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Assessment of groundwater quality of different villages of Malpura block in Tonk district, Rajasthan

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Abstract
Evaluating water quality stands as a crucial instrument for fostering sustainable development and furnishes vital insights for effective water management. When determining the suitability of water for irrigation, it becomes imperative to possess comprehensive knowledge pertaining to both the quantity and quality of the water resource. Therefore, a study was conducted in the Malpura block of Tonk district, Rajasthan, during 2021-2022 to assess the groundwater quality for irrigation. To ascertain groundwater quality, 60 water samples were collected from 6 different villages [Lawa (V_1), Borkhandi (V_2), Kadila (V_3), Jankipura (V_4), Diggi (V_5), and Nukkad (V_6)], and analyzed for various water quality parameters, including pH, EC, cations (Ca^{2+}, Mg^{2+}, Na^+, K^+), and anions (CO_3^{2-}, HCO_3,$^-$ Cl^- SO_4^{2-}). Irrigation water quality indices such as SAR, RSC, SSP, PI, and KR were also calculated for these samples. The pH, EC, Ca^{2+}, Mg^{2+}, Na^+, K^+ SAR, RSC, SSP, KR, and PI in groundwater ranged from 6.1 to 9.0, 0.16–4.8 dS m^{-1}, 0.22- 8.5 meq L^{-1}, 0.2 to 33.2 meq L^{-1}, 0.55-23.65 meq L^{-1}, 0.005-1.79 meq L^{-1}, 0.18-18.25 m mol/L, 3- 40.37 meq L^{-1}, 6.43- 91.79 meq L^{-1}, 26.69- 124.54 meq L^{-1}, and 2.09- 40.53%, respectively.

Keywords: Ground water quality, Alkaline water, PH, SAR, RSC, SSP, Malpura block

1. Introduction

The demand for water in contemporary societies is continually increasing, leading to degradation in both the quantity and quality of water required for irrigating cropped land. This degradation poses a significant challenge as crop productivity is directly influenced by both soil quality and the quality of irrigation water. Evaluating the quality of irrigation water should encompass various factors including salt content, sodium concentration, nutrient and trace element levels, alkalinity, acidity, and water hardness. Salinity, a global issue, results in the annual loss of fertile soils. Groundwater, primarily sourced in arid regions, serves as a crucial water supply for domestic, industrial, and agricultural sectors in many countries. However, despite its importance, the focus on water quality has often been neglected, particularly in developing nations [2].

Groundwater contamination, particularly due to salinization, is a significant concern, often triggered by various processes such as seawater intrusion, agrochemical pollution, geogenic contamination, and salinization induced by irrigation. The ratio of sodium ions to calcium and magnesium ions, known as the sodium-adsorption ratio (SAR), serves as an indicator to predict the extent to which irrigation water is likely to engage in cation-exchange reactions in soil. As SAR increases, indicating a higher sodium hazard, the suitability of water for irrigation decreases [11]. The impact of irrigation water on soil infiltration rates depends on the balance between the soil's flocculating effects caused by specific conductance and the dispersion effects of sodium. Soils can tolerate irrigation waters with high SAR values if specific conductance values are also high. However, besides water quality, other factors such as soil type, crop type, crop pattern, precipitation, etc., significantly influence the suitability of water for irrigation. The quality of water is crucial for its suitability in various uses, including irrigation. Maximum yields in agriculture can be achieved when water quality is good and managed appropriately with suitable soil conditions. However, the salt problem in soils arises when irrigation water contains high levels of soluble salts, which accumulate in the root zone as plants absorb water, thereby reducing yields.

Severe water scarcity is becoming increasingly prevalent in many parts of the world, especially in arid and semi-arid regions. The reliance on groundwater to fulfil the growing demands of domestic, agricultural, and industrial sectors has led to the overexploitation of groundwater resources in these areas [5],. The suitability of water for irrigation is determined by the concentrations of certain elements that contribute to the specific conductance of groundwater. Elevated levels of sodium, in particular, can cause soil dispersion and swelling, which is detrimental to soil structure [5]. This can lead to surface crusting, decreased infiltration rates, and reduced hydraulic conductivity of the soil, ultimately affecting agricultural productivity. Therefore, monitoring and managing water quality are essential to mitigate these issues and ensure sustainable water use in agriculture. Access to clean water is a fundamental right and a basic need for human health. Despite this, people in many countries (Especially developing ones) are deprived of this basic right [10].

