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Ground Water Quality Assessment of Different Villages of Kheda District of Gujarat, India

Bhavik J. Prajapati [a++*], J. K. Parmar [a#], Swati H. Patel [b†], and Nilesh S. Paragi [c‡]

[a] Department of Soil Science and Agricultural Chemistry, Anand Agricultural University, Anand, India.
[b] Micronutrient Research Center (ICAR), Anand Agricultural University, Anand, India.
[c] Regional Research Station, Kothara, SDAU, Dantiwada, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The Kheda district lies in the Cambay basin situated between Saurashtra crater and Aravalli Swell and Deccan Shield in the east. The basin comprises both marine formations, is the principal source of water supply for middle Gujarat region. The quality evaluation for this groundwater is very important tool for sustainable development and decision for water management. A survey work conducted during April-May, 2016 for ground water quality assessment of 'Kheda district of middle Gujarat. A total of 160 groundwater samples, from shallow, springs, and deep aquifers, were collected, storage and analysed to evaluate its quality suitability for domestic and agriculture purposes. The result of quality of underground wells/tube wells water revealed that the EC values

[++]Ph. D. (Scholar);
[#]Associate Professor;
[†]Senior Research Fellow;
[‡]Agriculture Officer;
**Corresponding author: Email: prajapatibhavik633@gmail.com;*

ranged 0.51 to 8.50 with a mean value of 2.04 dS m^{-1}. The waters were alkaline in reaction (pH 7.97). The overall RSC values ranged from -4.80 to 10.50 with a mean value of 2.41 me L^{-1}. The overall mean value of SSP was found 34.34, which varied from 8.00 to 77.26. The SAR values ranged from 0.36 to 29.96 with a mean value of 7.48.

Keywords: Ground water; physico-chemical analysis; water quality index.

1. INTRODUCTION

Water is a renewable resource, but its availability is variable and limited, especially under arid conditions [1]. At certain times of the year, almost every country in the world experiences water shortages [2]. In fact, water resources are of importance in increasing employment in all sectors of society [3] stated that experts describe the global water situation as a crisis. Freshwater quality will become the principal limiting factor for sustainable development for many countries in the twenty-first century [4].

Groundwater is an integral freshwater source that serves different human needs in many parts of the world. For agricultural purposes, groundwater contributes to approximately 43% of worldwide water usage for irrigation [5]. Despite its importance, the quantity and quality of groundwater resources are increasingly threatened by both natural and anthropogenic factors. Climate change has potential impacts on groundwater such as seawater intrusion and groundwater level decline. Additionally, a rapid increase in water demand and contamination from anthropogenic pollutants such as fertilizer residue and untreated wastewater has worsened this water source.

The water used for irrigation purpose always contain soluble salts in respective of their source, but the total concentrations and the kind of salt present in any irrigation water are important in deciding whether it will suitable for irrigation or not. Moreover, due to implementation of new irrigation project, coupled with important use of canal water, more and more areas are being affected by the problem of water logging as well as soil salinity and alkalinity in India. Quality of irrigation water is one of the main factors to be understood in irrigated agriculture. “Injudicious irrigations” even with good quality waters, turn many agriculturally good soils into saline or alkali conditions, specific ion toxicity in plants and restricted water infiltration into soils with consequent adverse effects on crop production.

The pressing demand of higher grain production for the increasing population of the country has urged the scientists and extension agencies to explore most suitable techniques for the best utilization of land and water resources of the country. Though, there has been a regular increase in the irrigated area of the country in the last decade leading to higher yield potential, but due attention has not been given for use of poor-quality irrigation waters. Irrigation facilities unfortunately have not smiled happy at Gujarat state. About 41.73 per cent of the total irrigated area is covered by ground water [6]. Globally, area equipped for irrigation is currently about 301 million ha of which 38% are equipped for irrigation with groundwater [5]. As per one estimate even if the potential of all the rivers in Gujarat is harvested, the total area that can be brought under irrigation will be only about one third of the total cultivated land. Thus, the remaining land has to depend upon underground water sources only. Thus, underground well/tube well water is an important source of irrigation in Gujarat, where water quality is highly variable due to climatological and hydrological conditions.

The use of saline water is indispensable in some area where no alternative facility for irrigation is available; such water is being used in Kheda district, knowing the problems related to seawater intrusion have seen a significant rise over the last decades. Seawater intrusion related problems have been reported in various countries and are especially of great concern to Gujarat State in India, as it has the longest coastline of about 1600 km where the quality of ground water would be continuously decreases. It is important to know the extent of damage caused to land due to use of poor-quality underground waters for irrigation in salt affected areas [7].

Soil fertility and water quality survey furnishes useful information for proper planning of soil and water management practices, which play an important role in augmenting crop production.

