Archives of Current Research International

Volume 24, Issue 10, Page 308-320, 2024; Article no.ACRI.125391
ISSN: 2454-7077

Assessment of Groundwater Quality for Irrigation in Jhagadia, Netrang and Valia Taluka of Bharuch District in South Gujarat, India

Patil, L. M. [a*], Patel, K. G. [b], Naik, V. R. [c] and Valvi, V. I. [a]

[a] Krishi Vigyan Kendra, BAIF, Bharuch, India.
[b] Department of Soil Science and Agril Chemistry, NMCA, NAU, Navsari, India.
[c] Navsari Agricultural University, Navsari, India.

Authors' contributions

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

Article Information

DOI: https://doi.org/10.9734/acri/2024/v24i10934

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/125391

Original Research Article

Received: 14/08/2024
Accepted: 16/10/2024
Published: 21/10/2024

ABSTRACT

Bharuch, a heavily industrialized district on the west coast, faces challenges like over-extraction and contamination, which threaten its groundwater quality. In response, a post-monsoon 2023 assessment was conducted in the Jhagadia, Netrang, and Valia talukas, where water samples from 78 locations were collected and analyzed. These locations were identified using landforms developed through GIS. The study found that around 40% of the TGA in these blocks is used for agriculture, with 52,106 hectares for single crops and 7,843 hectares for double crops, making up 15.05% of the total cultivated area. Eastern part of Jhagadia and Netrang recorded deep water

**Corresponding author: Email: lalitpatil59@gmail.com;*

Cite as: *L. M., Patil, Patel, K. G., Naik, V. R., and Valvi, V. I. 2024. "Assessment of Groundwater Quality for Irrigation in Jhagadia, Netrang and Valia Taluka of Bharuch District in South Gujarat, India". Archives of Current Research International 24 (10):308-20. https://doi.org/10.9734/acri/2024/v24i10934.*

levels (10–20 m), while other areas had moderately shallow levels (5–10 m). Tube wells were mainly found in Valia, northern Jhagadia, and western Netrang, whereas dug wells dominated eastern Netrang and southeastern Jhagadia. Irrigation water pH ranged from 6.31 to 8.82, averaging 6.97, with higher pH in Jhagadia. Electrical conductivity (EC) was highest in Valia (0.66–2.94 dSm^{-1}), and medium salinity was noted in Jhagadia (1.03 dSm^{-1}) and Netrang (0.71 dSm^{-1}), affecting irrigation suitability. All samples had a SAR classification of S1 (<10). Most water samples were "Suitable" based on RSC, except some in Valia with RSC >1.25 meL^{-1}. Chloride levels varied from 0.50 mg/L^{-1} to 25.48 mg/L^{-1}. The specific soil management practices, such as gypsum application, improving drainage and the growing of salt-tolerant crop varieties can help mitigate potential negative impacts on crop productivity.

Keywords: Irrigation; water quality; SAR; RSC; GIS; Bharuch.

1. INTRODUCTION

Groundwater is a critical resource for agricultural activities around the world, serving as a primary source of irrigation water, especially in regions with limited surface water availability. Globally, groundwater is a natural resource for domestic (65%), agricultural (20%), and industrial (15%) purposes [1]. Studies on groundwater resources have become vital in semiarid regions for various purposes [2,3]. It sustains crop production, supports livestock, and underpins food security in many parts of the world. However, the quality of groundwater is as important as its availability. Poor-quality groundwater can have detrimental effects on crop health, soil structure and overall farm productivity, making it crucial for farmers and agricultural planners to understand and manage this resource effectively. According to the study by Guo *et al*. [4], geologic setting, water-rock interaction, bedrock weathering and seasonal variation impact the sub-surface water quality. Subsequently, direct inputs of different contaminants including toxic elements from the industries, agricultural, municipal waste disposal are also responsible for water quality deterioration [5]. Groundwater quality is determined by various factors, including its chemical composition, mineral content, and potential contaminants. Parameters such as salinity, pH, sodium adsorption ratio (SAR), residual sodium carbonates (RSC), Chloride and the presence of heavy metals or nitrates are key indicators that influence its suitability for agricultural use.

With the increasing pressures of climate change, population growth, and intensive agricultural practices, the reliance on groundwater has grown significantly. This has led to challenges such as over-extraction, contamination and declining water tables, which threaten both the quantity and quality of groundwater resources. Understanding and effectively managing groundwater quality is crucial for sustainable agricultural practices to ensure that agriculture can thrive, supporting farmers and contributing to food security. In this context, the study was undertaken to assess groundwater quality for irrigation purposes.

2. MATERIALS AND METHODS

The study involves the characterization of water resources of tribal talukas of Bharuch district namely, Jhagadia, Netrang and Valia. The location of the study areas falls under the South Gujarat region, which comprises South Gujarat agro-climatic Zone II. The study area is located between 21°29'05" to 21°55'21" N latitude and 73°03'40" to 73°29'51" E longitude in Bharuch district, Gujarat (Fig. 1). It has an elevation up to 430 m above mean sea level (MSL). It covers an area of 1.32 lakhs ha which is 20.23 per cent of the total geographical area (TGA) of Bharuch district and is comprised of 264 villages with a population of 3.30 lakhs according to census 2011. More than 73 per cent of the population in these talukas is comprised of scheduled tribes, primarily the Bhil Vasava community.

The district is drained by Narmada, Dhadhar and Kim rivers. Narmada River is in the centre of these rivers. The climate of the study area is semi-arid with hot and moist summers and dry winters. The Arabian Sea has a significant role in controlling the weather.