The groundwater in north-western Rajasthan is characterized by high salinity levels, often accompanied by elevated chloride and sulphate concentrations. Despite these challenges, this water is commonly utilized for agriculture, with its usability depending on the extent of harmful constituents present. However, many farmers have been forced to abandon their underground irrigation sources due to soil degradation, leading to significant crop yield declines [3]. Despite the poor quality of irrigation water in these areas, its usage persists due to the absence of alternative water sources. Salinity levels in groundwater wells across Rajasthan range from 2.1 to 9.1 dSm^{-1}. The excessive rise in soil salinity due to irrigation with saline water can either hinder or completely halt plant growth. Apart from osmotic stress, plant productivity suffers from specific ionic toxicities, limited nutrient availability, and imbalanced cation levels within plants. These soils, which are irrigated with poor quality groundwater in arid and semi-arid regions, typically have low organic matter content and consequently lack fertility. Hence, it is crucial to manage irrigation water wisely in these soils, just as vital as their reclamation efforts [3].

Limited information exists regarding the groundwater quality suitable for irrigation in the Malpura block of Tonk district, and there have been observed variations in water quality parameters. Reports suggest that groundwater quality in the Malpura area is limited suitable for both drinking and irrigation, with salinity levels posing a significant concern. Consequently, there is a pressing need for an in-depth investigation into the characteristics, properties, and overall quality of irrigation water in this region. Such an investigation is vital to assess the risk of secondary salinization or sodification and ensure proper irrigation practices are implemented to mitigate potential adverse effects.

2. Materials and Methods

2.1 Present Study Area

Malpura is a block in Tonk district Rajasthan and it is located at latitude: 26° 16' 48.00" N longitude: 75° 22' 48.00" E. It has an average elevation of 132 metres (401 feet). Distance from Jaipur 90 km, Malpura is also known for Avikanagar – 4 km from Malpura. It is known for the Central Sheep and Wool Research Institute (CSWRI) the total geography area of Malpura block is 3164.46 hectares. Tonk district is situated in agro-climatic zone 3-A, specifically the semi-arid eastern plain zone the climate of malpura is different from typical semi-arid Rajasthan and is more sub-humid climate. The area does remain dry for almost part of the year and humidity increases only during the monsoon months. Summers are hot and during the peak summer months of May-June the temperature soars to more than 45 °C. In winter months that stretch from November to February the mean temperature is low, around 22 °C but the lowest temperatures dip to around 4-5 °C. Rainfall is moderate as the average annual rainfall in this district is about 508 mm and rains are received during the monsoon months of July to September.

2.2 Ground Water Samples Collection Sites

Sixty representative irrigation water samples were collected in 500 ml nerrow neck plastic water sampling bottles during the pre-monsoon period (April- may) in the year 2021 from 6 different villages of Malpura block. These villages include Lawa (V_1), Borkhandi (V_2), Kadila (V_3), Jankipura (V_4), Diggi (V_5) and Nukkad (V_6). The samples were analyzed for different water quality parameters. To prevent microbial growth, 2-3 drops of toluene were added to the water samples and brought to the laboratory for further analysis.

2.3 Analysis of Physico-Chemical Parameters of Groundwater Samples

According Table 1, these methods were used to check the irrigation groundwater quality In the laboratory, the water quality analysis was carried out following standard methods outlined in the APHA (American Public Health Association) guidelines from 1992. The specific parameters analyzed were as follows:

1. **pH:** The pH level of each water sample was determined using a pH meter, which measures the acidity or alkalinity of the water.
2. **Electrical Conductivity (EC):** An EC meter was used to measure the electrical conductivity of the water samples. This measurement provides an indication of the concentration of dissolved salts or ions, which influences the water's salinity.
3. **Chlorides:** The concentration of chlorides in the water samples was estimated using Mohr's titration method with the assistance of 0.02N silver nitrate and potassium chromate indicator.
4. **Carbonates and Bicarbonates:** The content of carbonates and bicarbonates in the water samples was determined through the simple acidimetric titration method described by (Richards in 1954) (9).
5. **Water-Soluble Sodium and Potassium:** A flame photometer was employed to measure the levels of water-soluble sodium and potassium in the water samples.
6. **Total Ca^{2+} + Mg^{2+}:** The total concentration of calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions was determined using a complexometric titration method that involved the use of ethylene diamine tetra acetic acid (EDTA).
7. **$SO4^{-2}$:** The turbidimetric method for the analysis of sulfate in irrigation water.

