Original Research Article

Groundwater Quality Assessment for Irrigation Suitability purpose in the Khelna River Basin of Aurangabad District, Maharashtra

ABSTRACT

The present study is based on irrigation suitability for groundwater samples in the Khelna river basin, Chhatrapati Sambhajinagar (Aurangabad), Maharashtra, India. A total 50 groundwater sample were collected, out of 50 groundwater sample 16 groundwater samples were collected from bore well and 34 groundwater samples collected from dug wells in high quality of one litter polyethylene bottles from different locations within the study area. The irrigation water quality parameters like sodium adsorption ratio (SAR), Percent sodium (%Na), Residual sodium carbonate (RSC), Residual Sodium Bicarbonate (RSBC), Kelly's ratio (KR), Magnesium adsorption ratio (MAR), and Permeability index (PI) were calculated. The irrigation water quality parameters values are measured like SAR (0.63 to 2.89), %Na (1.04 to 6.96), RSC (-6.14 to 0.59), RSBC (-1.54 to 3.91), KR (0.19 to 0.76), MAR (25.78 to 78.78) and PI (36.46 to 72.78). All the irrigation parameters are reveled the value in suitable category for irrigation except MAR (Magnesium hazard). Magnesium hazard water samples that exceed acceptable limits have been recognized in the study area because of different geological and human activities. This study is beneficial for farmers and policymakers in managing and planning groundwater resources.

Comment [E1]: Continer detail can be included in materials and methods

Comment [E2]: Auther can use any one of the unit, Magnesium Adsorption Ratio (MAR) or Magnesium Hazard (MH)

Keywords: Groundwater Quality, Irrigation, Kelly's ratio (KR), Permeability Index (PI), Percent Sodium (%Na), Sodium adsorption ratio (SAR), Khelna River, Aurangabad.

Comment [E3]: *First letter of any abbreviation should be in capitalised* ***Kelly's Ratio (KR)***

1. INTRODUCTION

Groundwater serves as a vital natural resource on Earth and is essential for all living beings to maintain a sustainable environment and ecosystem [1,2,3]. Forty-six percent of India's overall national output is derived from the agricultural sector, which plays a significant role in the nation's economic development [4]. Half of the irrigated area relies on groundwater extraction through dug and bore wells. Indian agriculture, especially in the Marathwada and Vidarbha areas of Maharashtra state, encounters a scarcity of surface water resources.

In many regions of the nation, the quality of groundwater poses a greater risk to human health, influenced by the swift rise in population, industrial growth, and urban development in developing nations [5,6]. It is a major issue alongside the decreasing water table [7,8]. Groundwater commonly contains certain soluble salts from recharge sources and the surrounding geological layers, which continue to filter through. Consequently, worries regarding the low-quality groundwater for irrigation have increased in recent years. Groundwater contamination arises from both excessive and inadequate use of chemical fertilizers [9,10,11,12]. Thus, it is essential to routinely evaluate water quality for sources used in drinking and irrigation [13,14,15].

Irrigation requires an adequate supply of water that is of usable quality. The index that reflects the concentration and composition of dissolved elements in water can aid in assessing its suitability for irrigation based on the characteristics of the mineral elements present and their effects on plants and soil [23]. Typically, Ca_2^+, Mg_2^+, $K^{+,}$ Na^+ (major cations), SO_4, NO_3^- Cl^-, HCO_3^-, CO_3^-, and NO_3^- (major anions), along with heavy metals, serve as indicators of drinking water quality parameters. In contrast, primary water quality parameters such as sodium adsorption ratio (SAR), percent sodium (%Na), residual sodium carbonate (RSC), residual sodium bicarbonate (RSBC), Kelly's ratio (KR), magnesium adsorption ratio (MAR), and permeability index (PI) are commonly utilized to assess the quality of water for irrigation purposes [11,14,16,17]. The connection between irrigation and groundwater resources is profoundly intertwined. In the competition to boost agricultural output, irrigation will rely on low-quality water sources.

In the present study area of Khelna river basin area of Aurangabad, Maharashtra state, India. Water quality assessment work for drinking purpose was carried out [18]. Since no records are available for water quality assessment work for irrigation, it is decided to take up the same.