2. MATERIALS AND METHODS

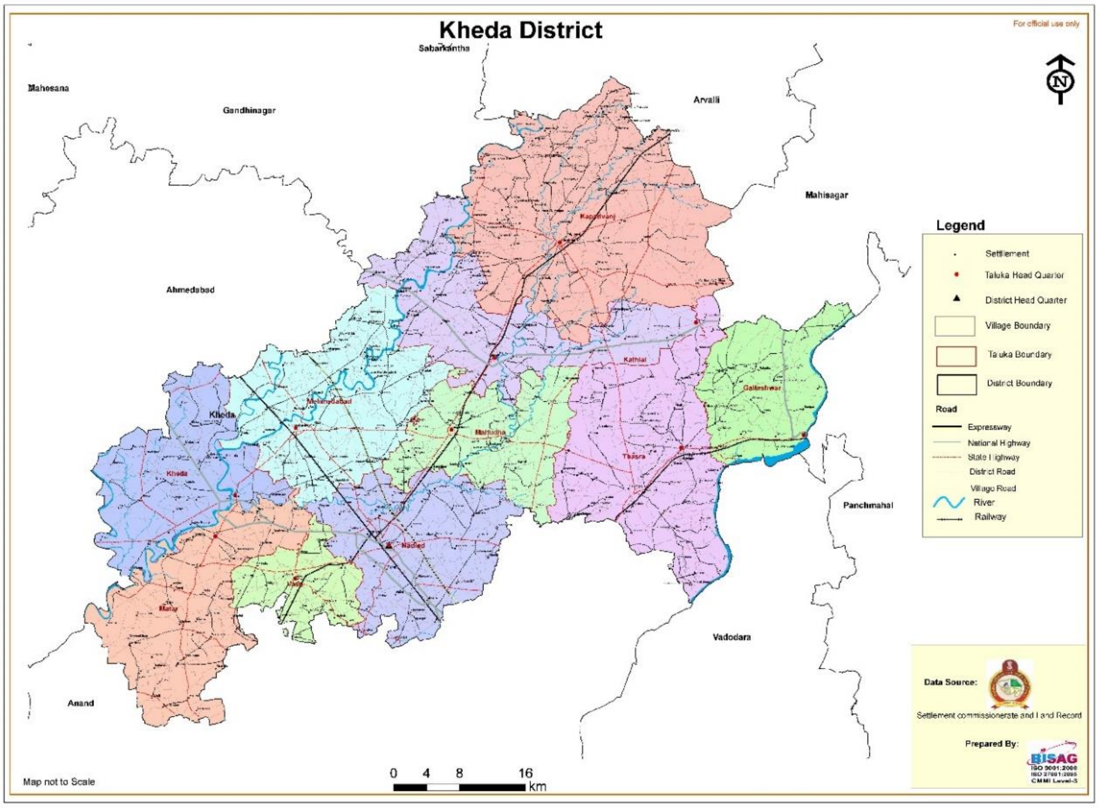
The general features of Kheda district viz, geographic location, physiography, geology, climate, soil, water, vegetation, land use pattern and cropping pattern are described below.

2.1 General Information of Kheda District

Geographic location: Kheda district falls in Middle Gujarat Agro Climatic Zone, located at 22º 30' N–72º 32' E, 23º 18' N–73º 37' E. It has an average elevation of 21 meters (68 ft). It is bounded by Sabarkantha district to the North, Ahmedabad district to the West, Panchmahal district to the East and Vadodara district to the South. On the Southern part, Khambhat Tehsil of Anand district has natural boundary of the Gulf of Cambay with Kheda district. Kheda district is famous by the name Golden Leaf since many decades it a major producer of tobacco in Gujarat State. The area covered by the district is 3959 sq.km. Sabarmati, Mahi, Mesvo, Khari, Luni, Vatrak and Shedhi are main rivers flowing in Kheda district.

Physiography: Kheda District is an administrative district of Gujarat state in western India and is popularly known as Charotar. Kheda consists of 8 talukas with 529 villages. Total district area is 3959 sq.km and total population of 2,299,885 as per 2011 census. The average rainfall of district is 723 mm. It covers 8 talukas viz., Nadiad, Mahudha, Matar, Kheda, Kapadvanj, Thasra, Mehmedabad and Kathlal. Geomorphologically, the district can be broadly classified into three major zones viz., Piedmont plain, Alluvial Plain, and The Coastal Plains (Bhal).

Geology: Quaternary, Post Miocene and Tertiary sediments in the area were deposited over a sinking basement. The main formation is of quaternary age, formed by alluvium deposited by Mahi, Sabarmati and Watrak rivers. They comprise multilayered formations of gravel, sand, clay and kankars intermixed at places. The clay and sand horizons form alternate layers having pinching and swelling nature. The kankars, pebbles and the gravels form lenses. Thickness of alluvium increases from north and North West towards south and south west direction. Alluvium is underlain by Deccan traps in general with intervening blue clays at some places.