The Digital Elevation Model (DEM), slope and land-use/land-cover layers were integrated into ArcGIS 10.8.2 software and a landforms layer was prepared. These landforms are relatively homogeneous in terms of the various natural factors viz. soil, water, vegetation and microclimate. The study area was subdivided into fifteen representative profile zones, derived from nine distinct landforms identified across three districts within Bharuch. A minimum of five water samples were collected from each profile zone. In total, 78 groundwater samples were gathered across the study area, with 25 from Jhagadia, 26 from Netrang, and 27 from Valia. These samples were sourced from both bore wells and dug wells, representing the fields of each respective profile following standard procedure. The groundwater quality was analyzed using standard procedures and assessed for its suitability for irrigation.

Sodium Absorption Ratio (SAR) and Residual Sodium Carbonates (RSC) were calculated by using following formula.

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

$$\mathrm{RSC} = (\mathrm{CO3} + \mathrm{HCO3}) - (\mathrm{Ca + Mg})$$

Statistical analysis: The descriptive statistics (minimum, maximum, mean, standard error, standard deviation, kurtosis and skewness) were calculated for the chemical variables in water samples.

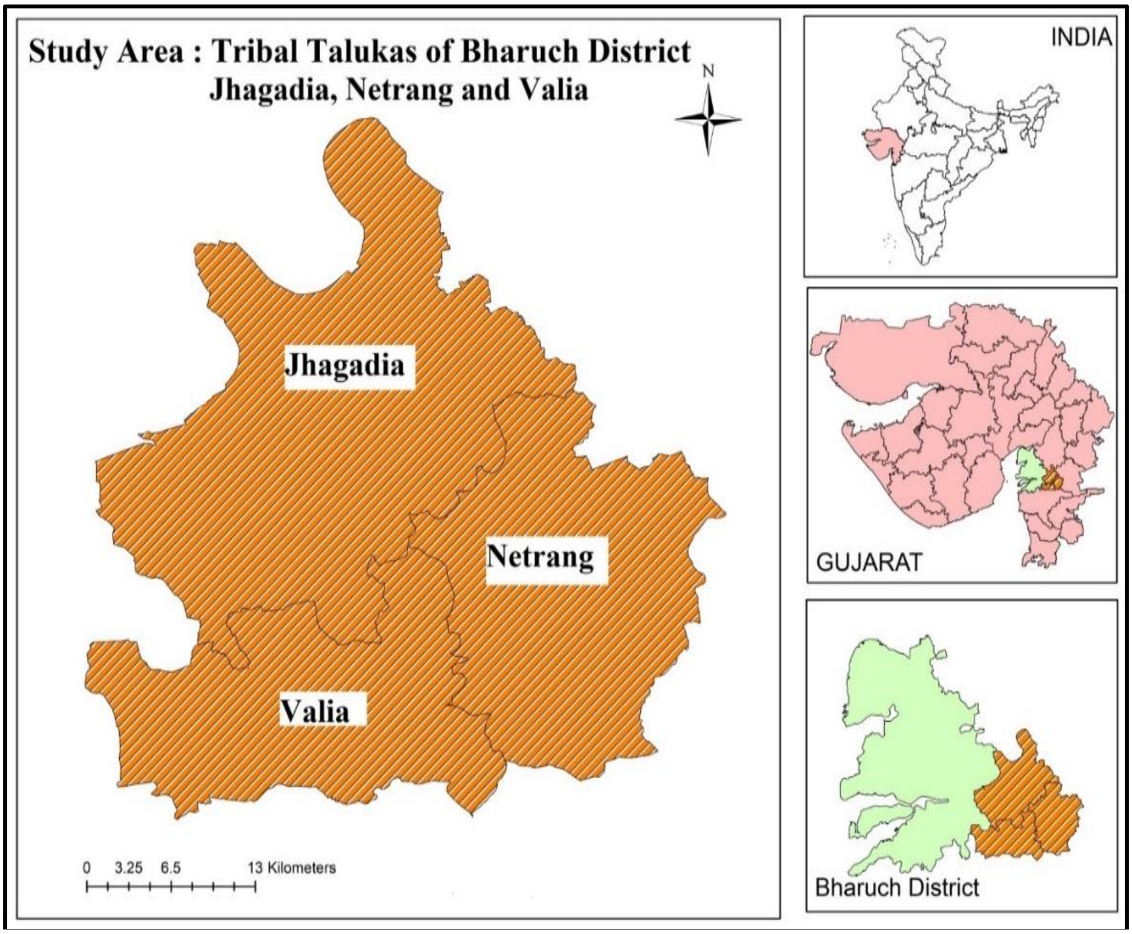

Fig. 1. Location map of study area

Table 1. Rating for EC and SAR of water (USSL, 1954)

Symbol	Rating	EC (dSm^{-1})	Symbol	Rating	SAR
C1	Low Salinity	<0.25	S1	Low Na	< 10
C2	Medium Salinity	0.25-0.75	S2	Medium Na	10-18
C3	High Salinity	0.75-2.25	S3	High Na	18-26
C4	Very High Salinity	2.25-5.00	S4	Very High Na	>26

3. RESULTS AND DISCUSSION

3.1 Groundwater Status in Bharuch District

All three tribal talukas under study have been categorized in safe stage with respect to future ground water development (CGWB, 2014). In major parts of the district the depth of water level ranged from 5 to 20 m below ground level. Deep water level between 10 to 20 m was observed in the eastern part of Jhagadia and Netrang taluka. Moderately shallow water level *i.e.* 5 to 10 m below ground level (bgl) was observed mainly in the remaining part of these talukas. Over exploitation of ground water is a major issue in some parts of the district resulting in the fast depletion of water resource. Piezometric heads of deep confined aquifer has also declined sharply owing to the huge withdrawal. The flood irrigation technique, which is practiced in the area, is also the major cause of wastage of ground water as there is no control on the watering depth [6].