2. MATERIAL AND METHODS

2.1 Study Area

The study area falls within the Chhatrapati Sambhajinagar (Aurangabad) district of the Maharashtra state. The study area situated between longitude 75^0 30' 00" to 75^0 45' 00" E and 20^0 20' 00" to 20^0 30' 00" N and shown in figure number 1. Apart from the south-west monsoon season, the district's climate is characterized by hot summers and generally dry conditions all year long. In Aurangabad, the rainy season lasts from June to September, October to February for the winter season, and March to May for the summer. In Aurangabad district, the average rainfall is 734 mm, with minimum temperatures of 23°C and maximum temperatures of 39°C.

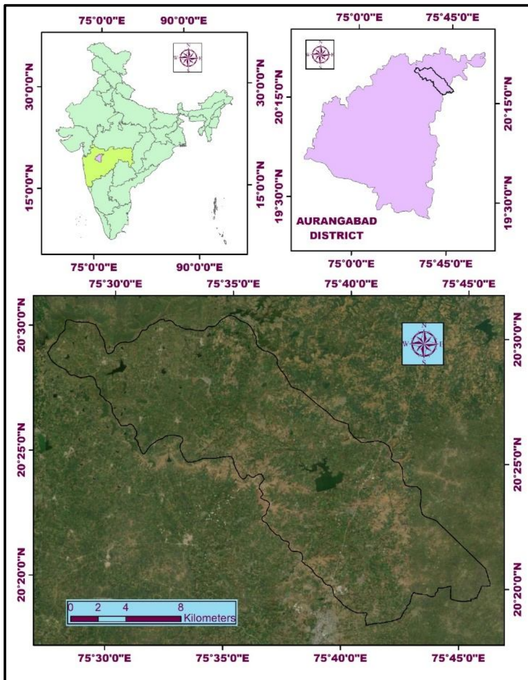

Fig. 1. Location map of the study area.

Geologically, the study area is occupied deccan basaltic lava flows of Upper Cretaceous to Lower Eocene age in Peninsular India. Basaltic lava flows found thick horizontal and flat top hills were observed with the study area. The lava traps of basaltic formations run parallel to the surface and are divided by two layers of lava flow. The top layer of vesicular and amygdaloidal basalt contains cavities filled with secondary minerals, while the lower layer is made up of dense and solid/ massive basalt [19,20]. Regur type of soils is occurred within the study area, which is formed due to the weathering of basaltic rocks. This type of soil is more fertile for all type of crops.

From an agricultural perspective, soil fertility is influenced by the texture and structure of the soil, which governs its ability to retain and transmit moisture and essential nutrients like nitrogen, phosphorus, and potassium that originate from the parent rock [21]. It has been determined that geology, topography, climate, and vegetation all influence the soil formation process in the study area. The region of the study is characterized by black cotton soil, also known as regur soil, which is formed through the weathering and erosion of the upper layer of basaltic lava flows. It is rich in plant nutrients like iron, lime, alkalis, and iron, enabling the growth of cotton and dry crops like jowar, pearl millet, wheat, gram, Soyabean and cotton are common practices in the study area.

2.2 Sampling Methods

A total 50 groundwater samples were collected from various dug and bore well's locations within the study area. Out of 50 groundwater sample 16 groundwater samples were collected from bore well and 34 groundwater samples collected from dug wells in high quality of one litter polyethylene bottles.

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Sampling and analysis were conducted following the International standard methods. Typically, the quality parameters of water, as well as the presence of anions and heavy metals, indicate the suitability of drinking water, whereas additional water quality parameters include sodium adsorption ratio (SAR), percentage of sodium (% Na), residual sodium carbonate (RSC), residual sodium bicarbonate (RSBC), Kelly's ratio (KR), magnesium adsorption ratio (MAR), and permeability index (PI). This assessment was based on essential water quality parameters such as pH, electrical conductivity (EC), total dissolved solids (TDS), chloride (Cl), total hardness (TH), magnesium (Mg), calcium (Ca), bicarbonates (HCO3), and sodium (Na). Potassium (K) and sulfate (SO4) are typically utilized to assess the quality of water for irrigation purposes (Singh et al., 2013, 2015; Gautam et al., 2015). The pH parameter was assessed using a Lapman Model LMHP-12, while EC and TDS were determined with a Cond/TDS meter (Deluxe Model 641E). Cl, Th, Ca, and HCO3 levels were evaluated through a volumetric titration method. Mg was assessed using the concentrations of Total Hardness (TH) and Calcium (Cl). Potassium (K) and Sodium (Na) were quantified using a flame photometer, while SO4 was assessed using a spectrophotometer.