https://kheda.gujarat.gov.in/village-maps

Fig. 1. Map of Kheda district

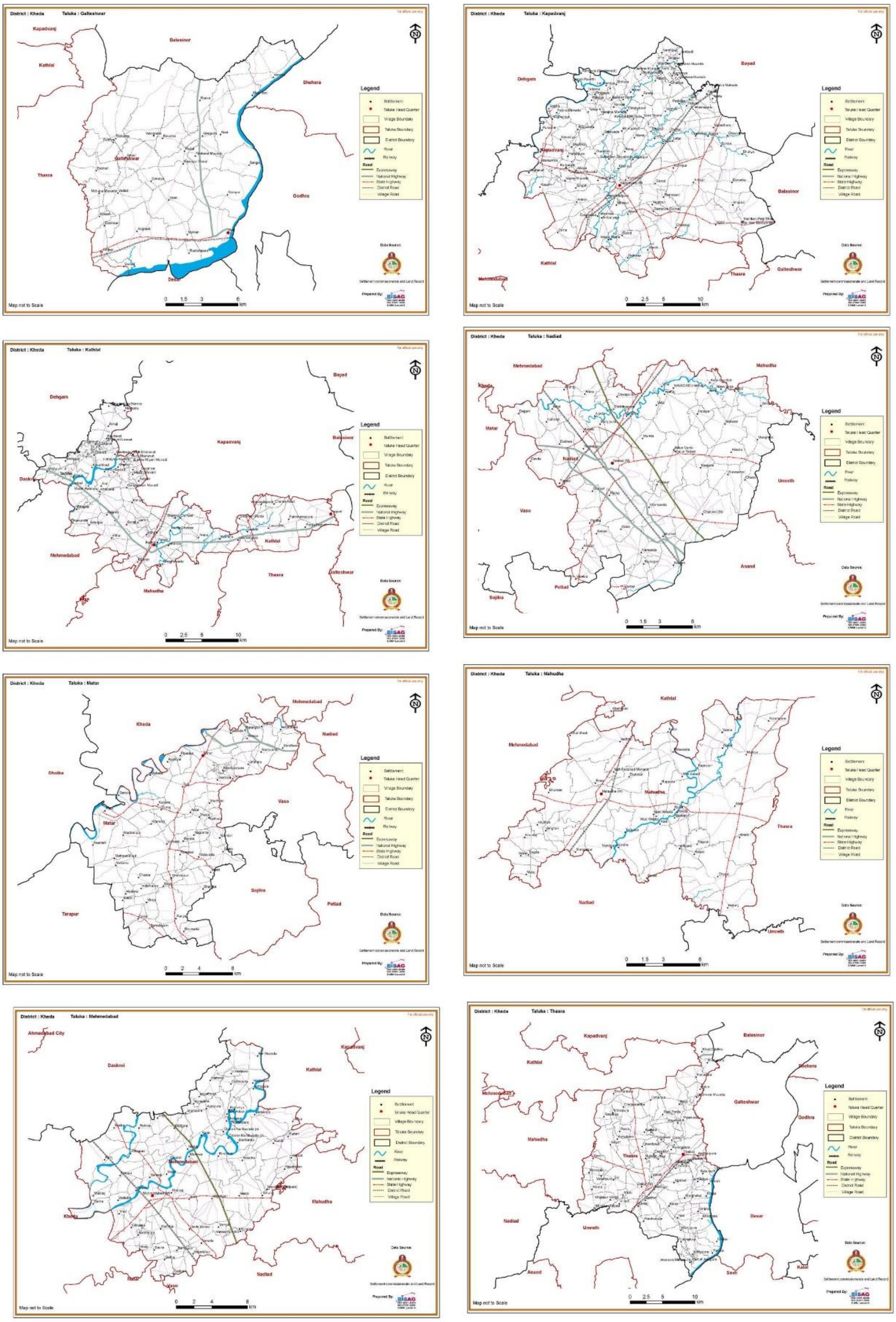


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Fig. 2. Different Taluka of Kheda District

Climate: The normal rainfall of this district is 723 mm from South-West Monsoon with an average of 45 rainy days. The normal onset of monsoon is from 3rd week of June and the normal cessation is in the 4th week of September. The climate of this district is semi-arid with hot, dry summers from mid-March to mid-June and the wet monsoon season from mid-June to October, when the area receives 776 mm of annual rain. The months from November to February are mild, the average temperature being around 20 °C, with low humidity. The year may be divided into four seasons. The cold season from December to February is followed by the hot season from March to May. June to September is the south-west monsoon season and two months of October and November form the post monsoon season.

Water: Sabarmati, Mahi, Mesvo, Khari, Luni, Vatrak and Shedhi are main rivers flowing in Kheda district. Source of irrigation water are open well, bore well, canals and ponds. Generally, water quality of Kheda district is good except Matar and some villages of Nadiad talukas. Sabarmati and Mahi are rivers that flow towards southeast and meet the Bay of Khambhat. Irrigation water is available throughout the year in most of the parts except in Matar and Mehmedabad taluka.

2.2 Collection of Water Samples

Twenty representative irrigation water samples were collected from each taluka of Kheda district. These talukas are Nadiad, Mahudha, Matar, Kheda, Kapadvanj, Thasra, Mehmedabad and Kathlal. Thus, 160 each soil as well as irrigation water samples were collected during April-May, 2016.