Aside from the primary water quality parameters mentioned above, secondary water quality parameters were also calculated based on the data obtained. These secondary parameters included the SAR, RSC, SSP, KR, and PI were as calculated by using the formula given by Richards (1954) [8], such as:

A) Sodium adsorption ratio (SAR): SAR, which measures the alkali/sodium hazard level to the crops, is the sodium toxicity indicator expressed in mmol L^{-1}.

$$\text{SAR }(\text{mmol}^{-1})^{1/2} = \frac{Na^{+}}{\sqrt{\frac{Ca^{+2}+Mg^{+2}}{2}}}$$

B) Residual sodium carbonate (RSC): Water containing carbonate plus bicarbonate concentration greater than the calcium plus magnesium concentration referred to as "Residual Sodium Carbonate" and calculated as (Raghunath 1987) [6].

$$\text{RSC (me L}^{-1}) = (CO3^{2-} + HCO3^{-}) - (Ca^{2+} + Mg^{2+})$$

C) Soluble sodium percentage (SSP) (Wilcox, 1955) [12]

$$\text{SSP (meq l}^{-1}) = \frac{Na \times 100}{Ca + Mg + Na}$$

D) Permeability index (PI): Permeability index was calculated using the following formula:

$$\text{PI(meq l}^{-1}) = \frac{Na + \sqrt{HCO3}}{Ca + Mg + Na} \times 100$$

E) Kelly's ratio (KR): Kelly's ratio of unity as given by Kelly (1963) of the samples was calculated by using the following formulae:

$$\text{KR(meq l}^{-1}) = \frac{Na^{+}}{Ca^{+2} + Mg^{+2}}$$

Water samples were classified into different categories as per the classification of All India Coordinated Research Project (AICRP, 1989) on the management of Salt Affected Soils and Use of Saline Water in Agriculture. Correlation coefficient of water properties was also calculated.