Comment [E5]: Auther can use any one of the unit, percentage of sodium or Percent sodium (%Na),

Comment [E6]: *First letter of any abbreviation should be in capitalised Magnesium* (Mg), Calcium (Ca),

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2.3 Irrigation Parameter

The irrigation water quality parameters like sodium adsorption ratio (SAR), Percent sodium (%Na), Residual sodium carbonate (RSC), Residual Sodium Bicarbonate (RSBC), Kelly's ratio (KR), Magnesium adsorption ratio (MAR), and Permeability index (PI) were derived using the standard formulas listed in Table 1.

Table 1. Groundwater quality irrigation parameter [modified after 22].

Comment [E9]: No need to cite the table head as **modified after 22, All** the standard formulas are with citation

Parameter	Formulae	References
Sodium adsorption ratio (SAR)	SAR= Na+/ (√Ca_2^++ Mg_2^+ / 2)	[23]
Percent sodium (%Na)	Na% = (Na++K+) / (Ca_2^++ Mg_2^+ + Na^++K^+) x100	[24]
Residual sodium carbonate (RSC)	RSC= (CO_3+ HCO_3^-) -(Ca_2^++ Mg_2^+)	[23,25]
Residual Sodium Bicarbonate (RSBC)	HCO_3-Ca_2^+	[26]
Kelly's ratio (KR)	Na^+/ Ca_2^++ Mg_2^+	[27]
Magnesium adsorption ratio (MAR)	MAR= (Mg2+/ Ca_2^++ Mg_2^+) x 100	[28]
Permeability index (PI)	PI= (Na+ √HCO3/ Ca + Mg + Na) x 100	[29]

3. RESULTS AND DISCUSSION

3.2 Sodium Adsorption Ratio (SAR)

The sodium adsorption ratio (SAR) represents the ratio of Na^+ ions to Ca_2^+ and Mg_2^+ ions in a water sample expressed as a percentage. This ratio is employed to forecast the likelihood of Na^+ accumulation in the soil, primarily at the cost of Ca_2^+, Mg_2^+, and K^+, as a result of frequent usage of sodic water. The SAR is determined using the formula provided in (Table 1). Depending on the quality of irrigation water, SAR values are divided into four categories (Table 2): SAR value 10 (excellent), SAR value from 10 to 18 (Good), SAR value from 18 to 26 (Doubtful), and SAR value above 26 (Unsuitable) (Rawat et al., 2018). Additionally, SAR influences the percolation rate of water through the soil. Consequently, irrigation water that

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has low SAR values is preferred. The study area shows that SAR values vary from 0.63 to 2.89 during pre-Manson season, with the mean SAR level being 1.5 for that season (Table 2), which is classified as excellent, i.e., SAR values < 10 [23]. Based on the SAR value, the irrigation classification of water indicates that all thirty water samples are classified as excellent. High-quality categorized samples are utilized for irrigation purposes. Therefore, all water samples are suitable for irrigation and planting.

3.2 Percent Sodium (%Na)

Elevated Na+ levels in irrigation water may cause sodium-related risks. The SAR is determined using the formula provided in Table 1. According to % Na values, water is categorized into five classes (Table 2); < 20% is classified as (Excellent), 20-40% as (Good), 40-60% as (Permissible), 60-80% as (Doubtful), and > 80% as (Unsuitable) (Khodapanah et al., 2009). Excessive Na+ levels in irrigation water can negatively impact soil permeability and properties, as well as hinder plant growth. Consequently, the amount of sodium carbonate in irrigation water is an essential element in evaluating its appropriateness for application. The sodium percentage (% Na) in the study area ranges from 1.04 to 6.96 meq/l, with an average of 2.79 meq/l for the pre-monsoon season (Table 2). The Bureau of Indian Standards (BIS, 2003) recommends that the Na^+ content in irrigation water should not exceed 60%. An excess of % Na beyond 60% can cause Na+ accumulation, thereby adversely affecting soil physical properties [30]. The % Classification for irrigation suitability percent such an Excellent (< 20 %), Good (20 to 40%), Permissible (40 to 60%) Doubtful (60 to 80%), Unsuitable (> 80%). The (100%) groundwater samples are show values less than the < 20% and as per irrigation parameters standard all the groundwater samples within the study are is excellent in class and it is suitable for irrigation.