2.3 Methods of Analysis of Irrigation Water Samples

The underground (well/tube well) water samples were collected, filtered and stored in the plastic bottle was analysed for different chemical properties like, pH, EC, CO^{-}_{3}, HCO^{-}_{3}, Cl^{-}, SO^{-}_{4}, Na^{+}, K^{+}, Ca^{++}, Mg^{++} by following Potentiometric method [8] for pH, Conductivity method [8] for EC, Volumetric titration [9] for CO^{-}_{3} and HCO^{-}_{3}, $AgNO_3$ precipitation method [8] for Cl^{-}, Turbidity method [10] for SO^{-}_{4}, Flame photometry [8] for Na^{+} and K^{+}, Versenate method [11] for Ca^{++} and Mg^{++} respectively.

The following water and soil quality indices were calculated by standard formulas for categorization purpose.

1) Soluble Sodium Percentage [8]

$$\mathrm{SSP} = \frac{Na^{+}}{\mathrm{Ca^{++}+Mg^{++}+Na^{+}+K^{+}}} \text{ X } 100$$

2) Sodium Adsorption Ratio [8]

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

(Concentrations of all cations in me L^{-1})

3) Residual Sodium Carbonate [12]

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

(All ionic concentrations are in me L^{-1})

2.4 Rating Used for Water Quality Appraisal

Electrical Conductivity [8]:

1. C_1 (Low Salinity)**:** Soil with an EC ranging from 0 to 0.25 dSm^{-1} falls into this category. It's considered low in salt content. Plants can generally thrive in such conditions.
2. C_2 (Medium Salinity)**:** The EC range for this class is 0.25 to 0.75 dSm^{-1}. While still manageable, it indicates a moderate salt presence. Some crops may tolerate this level, but careful management is necessary.
3. C_3 (High Salinity)**:** Soils in this category have an EC between 0.75 and 2.25 dSm^{-1}**.** High salinity can stress plants, affecting growth and yield. Proper irrigation practices and salt leaching are crucial here.
4. C_4 (Very High Salinity)**:** The most saline soils fall into this group, with an EC spanning 2.25 to 5.00 dSm^{-1}**.** Plant growth is severely impacted, and only salt-tolerant species can survive.

Sodium Adsorption Ratio [8]: The SAR is used to assess the suitability of water for agricultural irrigation and to evaluate the sodicity hazard of soils. It considers the concentrations of key cations (sodium, calcium, and magnesium) present in water. Here's how it works:

1. S_1 (Low Na water)**:** SAR values ranging from 0 to 10 fall into this category. Water with low sodium content is suitable for irrigation. Plants can thrive without adverse effects.

2. S_2 (Medium Na water)**:** SAR values between 10 and 18 indicate moderate sodium levels. While still manageable, it's essential to monitor soil health and consider amendments if needed.
3. S_3 (High Na water)**:** SAR values in the range of 18 to 26 signify high sodium content. Irrigation with such water may impact soil structure and permeability. Soil amendments become crucial to prevent long-term damage.
4. S_4 (Very high Na water)**:** When SAR exceeds 26**,** water becomes very saline. It can severely affect soil properties, leading to poor crop production. Mitigating measures are necessary.

Residual Sodium Carbonate [12]: The RSC index helps assess the alkalinity hazard associated with irrigation water or soil water. It considers the balance between bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}) anions relative to calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions.
Here's how the RSC value translates into practical classes:

1. Safe: When the RSC value is less than 1.25 me L^{-1}, the water is considered safe. It poses minimal alkalinity risk for soil and is suitable for irrigation.
2. Marginal: An RSC value falling between 1.25 and 2.50 me L^{-1}indicates moderate sodium levels. While manageable, monitoring soil health and considering amendments is essential.
3. Unsafe**:** If the RSC value exceeds 2.50 me L^{-1}, the water becomes very saline. It can severely affect soil properties, leading to poor crop production. Mitigating measures are necessary.

Soluble Sodium Percentage [8]: The SSP is a critical parameter used to assess the sodium hazard in irrigation water or soil water. It considers the proportion of sodium ions (Na^+) relative to other cations (such as calcium and magnesium).

Here's how the SSP translates into practical classes:

1. Good: When the SSP value is less than 60, it indicates a favorable sodium content. The water or soil is considered suitable for irrigation without significant sodicity risk.
2. Fair:An SSP value exceeding 60 suggests moderate sodium levels. While manageable, monitoring soil health and considering amendments is essential to prevent long-term issues.

2.5 Statistical Analysis

Descriptive statistic was used for percentage distribution of soil samples in a particular parameter. Correlation and regression were calculated as described by [13].

3. RESULTS AND DISCUSSION

3.1 Irrigation Water Quality Appraisal

In order to presence a water quality appraisal, 160 underground water/tube well water samples (20 samples from each taluka) were collected. Irrigation water samples were analysed for EC, pH, cations (Ca^{++}, Mg^{++}, Na^+ and K^+), anions (CO_3^- , HCO_3^{--}, Cl^- and SO_4^-) and water quality appraisal was prepared by making use of EC and SAR values as suggested by USDA.