The predominant groundwater structures in the region encompass tube wells, serving the entirety of Valia, the northern section of Jhagadia and the western area of Netrang. Conversely, dug wells are commonly observed in the eastern sector of Netrang and the south-eastern part of Jhagadia taluka. During the critical growth stages of crops, particularly during the monsoon season, farmers resort to utilizing groundwater for irrigation in case of extended dry periods. Similarly, throughout the *Rabi* and summer seasons, farmers rely on groundwater for cultivating crops.

3.2 Present Land Use and Land Cover of Jhagadia, Netrang and Valia

Based on the USGS Sentinel satellite image, 7 land-use/land-cover classes were identified. The land-use data (Fig. 2 and Table 2) indicates that about 40 per cent TGA of these blocks are under agriculture. These blocks has 37 per cent under various vegetation including forest area and other dispersed tree species, 11 per cent scrub land, 7.0 per cent fallow land and 3.0 per cent build-up area under residential and industries.

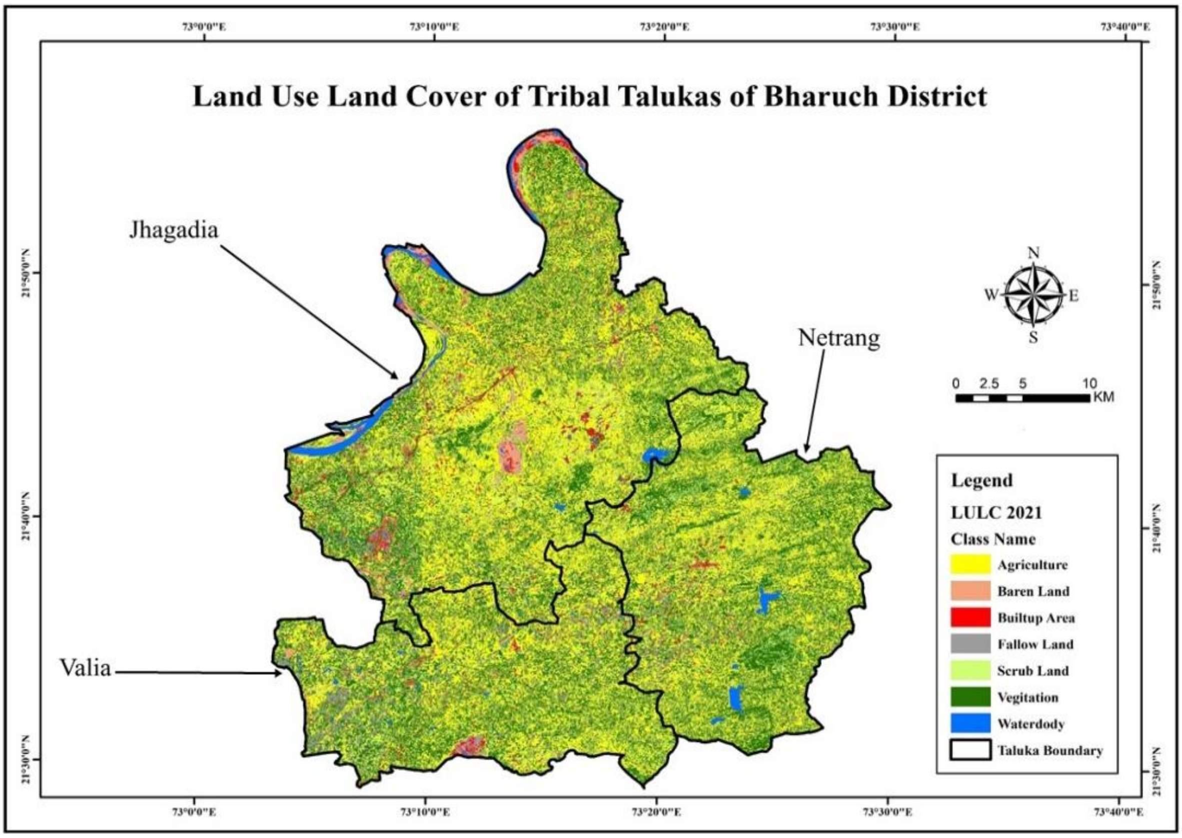

Fig. 2. Present land use and land cover map of study area

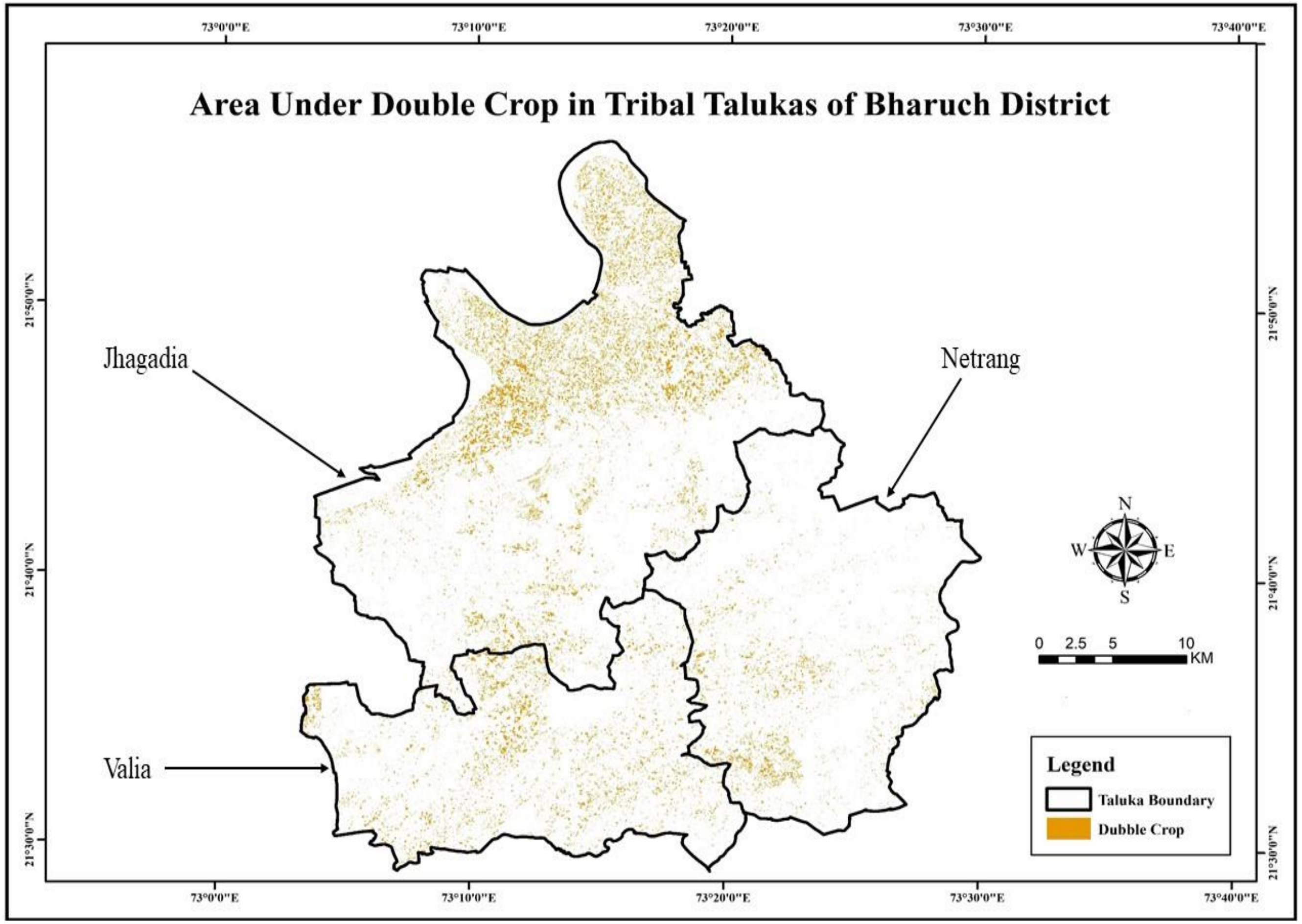

Fig. 3. Extent of double crops in area

Table 2. Land use and land cover of Jhagadia, Netrang and Valia talukas of Bharuch

Land use	Area (ha)	% of TGA
Agriculture	52106	39.55
Barren Land	1430	1.09
Built-up Area	3480	2.64
Fallow Land	8999	6.83
Scrub Land	14427	10.95
Vegetation (Forest and other species)	48980	37.18
Waterbodies	2315	1.76
Total	**131737**	**100.00**

Table 3. Extent of double crops in Jhagadia, Netrang and Valia talukas of Bharuch

Taluka	Area (hectares)		% of Cultivated area
	Single Crop	Double Crops	
Jhagadia	24918	5027	20.17
Netrang	14831	1046	7.05
Valia	12357	1770	14.32
Total	**52106**	**7843**	**15.05**

The Table 3 and Fig. 3 present the cultivated land areas and their percentages for single and double crops in Jhagadia, Netrang and Valia. Jhagadia has the highest double-crop area with 5027 hectares, constituting 20.17 per cent of the cultivated land. Netrang has the smallest double-crop area, with 1046 hectares, representing 7.05 per cent. Valia has a double-crop area making up 14.32 per cent of its cultivated land. Overall, the total cultivated area includes 52106 hectares for single crops and 7843 hectares for double crops, amounting to 15.05 per cent of the total cultivated area.

3.3 Quality Parameters of Groundwater Samples of Jhagadia taluka