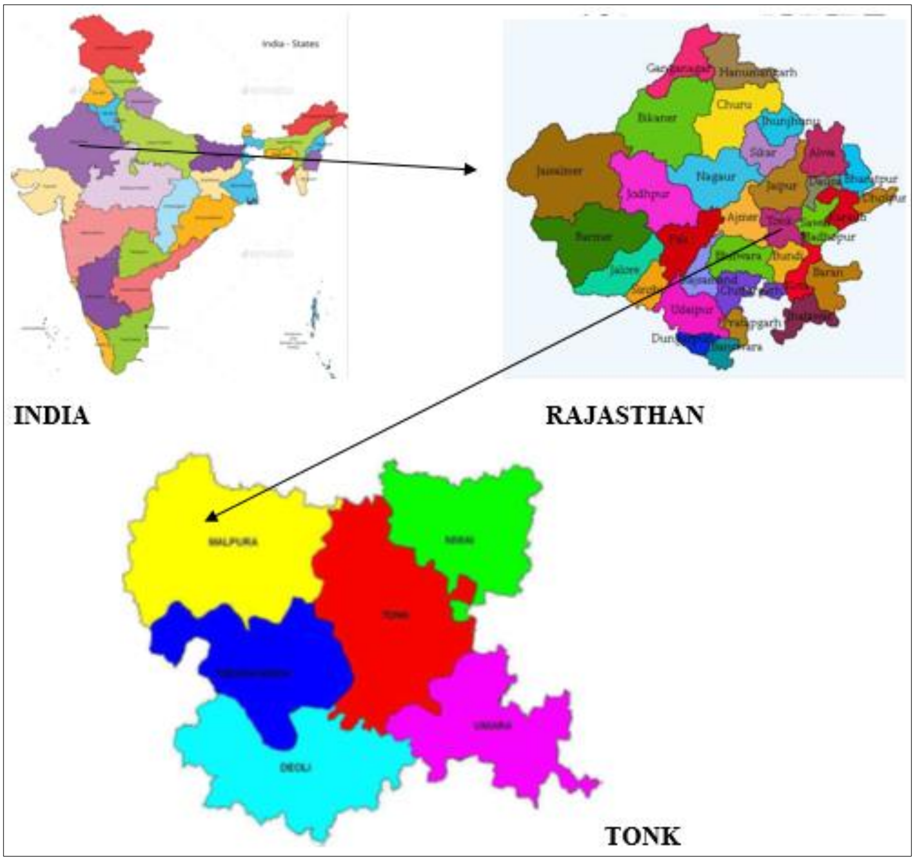

Fig 1: Location of Malpura Block in Tonk District Rajasthan.

Table 1: Methods to be used for checking of irrigation groundwater quality

S. No.	Experiment	Method	Reference
1.	EC	With the help of EC meter as per method (4b) USDA Hand book No. 60	Richards (1954) [8]
2.	pH	pH meter	Richards (1954) [8]
3.	$Ca^{2+} + Mg^{2+}$	With standard EDTA solution as per method No. 7 USDA, Hand book No. 60	Richards (1954) [8]
4.	Na^{+}	With the help of flame photometer as per method (10a) USDA, Hand book No. 60.	Richards (1954) [8]
5.	$CO3^{2-} + HCO3^{-}$	With standard H_2SO_4 as per method 12, USDA, Hand book No. 60.	Richards (1954) [8]
6.	Cl^{-}	With standard $AgNO_3$ as per method No. 13, USDA Hand Book No. 60	Richards (1954) [8]
7.	SAR	SAR = Na+ / [(Ca^{2+} + Mg^{2+})/2]0.5 Where soluble cations are in me/L	Richards (1954) [8]
8.	RSC	(CO32- + HCO3-) – (Ca2+ + Mg2+) Where $CO3^{2-}$ + $HCO3^{-}$, Ca^{2+} and Mg^{+} are in me/ L	Richards (1954) [8]
9.	$SO4^{-2}$	Turbidimetric method	Richards (1954) [8]

3. Results and Discussion

3.1 Cationic Concentration

The concentration of cations and anions in different village of Malpura block are depicted in Table 3. According to the research findings, the concentration of cations *viz*., Calcium, Magnesium, Sodium and Potassium in the Malpura block varied from 0.22 to 8.5 meq L^{-1}, 0.2 to 33.2 meq L^{-1}, 0.55 to 23.65 meq L^{-1} and 0.005 to 1.79 meq L^{-1} respectively. Whereas average calcium levels in groundwater samples of various village *viz*., Lawa (V_1), Borkhandi (V_2), Kadila (V_3), Jankipura (V_4), Diggi (V_5), and Nukkad (V_6), are 6.22 meq L^{-1}, 7.25 meq L^{-1}, 1.61 meq L^{-1}, 2.46 meq L^{-1}, 2.46 meq $L^{-1}$and 2.47 meq L^{-1} respectively. The average magnesium concentration in groundwater samples of various village *viz*., Lawa (V_1), Borkhandi (V_2), Kadila (V_3), Jankipura (V_4), Diggi (V_5), and Nukkad (V_6), are 3.79 meq L^{-1}, 5.50 meq L^{-1}, 16.70 meq L^{-1}, 2.51 meq L^{-1}, 2.2 meq $L^{-1}$and 2.15 meq L^{-1} respectively. The average sodium concentration in groundwater samples of various village *viz*., (V1), (V2), (V3), (V4), (V5), and (V6), are 13.98 meq L^{-1}, 7.78 meq L^{-1}, 13.35 meq L^{-1}, 12.62 meq L^{-1}, and 13.2 meq $L^{-1}$and 12.68 meq L^{-1} respectively. The average potassium concentration in groundwater samples of various village *viz*., (V_1), (V_2), (V_3), (V_4), (V_5), and (V_6), are 0.39 meq L^{-1}, 0.65 meq L^{-1}, 0.30 meq L^{-1}, 0.38 meq L^{-1}, and 1.2 meq $L^{-1}$and 12.68 meq L^{-1} respectively.