3.2 Cations Concentration in Well/Tube Well

Water Samples taluka wise range and mean values of different cations present in well/tube well water samples are given in Table 1. Among the cations, overall highest proportion of Na^+ (13.12 me L^{-1}) was observed, which was followed by Mg^{++} (4.79 me L^{-1}), Ca^{++} (1.62 me L^{-1}) and K^+ (0.07 me L^{-1}). The presence of large proportion of Na^+ in most of the area under investigation is indicative of a potential danger for the alkalinity hazards. The overall concentration of Ca^{++}, Mg^{++}, Na^+ and K^+ varied from 0.20 to 6.50, 0.50 to 13.10, 0.79 to 45.93 and 0.00 to 0.97 me L^{-1}, respectively (Table 1). The highest mean value for Na^+ (21.06 me L^{-1}) was found in Kheda taluka followed by Matar (17.74 me L^{-1}) and Mahudha (15.36 me L^{-1}), the lowest mean value for Na^+ (6.46 me L^{-1}) was reported in Kapadvanj taluka. Similar results were also found by Timbadia [14] for Jafrabad and Rajula talukas of Amreli district.

3.3 Anions Concentration in Well/Tube Well

Water Samples In case of anions, the highest overall mean value of 10.82 me L^{-1} was recorded for Cl^- and it was followed by HCO_3^- (7.52 me L^{-1}), CO_3^{--} (1.30 me L^{-1}) and SO_4^{--} (1.10 me L^{-1}). The highest mean value of Cl^- (20.83 me L^{-1}) was observed in Matar talukas while the highest mean value of HCO_3^- (8.90 me L^{-1}) was observed in Mehmedabad taluka as well as CO_3^{--} (1.55 me L^{-1}), SO_4^{--} (1.71 me L^{-1}) were observed in Mahudha and Kheda talukas, respectively. The overall range values for CO_3^{--}, HCO_3^-, Cl^- and SO_4^{--} were 0.00 to 4.00, 1.00 to 14.00, 1.00 to 71.50 and 0.00 to 2.13 me L^{-1}, respectively (Table 2). Similar results were also found by Timbadia [14] for Jafrabad and Rajula talukas of Amreli district.

Table 1. Taluka wise range and mean value of cations of well/tube well water samples of Kheda district

Name of Taluka	Cations in me L^{-1}			
	Ca^{++}	Mg^{++}	Na^+	K^+
Nadiad	0.20-3.40 (1.16)	1.00-10.60 (5.35)	0.94-45.93 (13.43)	0.00-0.58 (0.08)
Mahudha	0.40-2.70 (1.45)	2.70-13.10 (5.99)	1.99-40.71 (15.36)	0.00-0.20 (0.05)
Matar	0.60-4.70 (2.06)	1.30-11.00 (4.82)	4.35-45.80 (17.74)	0.01-0.65 (0.09)
Kheda	0.70-6.50 (2.66)	0.50-9.50 (4.03)	3.50-36.60 (21.06)	0.01-0.97 (0.13)
Kapadvanj	0.30-2.20 (1.18)	0.90-9.20 (3.69)	2.35-13.10 (6.46)	0.00-0.06 (0.02)
Thasra	0.40-3.00 (1.56)	2.20-7.80 (4.69)	0.79-31.53 (10.90)	0.01-0.48 (0.06)
Mehmedabad	0.50-2.90 (1.39)	4.10-9.70 (6.37)	2.74-30.02 (9.87)	0.01-0.97 (0.07)
Kathlal	0.60-2.90 (1.52)	0.70-6.60 (3.38)	2.91-19.30 (10.12)	0.01-0.20 (0.05)
Overall	0.20-6.50 (1.62)	0.50-13.10 (4.79)	0.79-45.93 (13.12)	0.00-0.97 (0.07)

Note: Values in parenthesis are mean values

Table 2. Taluka wise range and mean value of anions of well/tube well water samples of Kheda district

Name of Taluka	Anions in me L^{-1}			
	CO_3^-	HCO_3^{--}	Cl^-	SO_4^{--}
Nadiad	1.00-3.00 (1.30)	3.00-11.00 (7.30)	1.00-70.00 (12.43)	0.00-2.11 (1.52)
Mahudha	1.00-4.00 (1.55)	3.00-14.00 (8.15)	1.50-42.50 (12.20)	0.00-2.09 (1.01)
Matar	0.00-2.00 (1.15)	3.00-12.00 (8.00)	3.00-71.50 (20.83)	0.00-2.13 (1.61)
Kheda	0.00-3.00 (1.25)	4.00-13.00 (7.95)	3.00-37.50 (16.88)	0.75-2.11 (1.71)
Kapadvanj	1.00-2.00 (1.10)	3.00-12.00 (6.20)	2.00-10.00 (3.68)	0.00-1.96 (0.39)
Thasra	1.00-4.00 (1.40)	1.00-14.00 (6.85)	1.50-27.00 (8.25)	0.00-2.02 (0.68)
Mehmedabad	1.00-4.00 (1.30)	5.00-12.00 (8.90)	1.50-27.00 (6.35)	0.00-1.98 (0.83)
Kathlal	1.00-2.00 (1.35)	3.00-12.00 (6.80)	2.00-19.50 (5.93)	0.00-1.79 (1.08)
Overall	0.00-4.00 (1.30)	1.00-14.00 (7.52)	1.00-71.50 (10.82)	0.00-2.13 (1.10)