The Table 4 provides the quality parameters and classification of groundwater samples from various locations in Jhagadia taluka. The pH of the water samples varied from 6.61 to 8.82, with a mean value of 7.22, indicating that most of the water was neutral. The electrical conductivity (EC) of the water samples ranged between 0.31 and 1.90 dSm^{-1}, with a mean value of 1.03 dSm^{-1}, suggesting a salinity problem in the water of the study area. Of the 25 water samples, four were classified into the C2 class and 21 were classified into the C3 class. This distribution means that 16 per cent of the water samples fall into the C2 class (medium salinity problem), while 84 per cent were categorized into the C3 class (high salinity problem). Based on the residual sodium carbonate (RSC) values, which ranged from -6.91 to 1.91 meL^{-1} with a mean value of -1.04 meL^{-1}. The sodium adsorption ratio (SAR) values of the water samples ranged from 0.20 to 3.32, with a mean value of 1.33, indicating that all the water samples fall into the S1 class, which denotes a low sodium hazard. The chloride content varies from 2.36 to 9.14 mgL^{-1} with a mean value of 5.00 meL^{-1}. Similar findings were reported by Donga *et al*. [7].

3.4 Quality Parameters of Groundwater Samples of Netrang Taluka

In the case of water samples from Netrang, the pH ranged from 6.31 to 7.42 with a mean value of 6.77, indicating neutrality of the water. The electrical conductivity (EC) of the water samples varied from 0.34 to 1.40 dSm^{-1}, with a mean value of 0.71 dSm^{-1}, suggesting a slight salinity problem in Netrang taluka. Out of 26 water samples, 18 were classified into the C2 class and 8 were classified into the C3 class. This means that 69 per cent of the water samples fall into the C2 class (medium salinity problem), while 31 per cent were categorized into the C3 class (high salinity problem). The RSC values, which ranged from -2.83 to 1.84 meL^{-1} with a mean value of 0.03 meL^{-1}. The SAR values ranged from 0.35 to 2.96, with a mean value of 1.00, indicating that all water samples fall into the S1 class, which denotes a low sodium hazard. The range of chloride content was 0.50 to 6.20 mgL^{-1} with a mean value of 2.67 meL^{-1}. Overall, pH and SAR values are within acceptable limits, suggesting minimal risk to crop health and soil structure. However, EC and chloride levels in certain areas, particularly Kavchiya and Chaswad, indicate moderate to high salinity and chloride hazards, which could affect long-term soil health and crop yields.