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3.3 Residual Sodium Carbonate (RSC)

RSC is defined as the surplus of carbonate and bicarbonate levels exceeding those of alkaline earth, mainly the contents of Ca_2^+ and Mg_2^+ beyond permissible thresholds, adversely affecting irrigation [23,25]. The RSC is determined using the formula presented in Table 1. According to RSC ranges, sodium hazards are categorized into three classes: (Table 2) RSC < 1.25 (Good), 1.25-2.5 (doubtful), and > 2.5 (unsuitable), as outlined [12]. A high range of RSC in irrigation water suggests an increase in sodium adsorption in the soil. It is generally not recommended to use water with an RSC exceeding 5 for irrigation since it could negatively affect plant growth. Generally, a water source with an RSC exceeding 2.5 is deemed unsuitable for agricultural purposes, while water with an RSC below 1.25 is recommended as safe for irrigation. A low RSC value indicates that the levels of Ca_2^+ and Mg_2^+ are excessively high. A higher RSC suggests that the presence of Na+ in the soil is possible. The study area groundwater samples show variations in the RSC from -2.73 to -6.14 meq/l, with an average of 0.59 during the pre-monsoon (Table 2). Based on Richards' classification, All the groundwater samples are show values less than < 1.25 it means that the all the groundwater samples within study area is suitable for irrigation. Maximum sample number show negative RSC values (Table 2) because an abundance of Ca_2^+ and Mg_2^+ concentration is shown by a negative RSC value. A positive RSC suggests the potential presence of Na+ in the soil.

3.4 Residual Sodium Bicarbonate (RSBC)

The levels of carbonate and bicarbonate determine the appropriateness for irrigation. Elevated pH occurs in water with increased RSBC. RSBC was divided into three categories: < 5 meq/l (satisfactory), 5 to 10 meq/l (marginal), and > 10 meq/l (unsatisfactory) as classified [26]. The RSBC is determined using the formula provided in Table 1.

(RSBC) The ranges of residual sodium bicarbonate in water from the study area span from -1.54 to 3.91 meq/l, averaging 0.598 meq/l (Table 2). The RSBC indicates the higher concentration of HCO_3^- compared to Ca_2^+ (Hussain and Hussain, 2004). The water contains excess HCO3-, indicated by the negative values (Table 3) for each water category in the study area. The RSBC value for the study area is below 5 meq/l in all water samples, which is deemed safe or satisfactory category for irrigation [26,27].

3.5 Kelly's Ratio (KR)

To assess and classify water for irrigation, it introduced a novel aspect based on the ratio of Ca2+ to Na+ and Mg2+ levels [27]. The formula for calculating the Kelly's ratio (KR) is provided in Table 1. Waters with excessive Na+ levels are denoted by a KR > 1. Due to the risks associated with alkali, water with a KR<1 is generally advised for irrigation, while water with a KR of 1 to 2 is considered marginally acceptable, and water with KR > 2 is deemed unsuitable for irrigation (30, 31]. To evaluate the suitability of irrigation water quality, Kelly's ratio (KR) serves as an indicator, calculated from the K^+ parameter, which relies solely on Ca_2^+, Mg_2^+, and Na^+. As shown in Table 2, the average KR level throughout the study area is 0.42 meq/l, varying between 0.19 and 0.76 meq/l. It was determined that rainfall had a lesser effect on KR, as the diluting process causes the average KR value to remain within the acceptable range (Table 2). The 100% groundwater samples are classified as suitable for irrigation in the study area.

3.6 Magnesium Adsorption Ratio (MAR)

A surplus of magnesium (Mg) in groundwater alters the soil's pH, increasing its alkalinity and diminishing crop yields [14, 16,32]. The magnesium adsorption ratio (MAR) is determined using the formula provided in Table 1. Farmers argue that elevated levels of Mg2+ ions in water diminish soil quality, resulting in reduced crop yields [30]. MAR values below 50% are considered suitable, whereas MAR values above 50% are deemed unsuitable for irrigation [33]. MAR is based on Mg_2^+ and Ca_2^+ and is represented in percentage, comprising two categories: MAR < 50% (suitable) and > 50% (unsuitable). The MAR values fluctuate between 25.78% to 78.78% with an average of 49.57 % during the study period in the study area (Table 2). During the study duration, groundwater samples number 10, 12, 14, 15, 16, 20, 21, 23, 25, 26, 28, 31, 33, 34, 36, 37, 39, 41, 42, 43, 44, 46, 47, 48, 49 and 50 are exceed the MAR value is > 50%. A MAR values increase due to the geogenic and anthropogenic activates near to groundwater samples location in soil layer and this percolate into rock and groundwater within the study area. Hence, unsuitable for irrigation. A high MAR values influences the long-term impact on soil permeability.