The sodium ion was identified as the most abundant cation across all villages, likely curtailing from various factors such as erosion of salt deposits and sodium-rich rock minerals, intrusion of salt water into tube wells, irrigation practices, and leaching of sodium from soils or industrial sites. Following sodium, calcium emerged as the second most prevalent cation, primarily sourced from limestone, gypsum, and dolomite dissolution, resulting in elevated calcium levels. Conversely, potassium was found to be the least common element in groundwater samples, possibly due to the slower weathering of potassium-bearing rocks compared to sodium-bearing ones, resulting in lower concentrations of potassium. Furthermore, potassium may enter groundwater through fertilizer application and the decomposition of animal or waste products.

3.2 Anion Concentration

The anionic concentration (Table 4.) the Carbonate, Bicarbonate, Chloride and Sulphate contents in the Malpura block varied from 0 to 26 meq L^{-1}, 2.5 to 46.34 meq L^{-1}, 1 to 80.35 meq $L^{-1}$and 0.3 to 6.46 meq L^{-1}respectively. Whereas the average carbonate content in groundwater samples of various village *viz*., Lawa (V_1), Borkhandi (V_2), Kadila (V_3), Jankipura (V_4), Diggi (V_5), and Nukkad (V_6), are respectively 2.0 meq L^{-1}, 14 meq L^{-1}, 2.20 meq L^{-1}, 2.1 meq L^{-1}, 2.8 meq L^{-1} and 5.2 meq L^{-1}respectively. The mean bicarbonate content in groundwater samples of various village *viz*., Lawa (V_1), Borkhandi (V_2), Kadila (V_3), Jankipura (V_4), Diggi (V_5), and Nukkad (V6), are respectively 20.30 meq L^{-1}, 8.60 meq L^{-1}, 17.35 meq L^{-1}, 24.89 meq L^{-1}, 14.9 meq L^{-1} and 21.01 meq L^{-1}respectively. The average chloride content in groundwater samples of various village *viz*., (V_1), (V_2), (V_3), (V_4), (V_5), (V_6), were found 14.50 meq L^{-1}, 43.18 meq L^{-1}, 24.73 meq L^{-1}, 42.82 meq L^{-1}, 39.7 meq L^{-1} and 6.1 meq L^{-1}. The average sulphate content in groundwater samples of villages *viz*., (V_1), (V_2), (V_3), (V_4), (V_5), (V6), were found 3.48 meq L^{-1}, 3.10 meq L^{-1}, 3.15 meq L^{-1}, 2.15 meq L^{-1}, 1.2 meq L^{-1} and 3.72 meq L^{-1}.

The bicarbonate ion was found to be the predominant anion in most blocks, likely originating from organic matter in the aquifer oxidizing to produce carbon dioxide, which then accelerates mineral dissolution.(9) suggested that silicate minerals weathering could also contribute to bicarbonate ion production. Chloride content in groundwater may stem from various sources such as rock evaporation, saltwater intrusion, connate and juvenile water, or pollution from industrial or residential sewage.

Table 2: Grouping of low-quality ground waters for irrigation in India

Water quality	EC (dS/m)	SAR (m mol/L)	RSC (meq/L)
A. Good	<2	<10	<2.5
B. Saline			
Marginal saline	2-4	<10	<2.5
Saline	>4	<10	<2.5
High – SAR Saline	>4	>10	<2.5
C. Alkali water			
Marginally Alkali	<4	<10	2.5 – 4.0
Alkali	<4	<10	>4.0
Highly Alkali	Variable	>10	>4.0

D. Toxic water The toxic water has variable salinity, SAR and RSC but has excess of specific ions such as chloride, sodium, nitrate, boron, fluoride or heavy metals such as selenium, cadmium, lead and arsenic etc.