Table 4. Quality parameters and classification of groundwater samples of Jhagadia taluka

Profile	Sample No	pH	EC (dsm^{-1})	Class	RSC	Class	SAR	Class	Cl^- (mgL^{-1})
Amalzar (P1)	1	6.86	0.90	C3	-2.61	S1	0.50	S1	6.46
	2	6.74	0.58	C2	-0.65	S1	0.51	S1	4.84
	3	6.69	0.69	C2	-1.08	S1	0.94	S1	2.36
	4	6.76	0.95	C3	-1.53	S1	0.85	S1	3.12
	5	6.70	0.84	C3	-3.04	S1	0.74	S1	5.50
	Max	**6.86**	**0.95**		**-0.65**		**0.94**		**6.46**
	Min	**6.69**	**0.58**		**-3.04**		**0.50**		**2.36**
	Mean	**6.75**	**0.79**		**-1.78**		**0.71**		**4.46**
Dhundha (P2)	1	6.61	1.47	C3	-1.13	S1	3.57	S1	6.90
	2	7.44	1.13	C3	1.91	S2	0.32	S1	6.56
	3	7.33	1.11	C3	-0.66	S1	0.25	S1	5.10
	4	7.15	0.96	C3	-1.27	S1	2.08	S1	3.88
	5	8.82	0.80	C3	-1.64	S1	0.77	S1	5.52
	Max	**8.82**	**1.13**		**1.91**		**2.08**		**6.90**
	Min	**6.61**	**0.80**		**-1.64**		**0.25**		**3.88**
	Mean	**7.47**	**1.00**		**-0.42**		**0.85**		**5.59**
Jarsad (P3)	1	7.35	1.02	C3	-4.34	S1	0.20	S1	9.14
	2	7.68	0.58	C2	1.87	S2	0.23	S1	4.82
	3	6.73	0.95	C3	-0.66	S1	2.32	S1	3.10
	4	6.79	1.02	C3	-1.37	S1	2.34	S1	4.96
	5	7.11	0.85	C3	0.76	S1	2.31	S1	3.10
	Max	**7.68**	**1.02**		**1.87**		**2.34**		**9.14**
	Min	**6.73**	**0.58**		**-4.34**		**0.20**		**3.10**
	Mean	**7.13**	**0.88**		**-0.75**		**1.48**		**5.02**
Selod (P4)	1	7.18	1.57	C3	-2.52	S1	1.85	S1	5.46
	2	7.57	1.24	C3	1.47	S2	1.89	S1	5.18
	3	7.87	1.90	C3	-6.91	S1	0.87	S1	7.24
	4	7.72	1.74	C3	1.77	S2	0.91	S1	6.78
	5	7.78	1.75	C3	-3.38	S1	1.25	S1	6.82
	Max	**7.87**	**1.90**		**1.77**		**1.89**		**7.24**
	Min	**7.18**	**1.24**		**-6.91**		**0.87**		**5.18**
	Mean	**7.62**	**1.64**		**-1.91**		**1.35**		**6.30**

Profile	Sample No	pH	EC (dsm^{-1})	Class	RSC	Class	SAR	Class	Cl^- (mgL^{-1})
Shir (P5)	1	7.42	0.67	C2	-0.19	S1	2.58	S1	3.16
	2	7.54	0.31	C2	-2.70	S1	0.76	S1	3.78
	3	6.85	1.00	C3	-0.13	S1	2.41	S1	3.54
	4	7.06	1.26	C3	1.69	S2	3.32	S1	3.70
	5	6.79	1.01	C3	-0.32	S1	2.29	S1	3.94
	Max	**7.54**	**1.26**		**1.69**		**3.32**		**3.94**
	Min	**6.79**	**0.31**		**-2.70**		**0.76**		**3.16**
	Mean	**7.13**	**0.85**		**-0.33**		**2.27**		**3.62**
Overall Mean		**7.22**	**1.03**		**-1.04**		**1.33**		**5.00**

Table 5. Quality parameters and classification of groundwater samples of Netrang taluka

Profile	Sample No	pH	EC (dsm^{-1})	Class	RSC	Class	SAR	Class	Cl^- (mgL^{-1})
Chaswad (P6)	1	6.93	0.85	C3	-0.25	S1	1.65	S1	2.04
	2	6.82	0.99	C3	0.81	S1	1.61	S1	2.86
	3	6.55	0.71	C2	0.90	S1	0.57	S1	2.42
	4	6.65	0.97	C3	0.98	S1	2.83	S1	4.14
	5	6.51	0.61	C2	1.28	S2	1.47	S1	2.82
	Max	**6.93**	**0.99**		**1.28**		**2.83**		**4.14**
	Min	**6.51**	**0.61**		**-0.25**		**0.57**		**2.04**
	Mean	**6.69**	**0.83**		**0.74**		**1.62**		**2.86**
Kadwali (P7)	1	7.14	0.58	C2	0.37	S1	0.47	S1	2.02
	2	6.89	0.56	C2	0.79	S1	0.71	S1	0.50
	3	6.52	0.84	C3	-2.03	S1	0.79	S1	3.00
	4	6.60	0.59	C2	-1.29	S1	0.39	S1	2.12
	5	6.67	0.54	C2	0.24	S1	1.31	S1	2.66
	Max	**7.14**	**0.84**		**0.79**		**1.31**		**3.00**
	Min	**6.52**	**0.54**		**-2.03**		**0.39**		**0.50**
	Mean	**6.76**	**0.62**		**-0.38**		**0.73**		**2.06**
Kavchiya (P8)	1	6.78	1.00	C3	-0.20	S1	1.04	S1	3.50
	2	6.94	0.83	C3	1.64	S2	1.30	S1	2.78
	3	6.86	0.70	C2	0.92	S1	0.70	S1	2.40
	4	6.46	1.40	C3	-1.27	S1	1.39	S1	6.20
	5	6.73	0.77	C3	1.84	S2	2.96	S1	2.92