3.7 Permeability Index (PI)

The permeability index (PI) can be used as an indication to determine if water is suitable for irrigation. The permeability, or the capacity of soil to flow water, is impacted by the ions Na+, Ca2+, Mg2+and HCO3−in the soil and is altered by long-term usage of irrigation water (which has a high concentration of salt). The PI formula to evaluate soil water suitability and water movement capacity of any type of water source for irrigation [29]. The permeability index (PI) is calculated by the equation given in Table 1. The PI values are >75% (suitable), 25 to 75 % (good)and <25% (unsuitable), the value of PI > 75% and between 25 to 75 % is recommended for irrigation purposes, whereas PI values < 25% is not suitable for irrigation [29]. It is influenced by several factors such as the total soluble salt, sodium, calcium, magnesium, and bicarbonate levels present in the water. The PI values in the study area range from 36.46% to 72.11%, with an average of 51.16% (Table 2). According to the PI values, water samples are divided into three categories: > 75% (suitable), 75-25% (good), and < 25% (unsuitable) [29]. The study area is classified within the good class of the PI range for all groundwater samples. Theis class exhibit good soil permeability and are suitable for irrigation.

Table 2. Irrigation parameter calculated in Khelna river basin, Aurangabad, Maharashtra.

Sr. No.	Village	Well Type	SAR	% Na	RSC	KR	RSBC	PI	MAR	Latitude	L[illegible]
1	Kelgaon	DW	1.41	2.87	-4.69	0.35	-1.49	42.71	38.53	20.475048	[illegible]
2	Korhala	BW	1.64	2.7	-1.54	0.5	0.67	57.5	40.88	20.49458	75.488719
3	Sirsala	DW	1.78	3.26	-3.27	0.49	0.01	51.39	49.09	20.486526	75.533192
4	Sirsala Tanda	DW	1.8	4.04	-5.64	0.4	-1.54	43.52	40.58	20.484932	75.531648
5	Pimpalgaon	DW	2.25	4.87	-3.99	0.52	-0.22	50.48	40.24	20.466222	75.520923
6	Dhawada	DW	1.66	3.3	-3.03	0.42	-0.98	49.07	25.78	20.443973	75.476395
7	Jambhai	DW	1.58	2.52	-2.55	0.49	-0.09	54	48.13	20.440243	75.518232
8	Jalkighat	DW	2.02	3.73	-3.16	0.55	-1.28	53.44	27.58	20.418118	75.547677
9	Relgaon	DW	1.61	2.57	-2.82	0.51	-0.77	53.3	40.58	20.437003	75.54505
10	wadala	DW	1.68	4.26	-6.14	0.33	1.24	40.07	57.51	20.419542	75.572342
11	Sasurwada	DW	1.42	2.83	-3.97	0.36	-1.02	44.84	37.35	20.439675	75.595643
12	Bojgaon	BW	0.84	1.65	-4.6	0.21	0.65	36.46	67.72	20.439707	75.571325
13	Bojgaon	DW	1.14	1.78	-2.28	0.36	-0.73	50.85	31.74	20.44236	75.570697
14	Ambhai	BW	0.93	1.65	-2.41	0.26	0.87	45.63	52.22	20.461795	75.566239
15	Ambhai	DW	0.69	1.04	-2.3	0.23	0.08	45.54	52.51	20.466418	75.568304
16	Pangri	BW	1.06	2.09	-3.75	0.27	1.17	41.43	62.91	20.46432	75.589902
17	Pangri	DW	1.2	1.96	-2.84	0.37	-0.46	48.53	44.62	20.463775	75.587785
18	Ghatambri	BW	1.11	1.78	-2.47	0.35	-0.91	49.31	30.2	20.506456	75.595008
19	Ghatambri	DW	1.19	2.39	-4.07	0.29	-1.28	41.87	34.25	20.508403	75.593619
20	Virgaon	BW	1.01	1.83	-2.7	0.28	1.4	45.36	63.07	20.474026	75.607679
21	Hatti	DW	1.43	2.52	-2.18	0.4	1.02	51.75	51.17	20.438342	75.606665
22	Hatti	DW	2.14	4.91	-5.16	0.47	-0.32	46.81	45.9	20.442501	75.60727
23	Mohal	BW	0.76	1.35	-2.74	0.21	1.36	42.19	64.56	20.435929	75.646372
24	Mohal	DW	1.47	2.22	-1.6	0.49	0.45	58.16	45.05	20.436874	75.645743
25	Bahuli	BW	2.33	5.48	-4.98	0.5	1.08	48.11	55.06	20.412063	75.617104
26	Bahuli	DW	0.86	1.52	-2.16	0.24	1.12	45.65	52.64	20.410131	75.619175
27	Madna	BW	2.89	6.96	-0.19	0.6	3.91	55.7	35.34	20.427466	75.648267
28	Chinchpur	DW	0.88	1.77	-3.75	0.22	2.56	39.17	78.78	20.406527	75.623186
29	Chinchpur	DW	0.63	1.04	-1.62	0.19	1	46.3	48.37	20.405405	75.621754
30	Khedi	BW	1.47	2.48	-1.13	0.43	1.49	56.34	45.83	20.408585	75.675511
31	Khedi	DW	1.27	2.39	-3.93	0.34	0.25	43.98	59.04	20.41354	75.679357
32	Leha	BW	0.95	1.13	-0.52	0.4	0.55	67.04	37.85	20.407491	75.694065
33	Leha	DW	1.81	2.58	-1.64	0.63	0.58	62.27	54.47	20.406711	75.696149
34	Chandapur	BW	1.71	3.26	-3.75	0.45	-0.06	48.75	50.61	20.383894	75.634957
35	Chandapur	DW	1.65	2.17	-0.86	0.62	0.37	67.1	35.34	20.385764	75.632768
36	Palod	BW	0.9	1.46	-1.88	0.28	0.91	49.02	52.71	20.380672	75.668119
37	Palod	BW	1.9	3.04	-2.32	0.59	1.12	57.69	66.94	20.381469	75.664003
38	Mangrul	DW	1.93	4.13	-2.74	0.45	1.53	50.14	46.52	20.371852	75.639801
39	Mangrul	BW	2.25	4.52	-2.37	0.56	3.2	54.86	69.04	20.368106	75.641528
40	Anvi	DW	2.41	4.3	-3.04	0.67	-0.91	57.4	33.4	20.360346	75.685574
41	Anvi	BW	1.84	2.84	-1.23	0.6	1.39	62.04	54.95	20.362502	75.684012
42	Sarola	DW	2.01	4.26	-3.14	0.47	3.59	50.46	74.92	20.393683	75.731192