Note: Values in parenthesis are mean values

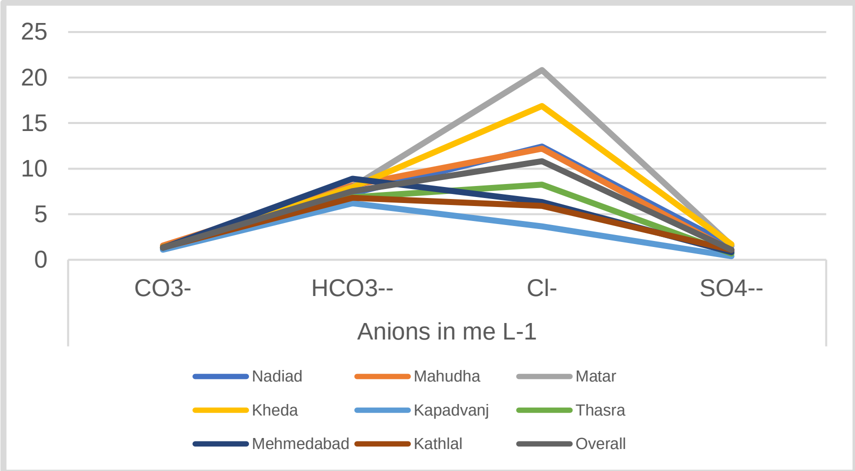

Fig. 3. Taluka wise mean value of cations of water samples of Kheda district

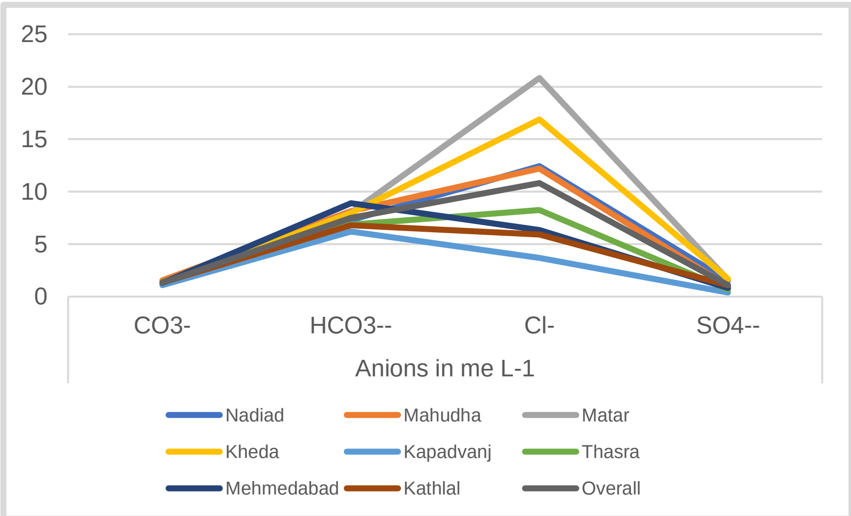

Fig. 4. Taluka wise mean value of anions of water samples of Kheda district

3.4 Electrical Conductivity (EC)

The overall mean value of EC was found 2.04 dS m^{-1}, which was varied widely from 0.51 to 8.50 dS m^{-1}. The lowest value of EC (0.51 dS m^{-1}) was recorded in a sample taken from Kapadvanj taluka whereas the highest value of EC (8.50 dS m^{-1}) was reported in Matar taluka. The highest mean value (3.16 dS m^{-1}) was obtained in Matar taluka followed by Kheda (2.77 dS m^{-1}) and Mahudha (2.25 dS m^{-1}) talukas due to poor quality ground water. The lowest mean value (1.07 dS m^{-1}) was obtained in Kapadvanj taluka (Table 3). The higher mean value of EC is an indicative of potential development of saline soils in Kheda district. Similar findings were made by Churu district (Rajasthan) by Verma *et al*, [15], for Amreli district by Kabaria [16] for Mahboob Nagar district of Andhra Pradesh by Prasad and Minhas [17] and for Bhavnagar district by Rajput and Polara [18].