3.3 Water Quality Parameters

Assessing the quality of irrigation water is crucial for its suitability in agriculture, particularly when considering salinity or alkalinity levels in a given area. Optimal water quality can positively impact soil conditions and contribute to maximizing agricultural yield. For instance, in the Malpura block, in different village exhibit varying pH, electrical conductivity (EC), residual sodium carbonate (RSC), and sodium adsorption ratio (SAR) values, as depicted in Table 4. Notably, water pH significantly influences both water quality and the degree of salinity hazard in the research area.The results of the study shows that the pH and EC values of Malpura block ranged from 6.1 to 9 and 0.16 dS m^{-1} to 4.8 dS m^{-1}, respectively. Whereas the pH of the groundwater samples in different village of Malpura block *viz* Lawa (V_1), Borkhandi (V_2), Kadila (V_3), Jankipura (V_4), Diggi (V_5), and Nukkad (V_6), are respectively was in the range of 6.40 to 7.90 with an average of 7.15, 7.20 to 8.20 with an average of 7.70, 6.8 to 8.50 with an average of 7.65, 7.8 to 9 with an average of 8.4, 6.1 to 7.8 with an average of 6.95, 7.3 to 8.5 with an average of 7.9 respectively. It indicates that most of the sample comes under slightly saline to alkaline in nature.

EC is a measurement of the total dissolved solids and ionised species in water that provides insight into the level of inorganic contamination. The mean EC values of various village of malpura block varied from 2.18 dS m^{-1}, 2.6 dS m^{-1}, 2.35 dS m^{-1}, 3.15 dS m^{-1}, 2.25 dS m^{-1}, 2.43 dS m^{-1}, in Lawa (V_1), Borkhandi (V_2), Kadila (V_3), Jankipura (V_4), Diggi (V_5), and Nukkad (V_6), respectively. Minimum EC was found 0.16 dS m^{-1} in Lawa (V_1), and maximum was found 4.8 dS m^{-1} in jankipura (V_4) due to water soluble salt more present in this village water sample.

The overall range of Residual Sodium Carbonate (RSC) in Malpura block varied from -3 to 40.37 meq L^{-1}, Prakash *et al.* (2020) reported (7) that RSC concentration ranged from 0-4.80 meq L^{-1} in the Faridabad district of Haryana. Out of 217 water samples collected, maximum water samples were of good quality and safe for irrigation. While the Sodium Adsorption Ratio (SAR) ranged from 0.80 to 18.25 mmol L^{-1}.the low (SAR) value found in Lawa (V_1), and maximum in Nukkad (V6), villages. The SSP and KR value found average 61.51 meq L^{-1}, and 11.95 meq L^{-1}, the lowest SSP value 6.43 meq L^{-1}, found in Borkhandi (V_2), and highest found in Kadila (V_3), village. While KR value 2.09 meq L^{-1}, found minimum in Borkhandi (V_2), and maximum Kadila (V_3), village.

Table 3: Cationic and anionic concentration of water in various various villages of Malpura block

Name of blocks	No. of sample	Range/Mean	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	$CO3^{-}$	$HCO3^{-}$	Cl^{-}	SO_4^{2-}
(Meq/L)										
Lawa (V_1)	10	Min	4.44	2.71	4.30	0.34	0.00	6.60	1.00	0.49
		Max	8.00	4.88	23.65	0.44	4.00	34.00	28.00	6.46
		Mean	6.22	3.79	13.98	0.39	2.00	20.30	14.50	3.48
Borkhandi (V_2)	10	Min	6.00	2.00	0.55	0.01	2.00	3.00	6.00	2.00
		Max	8.50	9.00	15.00	1.30	26.00	14.20	80.35	4.20
		Mean	7.25	5.50	7.78	0.65	14.00	8.60	43.18	3.10
Kadila (V_3)	10	Min	0.22	0.2	4.7	0.05	0.4	2.5	4.8	2.4
		Max	3	33.2	22	0.54	4	33	44.65	3.9
		Mean	1.61	16.70	13.35	0.30	2.20	17.75	24.73	3.15
Jankipura (V_4)	10	Min	0.42	0.34	3.7	0.09	1	3.44	33.4	0.3
		Max	4.5	4.67	21.54	0.67	3.2	46.34	52.23	4
		Mean	2.46	2.51	12.62	0.38	2.1	24.89	42.82	2.15
Diggi (V_5)	10	Min	0.9	0.76	7.9	0.54	0.5	5.21	24.94	0.43
		Max	5.7	3.55	18.44	1.79	5.1	24.54	54.45	2
		Mean	3.3	2.2	13.2	1.2	2.8	14.9	39.7	1.2
Nukkad (V_6)	10	Min	0.4	0.76	5.7	0.03	2.5	5.22	4.3	2.54
		Max	5.6	3.54	19.65	0.12	7.9	36.8	7.9	4.9
		Mean	3	2.15	12.68	0.08	5.2	21.01	6.1	3.72