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43	Sarola	DW	1.28	2.3	-3.08	0.36	0.61	47.21	56.85	20.394378	75.731749
44	Rahimabad	BW	0.9	1.22	-1.04	0.33	1.42	58.18	67.2	20.34323	75.725635
45	Rahimabad	DW	1.57	3.04	-3.57	0.41	-0.62	47.68	39.34	20.345473	75.724877
46	Dahigaon	BW	1.63	3.3	-4.69	0.4	-0.42	45.05	52.22	20.358837	75.69329
47	Dahigaon	BW	2.01	2.89	0.59	0.7	2.72	72.11	51.59	20.356967	75.69211
48	Asadi	DW	1.6	2.35	-0.79	0.54	1.42	63.43	51.31	20.343783	75.752916
49	Asadi	BW	2.06	2.78	-0.61	0.76	1.68	70.38	62.96	20.342928	75.750198
50	Jalkighat	DW	1.21	2.28	-2.2	0.32	1.57	47.86	52.95	20.423437	75.530745
	Average	-	1.51	2.79	2.73	0.42	0.598	51.16	49.57	-	-
	Minimum	-	0.63	1.04	-6.14	0.19	-1.54	36.46	25.78	-	-
	Maximum	-	2.89	6.96	0.59	0.76	3.91	72.11	78.78	-	-

4. CONCLUSION

The quality of groundwater and its suitability for irrigation purpose in the Khelna river basin of Aurangabad District, Maharashtra, has been measured. The irrigation water quality parameters values are measured like SAR (0.63 to 2.89), %Na (1.04 to 6.96), RSC (-6.14 to 0.59), RSBC (-1.54 to 3.91), KR (0.19 to 0.76), MAR (25.78 to 78.78) and PI (36.46 to 72.78). All the irrigation parameters are reveled the value in suitable category for irrigation except MAR (Magnesium hazard) values for sample number 10, 12, 14, 15, 16, 20, 21, 23, 25, 26, 28, 31, 33, 34, 36, 37, 39, 41, 42, 43, 44, 46, 47, 48, 49 and 50 have observed value is greater than > 50%. These locations are increasing MAR value due to geogenic and anthropogenic activity within the study area. According to this irrigation analysis, the majority of parameters are classified as suitable, indicating their suitability for irrigation use. Magnesium hazard water samples that exceed acceptable limits have been recognized in the study area because of different geological and human activities. Methods for artificial recharge could be implemented to support appropriate crops or reduce chemical levels in groundwater to preserve the current water quality. The findings of this study are beneficial for farmers and policymakers in managing and planning groundwater resources.