If we observe the percentage distribution of samples in different EC classes, then 0.00, 9.37, 63.75 and 27.50 per cent samples were falling under C_1, C_2, C_3 and C_4 classes of EC, respectively. None of the sample falls under C_1 classes of EC. In Kheda district 101 samples fall under C_3 class of EC and 44 samples under C_4 and 15 samples fall under C_2 class. So, the salinity hazard of irrigation water is the cause of the development of secondary salinization in the soils of Kheda district (Table 8). The result also revealed that overall, irrigation water of kheda district fall in C_3 class (highly saline) irrigation water. The Nadiad, Mahudha, Kapadvanj, Mehmedabad and Kathlal talukas having high saline irrigation water. Whereas, Matar and Kheda having very high saline irrigation water (Table 8). This finding is in conformity with the findings for Churu district (Rajasthan) by Verma *et al*, [15], for Amreli district by Kabaria [16], For Mahboob Nagar district of Andhra Pradesh by Prasad and Minhas [17] and for Bhavnagar district by Rajput and Polara [18].

3.5 pH

In general, the waters of this district were alkaline in reaction. The pH values were ranged from 6.84 to 9.30 with a mean value of 7.97. The highest mean value of pH 8.27 was recorded in Kathlal taluka whereas the lowest mean value of pH 7.70 was recorded in Mahudha taluka (Table 3). This finding is in conformity with the findings for Churu district (Rajasthan) by Verma *et al*, [15], for Amreli district by Kabaria [16], For Mahboob Nagar district of Andhra Pradesh by Prasad and Minhas [17] and for Bhavnagar district by Rajput and Polara [18].

3.6 Residual Sodium Carbonate (RSC)

Taluka wise range and mean values of RSC is given in Table 3 and percentage distributions of water samples in different RSC Table 8. The overall RSC values were ranged from -4.80 to 10.50 with a mean value of 2.41 me l^{-1} which was less than 2.5 me l^{-1} indicated poor quality irrigation water. The highest mean value of RSC (3.26 me l^{-1}) was recorded in Kathlal taluka indicate poor quality water, whereas the lowest mean value (2.01 me l^{-1}) was obtained in Thasra taluka (Table 8). For all talukas, except Kheda and Kathlal the RSC mean values were falling between 1.25 to 2.50 me l^{-1}, which showed that irrigation water having marginal carbonate hazards and marginally fit for irrigation with adequate leaching. It also noted that the Kheda and Kathlal talukas having irrigation water not suitable for irrigation purpose. This finding is in conformity with the findings for Churu district (Rajasthan) by Verma *et al*, [15], for Amreli district by Kabaria [16], For Mahboob Nagar district of Andhra Pradesh by Prasad and Minhas [17] and for Bhavnagar district by Rajput and Polara [18].

Overall, 34.37, 20.62 and 45.0 per cent samples fall under safe, marginal and unsafe classes of RSC, respectively (Table 8). This finding is in concurrence with the findings of Sood *et al*. [19].

3.7 Soluble Sodium Percentage (SSP)

Taluka wise range and mean values of SSP is given in Table 8. and percentage distributions of water samples in different SSP classes (as suggested by USDA) are presented in Table 3. The overall mean value of SSP was 34.34 and ranged from 8.00 to 77.26 (Table 3). The highest mean value (43.65) was recorded in Mehmedabad taluka whereas, the lowest mean value (22.83) was recorded in Kheda taluka. Overall, 94.37 and 5.62 per cent samples fall under safe and unsafe classes of SSP, respectively (Table 8). The result also revealed that in respect to SSP, all the talukas and overall Kheda district was safe from SSP hazards. This finding is in concurrence with the findings of Sood *et al*. [19]. For most of soil samples SSP values were more than 60, which in an indicative of alkali hazards in these waters. This finding is in conformity with the findings for Churu district (Rajasthan) by Verma *et al*, [15], for Amreli district by Kabaria [16] , For Mahboob Nagar district of Andhra Pradesh by Prasad and Minhas [17] and for Bhavnagar district by Rajput and Polara [18].

3.8 Sodium Adsorption Ratio (SAR)

The SAR value is an important criterion for studying the alkali hazards in irrigation water. Therefore, taluka wise, range and mean values of SAR is given in Table 3. and per cent distribution of water sample in different SAR classes (as suggested by USDA) are presented in Table 3. The overall mean value of SAR was 7.48 and it was varied from 0.36 to 29.96. The lowest (0.36) and the highest (29.96) SAR value was reported in water samples collected from Nadiad taluka, respectively. The highest (11.55) and the lowest (4.64) mean SAR values were registered in water samples collected from Kheda and Kapadvanj talukas, respectively. This finding is in conformity with the findings for Churu district (Rajasthan) by Verma *et al*, [15], for Amreli district by Kabaria [16], For Mahboob Nagar district of Andhra Pradesh by Prasad and Minhas [17] and for Bhavnagar district by Rajput and Polara [18]. About 75.0, 21.87, 2.50 and 0.62 per cent samples fall under S_1, S_2, S_3 and S_4 classes of SAR, respectively. Almost 120 samples had SAR value less than 10 and 35 samples had SAR value greater than 10 (Table 8). The result also revealed that overall, irrigation water of Kheda district fall in S_1 class (Low Na) irrigation water. Whereas, all the talukas of Kheda district having low Na irrigation

