapur	AMBW1	0.68	1.70	40.50
Ambikapur	AMBW2	0.73	1.48	40.69
Katyar	KTBW1	0.72	1.14	42.10
Katyar	KTBW2	0.65	1.35	41.11
Katyar	KTBW3	0.68	1.66	41.17
Mhaisang	MHBW1	0.68	0.96	41.50
Mhaisang	MHBW2	0.72	1.10	41.66
Karatkhed	KRBW1	0.70	0.97	42.05
Ramtirth	RTBW1	0.70	0.89	43.96
Ramtirth	RTBW2	0.71	0.86	43.69
Ramagad	RGBW1	0.78	1.31	41.48
Ramagad	RGBW2	0.77	1.52	41.37
Siloda	SLBW1	0.65	1.18	41.83
Ugava	UGBW1	0.70	0.87	43.22
Ugava	UGBW2	0.70	0.91	42.85
Ugava	UGBW3	0.71	0.92	42.34
Dongargaon	DGBW1	0.76	1.78	39.47
Dongargaon	DGBW2	0.75	1.64	40.50
Ganori	GNBW1	0.69	0.88	44.06
Chandikapur	CDBW1	0.65	1.32	43.90
Chandikapur	CDBW2	0.68	0.90	43.58
Chandikapur	CDBW3	0.68	0.89	44.16
Chandikapur	CDBW4	0.78	0.89	44.06
Chandikapur	CDBW5	0.78	0.89	44.34
Khalar	KHBW1	0.77	1.87	43.67
Khalar	KHBW2	0.79	1.75	41.57
Khalar	KHBW3	0.78	0.97	37.73
Khalar	KHBW4	0.79	1.04	38.23
Khalar	KHBW5	0.77	1.05	42
	Mean	**0.72**	**1.19**	**42.02**
	CV	**0.0633**	**0.2773**	**0.0405**

Table 4(b): Magnesium: Calcium Ratio (Mg:Ca) ,Kelley's Ratio (KR) and Magnesium Absorption Ratio of water samples of other sources of irrigation

Village name	Sample No.	Mg/Ca Ratio	Kelly's Ratio	MAR
Ghusar	GHFP1	0.65	1.67	39.74
Ghusar	GHFP2	0.68	1.86	40.54
Ghusar	GHHP1	0.73	1.25	42.26
Ambikapur	AMDam	0.65	1.51	39.47
Mhaisang	MHRiver	0.69	1.17	39.18
Ramagad	RGFP1	0.64	1.21	39.47
Ramagad	RGFP2	0.72	1.24	39.74
Ugava	UGRiver	0.65	1.03	48.19
Gandhigram	GGRiver	0.93	0.93	40.90
Dongargaon	DGWell	0.73	1.39	40.54
	Mean	**0.71**	**1.33**	**41.00**

	CV	**0.1170**	**0.2160**	**0.0654**

Table 5(a): Residual Sodium Bicarbonates and Residual Sodium Carbonates of water samples of borewell

Village name	Sample No.	RSBC(meL^{-1})	RSC(meL^{-1})
Apatapa	APBW1	5.7	1.3
Ambikapur	AMBW1	3.9	0.7
Ambikapur	AMBW2	4.7	1.2
Katyar	KTBW1	5.1	1.1
Katyar	KTBW2	4.9	1.2
Katyar	KTBW3	5.1	1.6
Mhaisang	MHBW1	6.1	1.7
Mhaisang	MHBW2	6.6	2.6
Karatkhed	KRBW1	6.2	1.7
Ramtirth	RTBW1	6	0.9
Ramtirth	RTBW2	5.6	0.4
Ramagad	RGBW1	4.7	0.8
Ramagad	RGBW2	4.1	0.5
Siloda	SLBW1	4.9	0.8
Ugava	UGBW1	5.4	0.3
Ugava	UGBW2	6.3	1.5
Ugava	UGBW3	6	1.3
Dongargaon	DGBW1	4.6	1.6
Dongargaon	DGBW2	3.9	0.7
Ganori	GNBW1	6.1	0.9
Chandikapur	CDBW1	7.7	2.3
Chandikapur	CDBW2	8.7	3.6
Chandikapur	CDBW3	6.5	1.2
Chandikapur	CDBW4	5.7	0.5
Chandikapur	CDBW5	7.4	2.3
Khalar	KHBW1	5.4	1.6
Khalar	KHBW2	5.4	1.7
Khalar	KHBW3	4.6	0.6
Khalar	KHBW4	4.3	0.4
Khalar	KHBW5	5.3	1.1
	Mean	5.56	1.27
	CV	0.1995	0.5808

Table 5(b): Residual Sodium Bicarbonates and Residual Sodium Carbonates of water samples of other sources of irrigation

Village name	Sample No.	RSBC(meL^{-1})	RSC(meL^{-1})
Ghusar	GHFP1	4.5	1.4
Ghusar	GHFP2	3.9	0.9
Ghusar	GHHP1	6.7	2.6
Ambikapur	AMDam	3.2	0.2
Mhaisang	MHRiver	5.1	2.2
Ramagad	RGFP1	3.3	0.3
Ramagad	RGFP2	3.3	0.2
Ugava	UGRiver	5.5	1.5
Gandhigram	GGRiver	4.2	0.6
Dongargaon	DGWell	3.3	0.3

	Mean	4.3	1.02
	CV	0.2714	0.8544