Profile	Sample No	pH	EC (dsm^{-1})	Class	RSC	Class	SAR	Class	Cl^- (mgL^{-1})
	Max	**6.94**	**1.40**		**1.84**		**2.96**		**6.20**
	Min	**6.46**	**0.70**		**-1.27**		**0.70**		**2.40**
	Mean	**6.75**	**0.94**		**0.59**		**1.48**		**3.56**
Mungaj	1	6.80	0.55	C2	-2.83	S1	0.35	S1	2.76
(P9)	2	6.66	0.51	C2	-2.80	S1	0.45	S1	3.76
	3	6.59	0.74	C2	0.56	S1	0.65	S1	2.26
	4	6.82	0.66	C2	0.51	S1	0.89	S1	2.28
	5	7.31	0.62	C2	1.28	S2	0.41	S1	1.64
	Max	**7.31**	**0.74**		**1.28**		**0.89**		**3.76**
	Min	**6.59**	**0.51**		**-2.83**		**0.35**		**1.64**
	Mean	**6.84**	**0.62**		**-0.66**		**0.55**		**2.54**
Shankoi	1	6.31	0.34	C2	0.33	S1	0.55	S1	3.16
(P10)	2	6.79	0.54	C2	0.59	S1	0.43	S1	3.78
	3	7.42	0.53	C2	0.90	S1	0.41	S1	3.54
	4	6.67	0.53	C2	0.67	S1	0.46	S1	3.70
	5	6.55	0.74	C2	-2.45	S1	0.80	S1	3.94
	6	7.03	0.73	C2	-0.75	S1	0.95	S1	3.94
	Max	**7.42**	**0.74**		**0.90**		**0.95**		**3.94**
	Min	**6.31**	**0.34**		**-2.45**		**0.41**		**3.16**
	Mean	**6.80**	**0.57**		**-0.12**		**0.60**		**2.34**
Overall Mean		**6.77**	**0.71**		**0.03**		**1.00**		**2.67**

Table 6. Quality parameters and classification of groundwater samples of Valia taluka

Profile	Sample No	pH	EC (dsm^{-1})	Class	RSC	Class	SAR	Class	Cl^- (mgL^{-1})
Daheli	1	7.60	1.66	C3	5.30	S3	1.17	S1	5.52
(P11)	2	6.33	2.38	C4	-10.26	S1	0.79	S1	11.00
	3	6.98	1.86	C3	9.68	S3	1.59	S1	5.22
	4	6.76	1.65	C3	3.99	S3	0.80	S1	5.76
	5	7.01	1.77	C3	3.81	S3	0.83	S1	7.54
	Max	**7.60**	**2.38**		**9.68**		**1.59**		**11.00**
	Min	**6.33**	**1.65**		**-10.26**		**0.79**		**5.22**
	Mean	**6.94**	**1.86**		**2.50**		**1.04**		**7.01**
Jamniya	1	6.95	1.61	C3	4.27	S3	0.75	S1	5.08
(P12)	2	6.74	1.27	C3	0.91	S1	0.34	S1	5.64

Profile	Sample No	pH	EC (dsm^{-1})	Class	RSC	Class	SAR	Class	Cl^- (mgL^{-1})
	3	6.91	1.00	C3	0.24	S1	2.41	S1	5.40
	4	7.16	0.93	C3	1.22	S1	1.91	S1	5.52
	5	6.90	1.51	C3	2.66	S3	3.79	S1	5.16
	Max	**7.16**	**1.61**		**4.27**		**3.79**		**5.64**
	Min	**6.74**	**0.93**		**0.24**		**0.34**		**5.08**
	Mean	**6.93**	**1.26**		**1.86**		**1.84**		**5.36**
Kesargam (P13)	1	7.07	0.74	C2	0.03	S1	0.29	S1	1.96
	2	6.90	1.04	C3	2.19	S2	0.60	S1	3.96
	3	7.16	0.81	C3	-0.80	S1	0.25	S1	4.34
	4	7.13	0.74	C2	-0.99	S1	1.79	S1	6.28
	5	6.85	1.16	C3	2.51	S3	0.41	S1	4.00
	6	6.85	0.98	C3	-1.62	S1	2.58	S1	5.24
	7	6.68	0.66	C2	-1.77	S1	0.50	S1	2.96
	Max	**7.16**	**1.16**		**2.51**		**2.58**		**6.28**
	Min	**6.68**	**0.66**		**-1.77**		**0.25**		**1.96**
	Mean	**6.93**	**0.87**		**-0.53**		**1.10**		**4.11**
Naldhari (P14)	1	6.91	1.74	C3	-3.25	S1	1.79	S1	21.48
	2	7.18	2.35	C4	-5.82	S1	1.66	S1	25.22
	3	6.57	2.21	C3	-1.76	S1	1.10	S1	19.32
	4	6.81	2.01	C3	0.79	S1	1.31	S1	15.64
	5	6.58	2.28	C4	-0.71	S1	1.58	S1	23.20
	Max	**7.18**	**2.35**		**0.79**		**1.79**		**25.22**
	Min	**6.57**	**1.74**		**-5.82**		**1.10**		**15.64**
	Mean	**6.81**	**2.12**		**-2.15**		**1.49**		**20.97**
Pansoli (P15)	1	7.01	2.94	C4	-4.00	S1	9.61	S1	15.80
	2	6.82	1.71	C3	-6.59	S1	6.34	S1	25.48
	3	7.22	2.61	C4	-0.66	S1	7.12	S1	22.66
	4	6.82	2.92	C4	-4.63	S1	11.07	S2	25.46
	5	7.24	1.20	C3	0.92	S1	4.17	S1	16.28
	Max	**7.24**	**2.94**		**0.92**		**11.07**		**25.48**
	Min	**6.82**	**1.20**		**-6.59**		**4.17**		**15.80**
	Mean	**7.02**	**2.28**		**-2.99**		**7.66**		**21.14**
Overall Mean		**6.93**	**1.68**		**-0.26**		**2.63**		**11.72**