Table 3. Taluka wise range and mean values of EC, pH and different indices of well/tube well water samples of Kheda district

Name of Taluka	EC (dS m^{-1})	pH	RSC (me L^{-1})	SSP	SAR	EC and SAR classes
Nadiad	0.73-8.20 (2.22)	7.32-9.30 (8.20)	-3.40-6.70 (2.10)	9.18-77.26 (33.89)	0.36-29.96 (7.79)	C_3S_1
Mahudha	0.60-5.50 (2.25)	6.85-8.70 (7.70)	-4.80-8.70 (2.26)	16.65-62.77 (35.92)	1.39-15.93 (7.58)	C_3S_1
Matar	0.70-8.50 (3.16)	7.49-9.16 (7.90)	-4.00-7.40 (2.28)	12.72-43.38 (26.89)	3.55-18.12 (9.60)	C_4S_1
Kheda	0.70-4.80 (2.77)	7.18-8.54 (7.91)	-4.20-8.60 (2.51)	14.65-47.94 (22.83)	2.30-16.68 (11.55)	C_4S_2
Kapadvanj	0.51-2.10 (1.07)	7.30-8.42 (7.82)	-1.80-8.80 (2.44)	8.82-60.73 (40.90)	1.33-15.63 (4.64)	C_3S_1
Thasra	0.62-4.10 (1.66)	6.84-8.90 (7.82)	-3.00-10.40 (2.01)	10.87-73.83 (39.61)	0.41-18.73 (6.48)	C_3S_1
Mehmedabad	0.69-4.10 (1.69)	7.61-8.58 (8.11)	-0.70-7.20 (2.45)	25.33-61.65 (43.65)	1.73-12.80 (4.93)	C_3S_1
Kathlal	0.70-2.40 (1.48)	7.64-8.62 (8.27)	-4.60-10.50 (3.26)	8.00-54.01 (31.04)	1.77-20.11 (7.25)	C_3S_1
Overall	0.51-8.50 (2.04)	6.84-9.30 (7.97)	-4.80-10.50 (2.41)	8.00-77.26 (34.34)	0.36-29.96 (7.48)	C_3S_1

Note: Values in parenthesis are mean values

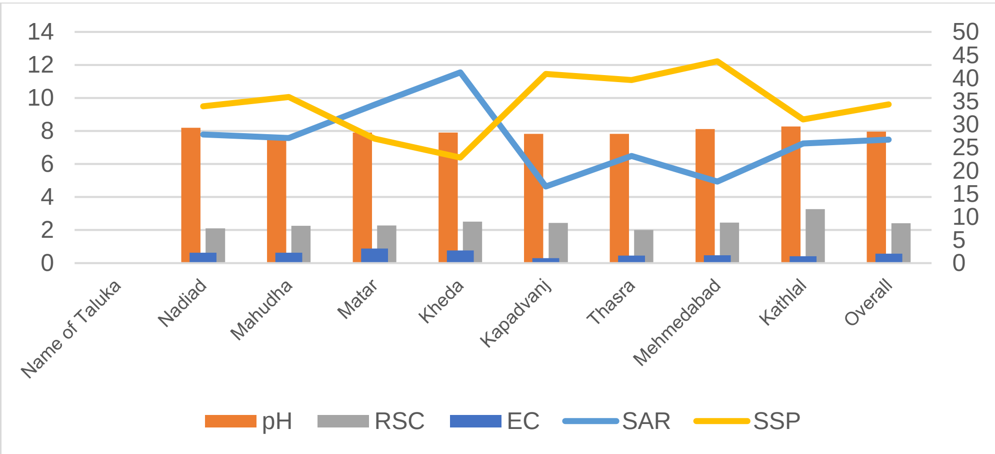

Fig. 5. Taluka wise mean values of different indices of water samples

water except Kheda taluka fall in S_2 (Medium Na) irrigation water (Table 8). This finding is in concurrence with the findings of Sood *et al*. [19] and Kabaria [16].

3.9 EC and SAR classes of Well/Tube Well Water Samples

Taluka wise EC and SAR classes of well/tube well water samples are given in Table 3. The result revealed that overall, irrigation water of Kheda district fall in C_3S_1 class (high saline-low Na) irrigation water. Whereas, same result found in all talukas of Kheda district except Matar and Kheda fall in C_4S_1 and C_4S_2 irrigation water classes, respectively. This finding is in concurrence with the findings of Sood *et al*. [19] and Kabaria [16].

4. CONCLUSIONS

The well/tube waters of Kheda (C_4S_2) and Matar (C_4S_1) talukas of Kheda district are poor in quality. More than half of the samples of well/tube well waters from cultivator's fields were saline (EC 0.75 dS m^{-1} and above). This is indicative of the potential development of saline soils in the Kheda district. Therefore, secondary salinization is one of the causes for development of salt affected soils. The problem of salinity will be even increased in this district in future. Therefore, suitable holistic management practices should be implemented for the sustainable agriculture in this district.

COMPETING INTERESTS

Authors have declared that no competing interests exist

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