Table 4: The groundwater quality in Different villages of Malpura block

Name of blocks	No. of sample	Range/Mean	PH	Ec(dsm^{-1})	SAR (m mol/L)	RSC (meq/L)	SSP(meq/L)	KR (meq/L)	Pi(%)
Lawa (V_1)	10	Min	6.40	0.16	0.80	-0.55	37.56	3.68	60.00
		Max	7.90	4.20	13.30	25.12	64.74	7.83	80.71
		Mean	7.15	2.18	7.05	12.29	51.15	5.76	70.36
Borkhandi (V_2)	10	Min	7.20	0.70	4.10	-3.00	6.43	2.09	26.69
		Max	8.20	4.50	13.70	22.70	46.15	10.76	57.75
		Mean	7.70	2.60	8.90	9.85	26.29	6.43	42.22
Kadila (V_3)	10	Min	6.8	0.50	3.63	2.48	91.80	21.56	122.68
		Max	8.50	4.20	1.83	0.80	37.80	40.53	47.67
		Mean	7.65	2.35	2.73	1.64	64.80	31.05	85.17
Jankipura (V_4)	10	Min	7.8	1.5	2.12	3.68	82.96	9.15	124.55
		Max	9	4.8	11.10	40.37	70.14	9.46	92.31
		Mean	8.4	3.15	6.61	22.03	76.55	9.30	108.43
Diggi (V_5)	10	Min	6.1	1	3.07	4.05	82.64	9.54	106.51
		Max	7.8	3.5	3.03	20.39	66.59	6.79	84.48
		Mean	6.95	2.25	3.05	12.22	74.62	8.16	95.50
Nukkad (V_6)	10	Min	7.3	0.87	2.65	6.56	83.09	15.01	116.40
		Max	8.5	4	18.25	35.56	68.25	7.05	89.32
		Mean	7.9	2.43	10.45	21.06	75.67	11.03	102.86

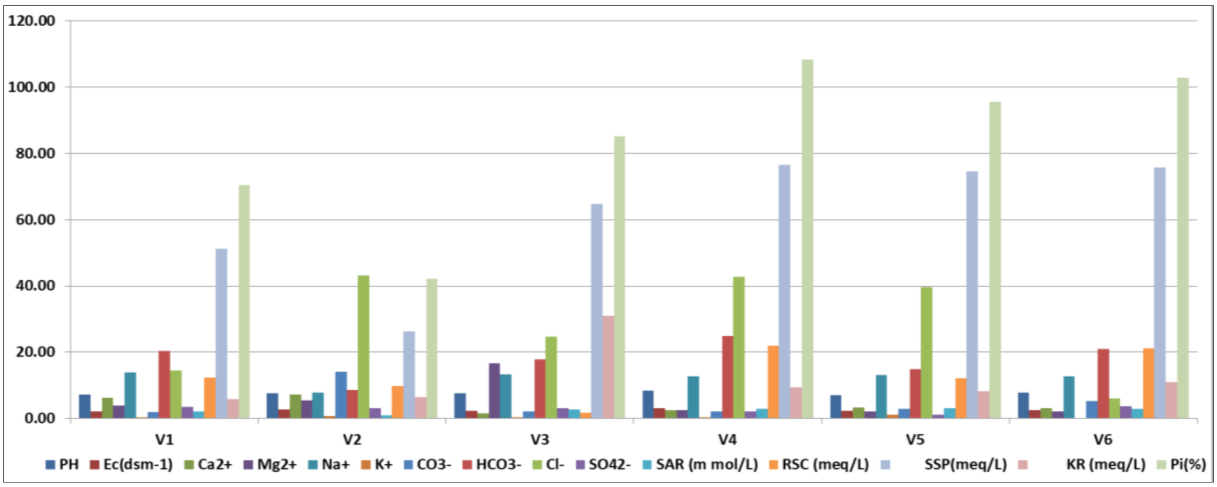

Fig 2: Status of ground water quality

Table 5: Correlation matrix among the chemical constituents of the groundwater.