COMPETING INTERESTS

There is no conflict of interest from both authors.

REFERENCES

1. Liu J., Gao Z., Zhang Y., Sun Z., Sun T., Fan H., Wu B., Li M. and Qian L. Hydrochemical evaluation of groundwater quality and human health risk assessment of nitrate in the largest peninsula of China based on high-density sampling: A case study of Weifang. Journal of Cleaner-Production. 2021; 322:129164. https://doi.org/10.1016/j.jclepro.2021.129164
2. Jabbo J. N., Isa N. M., Aris A. Z., Ramli M. F. and Abubakar M. B. Geochemometric approach to groundwater quality and health risk assessment of heavy metals of Yankari Game Reserve and its environs, Northeast Nigeria. Journal of Cleaner Production. 2021; 330:129916. https://doi.org/10.1016/j.jclepro.2021.129916
3. Paneerselvam B., Ravichandran N., Li P., Thomas M., Charoenlerkthawin and Bidorn B. Machine learning approach to evaluate the groundwater quality and human health risk for sustainable drinking and irrigation purposes in South India. Chemosphere. 2023; 336:139228. https://doi.org/10.1016/j.chemosphere.2023.139228
4. Jafar Ahmed A., Ananthakrishnan S., Loganathan K. and Manikandan K. Assessment of groundwater quality for irrigation use in Alathur Block, Perambalur

District, Tamil Nadu, South India. Appl. Water Sci. 2013;3(4):763-771. https://doi.org/10.1007/s13201-013-0124-z

5. Adimalla N. Application of the Entropy Weighted Water Quality Index (EWQI) and the Pollution Index of Groundwater (PIG) to Assess Groundwater Quality for Drinking Purposes: A Case Study in a Rural Area of Telangana State, India. Arch Environ Contam. Toxicol. 2021;80: 31- 40. https://doi.org/10.1007/s00244-02000800-4
6. Kom K. P., Gurugnanam B., Sunitha V., Reddy Y. S. and Kadam A. K. Hydrogeochemical assessment of groundwater quality for drinking and irrigation purposes in western Coimbatore, South India.International Int. J. Energ. Water Res. 2021;6(7):475-494. https://doi.org/10.1007/s42108-021-00138-0
7. Vasanthavigar M., Srinivasamoorthy K., Rajiv R. G., Vijayaraghavan K. and Sarma V. S. Charactersiation and quality assessment of groundwater with a special emphasis on irrigation utility: Thirumanimuttar sub-basin, Tamil Nadu, India. Arab J. Geosci. 2012;5(2):245-258. https://doi.org/10.1007/s12517-010-0190-6
8. Hossain M. and Patra P. K. Investigation of groundwater quality for agriculture use in a lateric soil belt. Indian J. Environmental Protection. 2021;14(1):34-41.
9. Ayers R. S. and Westcot D. W. Water quality for agriculture. Irrigation and drainage paper No. 29. Food and agriculture organization of the United Nations, Rome. 1985; pp 1–117.
10. Rowe D. R. and Abdel-Magid I. M. Handbook of wastewater reclamation and reuse. CRC Press, Boca Raton. 1995.
11. Singh S. K., Srivastava P. K., Singh D., Han D., Gautam S. K. and Pandey A. C. (2015). Modeling groundwater quality over a humid subtropical region using numerical indices, earth observation datasets, and X-ray diffraction technique: a case study of Allahabad district, India. Environ. Geochem Health. 2015;37(1): 157-180. https ://doi.org/10.1007/s10653-014-9638-z
12. Rawat K. S., Singh S. K and Gautam S. K. Assessment of groundwater quality for irrigation use: a peninsular case study. Appl. Water Sci.2018; 8:233. https://doi.org/10.1007/s13201-018-0866-8
13. Gupta P, Vishwakarma M. and Rawtani P. M. Assessment of water quality parameters of Kerwa Dam for drinking suitability. Int. J. Theor. Appl. Sci. 2009;1(2):53-55.
14. Gautam S. K., Maharana C., Sharma D., Singh A. K., Tripathi J. K. and Singh S. K. (2015). Evaluation of groundwater quality in the Chotanagpur Plateau region of the Subarnarekha River Basin, Jharkhand State, India. Sustain Water Qual Ecol. 2015; 6:57-74. https://doi.org/10.1016/j.swaqe.2015.06.001
15. Jacintha T.G.A., Rawat K. S, Mishra A. and. Singh S. K. Hydrogeochemical characterization of groundwater of Peninsular Indian region using multivariate statistical techniques. Appl Water Sci. 2017; 7:3001–3013. https://doi.org/10.1007/s13201-016-0400-9
16. Singh S. K., Srivastava P. K., Pandey A. C. and Gautam S. K. Integrated assessment of groundwater influenced by a confluence river system: concurrence with remote sensing and geochemical modelling. Water Resour. Manag. 2013;27(12):4291-4313. https://doi.org/10.1007/s11269-013-0408-y
17. Sreedevi P. D., Sreekanth P. D., Shakee A. I and Reddy D. V. Evaluation of groundwater quality for irrigation in a semi-arid region of South India. Sustainable Water Resources Management. 2018;5(2):1-14. doi:10.1007/s40899-018-0279-8
18. Deshpande S. M. and Sayed V. G. (2021). Study of groundwater quality for drinking purposes in Khelna river basin, Aurangabad, Maharashtra. Bulletin of Pur and Applied Sciences 40F(2), 123-128.
19. Deshpande S. M., Kamble S. N, Aher R. K., Sirsat S. K., Gaikwad G. D. and Aher K. R. Appraisal of Groundwater Quality in parts of Ranjangaon Shenpunji Area of