Table 7. Descriptive statistics of the water quality parameters

	Min	Max	Mean	Standard Error	Standard Deviation	Kurtosis	Skewness
pH	6.31	8.82	6.97	0.05	0.40	4.88	1.64
EC	0.31	2.94	1.13	0.07	0.60	0.95	1.21
CO_3^{2-}	0.00	3.08	0.17	0.06	0.51	14.76	3.63
HCO_3^-	2.99	15.78	7.51	0.29	2.56	0.92	0.88
Cl^-	0.00	50.46	7.33	0.97	8.53	8.95	2.76
Ca^{2+}	0.81	12.81	4.33	0.24	2.09	3.65	1.64
Mg^{2+}	0.05	15.63	3.73	0.31	2.69	3.67	1.44
Na^+	0.44	35.37	3.67	0.64	5.66	17.86	3.99

The water quality in Netrang taluka is generally regarded as good, primarily due to the natural filtration process that occurs as water percolates through rock formations and is filtered by thick vegetation. These natural barriers help reduce contaminants and improve the overall purity of the water, making it suitable for various uses in the region. Similar results were obtained by Chakravarty and Gupta [8].

3.5 Quality Parameters of Groundwater Samples of Valia Taluka

The Table 6 presents the quality parameters and classification of groundwater samples from Valia taluka, covering five different profile locations. In Valia taluka, the pH of water samples ranged from 6.33 to 7.60, with a mean value of 6.93, indicating that the majority of the water was neutral. The electrical conductivity of the water samples varied between 0.66 and 2.94 dSm^{-1}, with a mean value of 1.68 dSm^{-1}, suggesting a high salinity problem in the taluka. Profile area such as Pansoli (mean 2.28 dSm^{-1}) and Daheli (mean 1.86 dSm^{-1}) show higher EC values, which are classified as C3 (high salinity hazard) and C4 (very high salinity hazard). Out of 27 water samples, 3 were classified into the C2 class, 18 into the C3 class and 6 into the C4 class. This distribution means that 11 per cent of the samples fall into the C2 class (medium salinity problem), 67 per cent into the C3 class (high salinity problem) and 22 per cent into the C4 class (very high salinity problem). Leaching of ions, water-rock interaction and anthropogenic activities such as excessive pumping, industrial effluents, irrigation and domestic uses can be the probable reasons for the same (Reza & Singh, 2010).

The residual sodium carbonate values ranged from -10.26 to 9.68 meL^{-1}, with a mean value of -0.26 meL^{-1}. The sodium adsorption ratio values ranged from 0.25 to 11.07, with a mean value of 2.63. The chloride content varies from 1.96 to 25.48 mgL^{-1} with a mean value of 11.72 meL^{-1}. In the study area, chemical analysis indicates elevated concentrations of HCO_3^- and Na^+, along with other ions. This phenomenon is attributed to the geological composition, as the region is predominantly occupied by silicate minerals originating from crystalline hard rocks. The weathering of these minerals likely contributes to the high levels of HCO_3^- and Na^+ in the soil and water, influencing the local geochemical environment. The findings are consistent with previous studies by Adimalla and Venkatayogi [9] and Narsimha and Sudarshan [10]. The higher concentration of HCO_3^- in the water infers a dominance of mineral dissolution. The carbonates available in carbonate rocks could have been dissolved during irrigation, rainfall infiltration and groundwater movement, and added to the groundwater system with recharging water [11]. A higher concentration of sodium was also reported by Saha and Kanchan [12] in Bharuch district.

The groundwater quality in Valia taluka with respect to chloride levels are concerning in some locations, particularly Naldhari and Pansoli with mean value 20.97 mgL^{-1} and 21.14 mgL^{-1}, respectively, where high chloride concentrations could negatively impact crop growth. These areas may require the use of salt-tolerant crops, proper irrigation management, and soil amendments to mitigate the impact of salinity and chloride.

3.6 Descriptive Statistics of the Water Quality Parameters

The descriptive statistics concerning quality of water from 78 locations of three talukas are presented (Table 5). The table presents summary statistics for various soil chemical parameters, including pH, EC, CO_3^{2-}, HCO_3^-, Cl^-, (a^{2+}, Mg^{2+} and Na^+. The values shown include the minimum, maximum, mean, standard error, standard deviation, kurtosis, and skewness for each parameter. The pH values range from 6.31 to 8.82, with a mean of 6.97. The low standard deviation (0.40) indicates that most of the water samples have pH values close to the mean. The high kurtosis (4.88) implies that there are infrequent extreme values, while the positive skewness (1.64) shows that more samples tend to have lower pH values, with fewer alkaline outliers. The relatively low standard deviation (0.60) in EC values suggests moderate variation in salinity across samples. Positive skewness (1.21) suggests that most samples have low to moderate salinity, while a few have higher salinity levels. This suggests localized soil salinity issues that could affect crop growth in certain areas. Patil *et al*. [13] reported an increase in soil salinity due to the use of saline water.