	PH	$Ec(dsm^{-1})$	Ca^{2+}	Mg^{2+}	Na^+	K^+	$CO3^-$	$HCO3^-$	Cl^-	$SO4^{2-}$	SAR (m mol/L)	RSC (meq/L)	SSP(meq/L)	KR (meq/L)	Pi(%)
PH	1														
Ec	0.849	1													
Ca^{2+}	0.295	0.526	1												
Mg^{2+}	0.388	0.654	0.370**	1											
Na^+	0.662	0.903	0.408	0.469	1										
K^+	0.126	0.471	0.429)	0.125	0.428**	1									
$CO3^-$	0.374	0.513	0.623	0.159	0.230	0.455	1								
$HCO3^-$	0.765**	0.513	0.352**	0.367	0.924	0.223	0.079	1							
Cl^-	0.501	0.692	0.367**	0.323**	0.468**	-0.072	0.622**	0.325	1						
$SO4^{2-}$	0.627	0.720	0.556	0.332	0.726**	-0.011	0.408	0.689	0.150	1					
SAR	0.209	0.324	-0.337	-0.150	0.498**	0.107	-0.200	0.453**	0.068	0.257	1				
RSC	0.678	0.764	0.427	-0.175	0.699**	0.288	0.343	0.779**	0.366	0.595	0.539**	1			
SSP	-0.029	-0.034	-0.633	-0.339	0.104**	-0.067	-0.311	0.067	-0.074	-0.112	0.873	0.261	1		
KR	0.207	0.154	-0.429	0.817	0.250**	-0.113	-0.084	0.145	0.089	0.177	0.182	-0.309	0.119	1	
Pi	-0.075	-0.175	-0.711	-0.434	-0.071	-0.198	-0.389	-0.057	-0.173	-0.232	0.768	0.169	0.976	0.050	1

*Represents significant at $p \leq 0.05$ level **Represents significant at $p \leq 0.01$ level

4. Correlation between water quality parameters

The correlation between the water qualities parameters were given in the Table 5. Significant positive correlation was observed between Na+ and K^+ (r = 0.428**) or Na+ and Cl^- (r = 0. 468**). The positive correlation may imply sodium dissolution from the respective ion containing minerals. Positive correlation also found significantly between $HCO3^-$ and SAR (r = 0.453**), and $HCO3^-$ and RSC (r = 0.779**), Highly significant positive correlation found between Ca2+ and Mg2+ (r = 0.370**) and Ca_2^+ and Cl^- (r = 0.367**). Also significant positive correlation was observed between $Mg2^+$ and Cl^- (r = 0.323**). Positive and significant correlation was observed between Na^+ and $SO4^{2-}$ (r = 0.726**), Na^+ and KR (r = 0.250**), Na^+ and SSP (r = 0.104**), Na^+ and SAR (r = 0.498**) and Na^+ and RSC(r = 0.699**).

5. Conclusions

In the surveyed region, there is a significant abundance of major anions and cations in the groundwater used for irrigation, resulting in high alkalinity levels. The groundwater quality in two villages of Malpura block is deemed unsuitable for irrigation purposes. Prolonged utilization of this groundwater may exacerbate issues related to soil salinity and alkalinity. Groundwater contamination resulting from salinization is a significant concern, often caused by different factors such as agrochemical pollution, natural geogenic contamination, and salinization induced by irrigation practices. Various indices are utilized to categorize and evaluate groundwater quality, playing a crucial role in this assessment. Given the importance of groundwater as a vital resource, it's imperative to implement preventive measures to manage and mitigate contamination, thus safeguarding this invaluable resource.

6. References

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