Aurangabad District, Maharashtra. Bulletin of Pure and Applied Sciences. 2022;41(1):38-50.
20. Kadam V. B., Tejankar A. V. and Sirsat S. K. The study of heavy metal contamination in industrial soils of Aurangabad using GIS techniques. Journal of Geomatics. 2023;17(1):53-61. https://doi.org/10.58825/jog.2023.17.1.73
21. CGWB. Groundwater information Aurangabad district, Maharashtra, Central Groundwater Board, Ministry of water Resources, Govt. of India. 2023;1791/DBR/2013.
22. Kamble S., Sirsat S., Deshpande S., Wanjarwadkar K., Kadam V. Assessment of Groundwater Quality for Irrigation Suitability in Rajangaon Shenpunji and Surrounding Area, Aurangabad, Maharashtra, India. *Journal of Geomatics. 2024; 18*(2):32–41. https://doi.org/10.58825/jog.2024.18.2.132
23. Richards L. A. Diagnosis and improvement of saline and alkali soils. USDA Hand Book No 60. 1954;160
24. Wilcox L. V. The quality of water for irrigation use. USDA Technical Bulleten No 962, Washington, DC. 1948; p40.
25. Eaton F. M. Significance of carbonates in irrigated water. Soil Sci. 1950;69(2):123-134.
26. Gupta S. K. and Gupta I. C. Management of Saline Soils and Water. Oxford and IBH Publication Coy, New Delhi, India. 1987; pp 399.
27. Kelly W. P. Permissible composition and concentration of irrigated waters. In: Proceedings of the A.S.C.F. 1940;607.
28. Oladeji S. O., Adewoye A. O. and Adegbola A. A. Suitability Assessment of Ground Water Resources for Irrigation around Otte Village, Kwara State, Nigeria. Int. J. of Applied Sciences and Engineering Research. 1212;1(3):434-445.
29. Doneen L. D. (1964). Notes on water quality in agriculture. Published as a water science and engineering paper 4001, Department of Water Science and Engineering, University of California.
30. Ramesh K. and Elango L. Groundwater quality and its suitability for domestic and agricultural use in Tondiar river basin, Tamil Nadu, India. Environ. Monit. Assess. 2012;184(6):3887-3899.
31. Karanth K. R. Groundwater assessment development and management. Tata McGraw Hill Publishing Company Ltd., New Delhi. 1987; p725.
32. Gowd S. S. Assessment of groundwater quality for drinking and irrigation purposes: a case study of Peddavanka watershed, Anantapur District, Andhra Pradesh, India. Environ. Geol. 2005;48(6):702–712
33. Khodapanah L., Sulaiman W. N. A. and Khodapanah D. N. Groundwater quality assessment for different purposes in Eshtehard District, Tehran, Iran. Eur. J. Sci. Res. 2009;36(4):543-553.