The high kurtosis (14.76) and skewness (3.63) of carbonates highlight the presence of some extreme high values in the data. HCO_3^- concentrations range from 2.99 to 15.78 meq/L, with a mean of 7.51 meq/L. The standard deviation (2.56) shows moderate variability. Both kurtosis (0.92) and skewness (0.88) are close to zero, suggesting a fairly normal distribution of bicarbonate levels. Cl^- concentrations vary widely, from 0 to 50.46 meq/L, with a mean of 7.33 meq/L. The high standard deviation (8.53) indicates significant variability across samples, while the high kurtosis (8.95) and skewness (2.76) point to a small number of samples with very high chloride content. High kurtosis (3.65) and skewness (1.64) suggest that most samples have lower calcium levels, with a few areas showing relatively high concentrations. Magnesium concentrations range from 0.05 to 15.63 meq/L, with a mean of 3.73 meq/L, and a standard deviation of 2.69. The standard deviation (5.66) reflects high variability in sodium content across the samples. High kurtosis (17.86) and skewness (3.99) indicate that the majority of samples have low sodium concentrations, while a few have extremely high values. High sodium levels lead to structural damage to the soil due to the dispersion of clay particles, decreased soil hydraulic conductivity, soil instability due to the clogging of soil pores [14].

4. CONCLUSION

The groundwater in Jhagadia, Netrang and Valia talukas is deemed safe for future development. Primarily served by tube wells, these areas face medium salinity issues, particularly in Valia, where 67 per cent and 22 per cent samples of irrigation water exhibit high (C3) to very high salinity (C4) indicating an urgent need for water quality management in Valia taluka. However, medium salinity issues were present in all water samples collected across all talukas, which is also a concerning factor. Despite low sodium hazards (SAR), water quality management is crucial, especially for Valia, where some samples show unsuitable RSC levels. These areas may require specific soil management practices, such as gypsum application, improved drainage, or the use of salt-tolerant crop varieties, to mitigate potential negative impacts on crop productivity.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Saeid S, Chizari M, Sadighi H, Bijani M. Assessment of agricultural groundwater users in Iran: a cultural environmental bias. Hydrogeol J. 2018;26:285–95.
2. Laxman DK, Ratnakar D, Sakram G, Srinivas B. Hydrochemical appraisal of groundwater quality for drinking and agricultural utility in a granitic terrain of Maheshwaram area of Ranga Reddy district, Telangana State, India. HydroResearch. 2021;4:11–23.
3. Subba Rao N. Spatial distribution of quality of groundwater and probabilistic non-carcinogenic risk from a rural dry climatic region of South India. Environ Geochem Health. 2021;43:971–93.
4. Guo X, Zuo R, Meng L, Wang J, Teng Y, Liu X, Chen M. Seasonal and spatial variability of anthropogenic and natural factors influencing groundwater quality based on source apportionment. Int J Environ Res Public Health. 2018;15(2):279.
5. Upadhyaya D, Survaiya MD, Basha S, Mandal SK, Thorat RB, Haldar S, Mody

KH. Occurrence and distribution of selected heavy metals and boron in groundwater of the Gulf of Khambhat region, Gujarat, India. Environ Sci Pollut Res. 2014;21(5):3880–90.

6. Sharma RP, Jangir A, Tiwari G, Dash B, Naitam RK, Kumar N, Singh RS, Singh SK, Chandran P, Dwivedi BS. Land resource inventory of Jhagadia Taluka, Bharuch District, Gujarat on 1:10,000 scale for optimal agricultural land use planning, using geo-spatial techniques. NBSS Publ. No. 1138, NBSS&LUP, Nagpur; 2020. p. 1–150.
7. Donga PP, Korant KG, Raman S. Quality of ground water used for irrigation in Gujarat. In: Management of Water Resources in Gujarat. p. 25–42; 2009.
8. Chakravarty T, Gupta S. Assessment of water quality of a hilly river of south Assam, north east India using water quality index and multivariate statistical analysis. Environ Challenges. 2021;5:100392.
9. Adimalla N, Venkatayogi S. Mechanism of fluoride enrichment in groundwater of hard rock aquifers in Medak, Telangana State, South India. Environ Earth Sci. 2017; 76:45.
10. Narsimha A, Sudarshan V. Contamination of fluoride in groundwater and its effect on human health: a case study in hard rock aquifers of Siddipet, Telangana State, India. Appl Water Sci. 2017;7:2501–12.
11. Singh AK, Mondal GC, Singh TB, Singh S, Tewary BK, Sinha A. Hydrogeochemical processes and quality assessment of groundwater in Dumka and Jamtara districts, Jharkhand, India. Environ Earth Sci. 2012;67:2175–91.
12. Saha S, Kanchan R. Sub-surface water quality assessment using GIS techniques in Surat-Bharuch industrial region, Gujarat, India. Indian Geogr J. 2021;96(2):34–48.
13. Patil LM, Gomkale SR, Roy SS, Mori JR, Kauthale VK. Performance of Ber (*Zizyphus mauritiana* Lamk.) varieties under two irrigation scheduling of saline water in central Gujarat conditions in India. Int J Plant Soil Sci. 2020;32(9):86–92.
14. Al-Zu'bi Y. Effect of irrigation water on agricultural soil in Jordan Valley: an example from arid area conditions. J Arid Environ. 2007;7:63–79.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/125391