Plant Archives Vol. 25, Supplement 2, 2025 pp.2082-2087 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2025.v25.supplement-2.263

ASSESSMENT OF IRRIGATION WATER QUALITY IN GWALIOR DISTRICT, MADHYA PRADESH INDIA

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(Date of Receiving : 02-04-2025; Date of Acceptance : 06-06-2025)

ABSTRACT

This research aimed to assess irrigation water quality in various villages within the Morar block of Gwalior district, Madhya Pradesh. Groundwater and sewage water samples were analyzed in the Soil Science and Agricultural Chemistry Laboratory at the College of Agriculture, RVSKVV, Gwalior. The findings revealed that the concentrations of soluble cations and anions varied significantly between water sources. Groundwater showed moderate levels of calcium (0.17–4.36 me L^{-1}), magnesium (0.05–1.24 me L^{-1}), sodium (1.18–5.98 me L^{-1}), and potassium (0.02–0.09 me L^{-1}). In contrast, sewage water exhibited higher concentrations of these ions. Parameters such as pH, electrical conductivity, Sodium Adsorption Ratio (SAR), and Residual Sodium Carbonate (RSC) were also evaluated to assess the suitability of these water sources for irrigation.

Keywords **:** Cation, groundwater, sewage water, water quality, irrigation

Introduction

Water is one of the most essential natural resources for sustaining life, and it is projected to face severe shortages in the coming decades due to increasing demand, rapid population growth, and economic expansion. Given the dynamic and renewable nature of water resources, they must be measured in terms of flow rates to ensure efficient management and utilization. Recognizing the value of water, there is a growing emphasis on its sustainable use and management. Surface and groundwater resources play a vital role in supporting agriculture, hydropower generation, livestock production, industrial activities, forestry, fisheries, navigation, and recreational pursuits.

However, unplanned management, rapid industrialization, extensive agricultural development, and the discharge of untreated sewage, agricultural runoff, and other human and animal wastes into rivers, lakes, reservoirs, and other water bodies have led to the continuous degradation of water quality and aquatic ecosystems (Venkatesan, 2007; Elmaci *et al*., 2008). The health and biodiversity of lakes, in particular, are closely linked to the overall health of the surrounding ecosystem (Indira and Sivaji, 2006; Krishnan *et al*., 2007). The unsustainable management of soil and water resources, without systematic, long-term planning, poses a significant threat to agricultural productivity and national economic development.

A study by Singh *et al*. (2021) investigated groundwater quality in rural areas of Ujjain District, Madhya Pradesh, India, to assess its suitability for drinking. The study involved water quality analysis at seven intervals over two years in six villages, with 868 groundwater samples collected from 124 households. Although the overall groundwater quality was deemed suitable for drinking, the presence of high levels of dissolved solids (>800 mg/L) and hardness (>400 mg/L) raised concerns, as long-term consumption of

such water could lead to health issues such as kidney stones and atopic dermatitis in children.

Material and Methods

The present investigation, titled "Assessment of Irrigation Water Quality in Gwalior District, Madhya Pradesh" was conducted during 2021-22 to assess the water quality in the Morar block of Gwalior district, Madhya Pradesh. The study involved sampling from various villages within the Morar block. The study area is geographically located between 26°14'15" N latitude and 78°13'50" E longitude in the northern part of Gwalior district, with an elevation ranging from 663 ft in the northeast (lowest point) to 1360 ft in the southwest (highest point). The locations where water samples were collected are presented in Figure 1.

Climate

The region experiences a semi-arid climate. During summer, the average maximum temperature reaches 45°C, while in winter, the minimum temperature drops to around 2°C. The block receives an average annual rainfall of 751 mm.

Site selection and sampling

A preliminary survey of the study area was conducted between October and December 2021 to identify suitable locations for water sampling and assess water quality**.** Ten villages from the Morar block of Gwalior district were selected for the collection of irrigation water samples from tube wells and sewage sources.

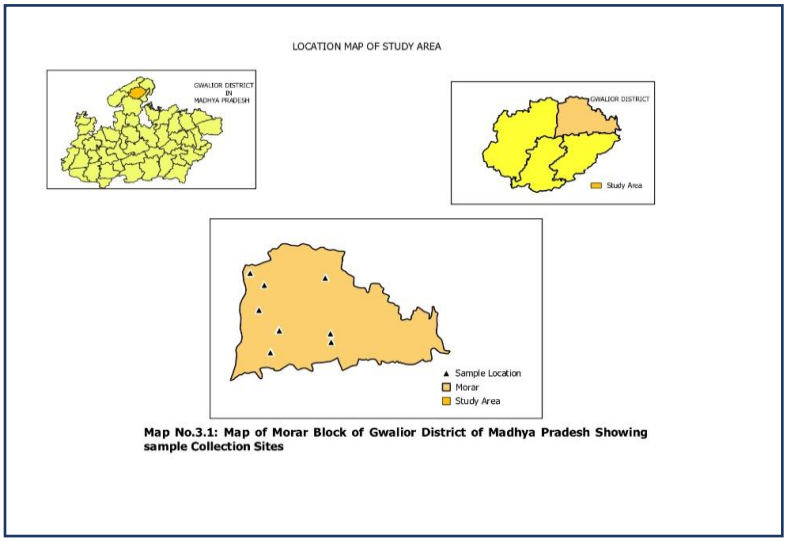

Fig. 1 : Map of Morar Block, Gwalior District, Madhya Pradesh, Indicating Water Sample Collection Sites

Water Sample Collection

A total of 30 georeferenced water samples were collected from the identified ten villages in the Morar block between October and December 2021. To ensure representative samples, the water pumps were run continuously for 30 minutes to 1 hour before collection. Water samples were stored in clean, pre-rinsed plastic bottles, which were properly labeled. A few drops of toluene were added to prevent microbial growth during storage before the bottles were securely sealed

Analysis of samples

The collected water samples were analyzed in the laboratory to determine their chemical composition. The parameters measured included pH, electrical conductivity (EC), and concentrations of soluble cations (Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+}) as well as soluble anions (CO_3^{2-}, HCO_3^{-}, Cl^{-}, and SO_4^{2-}). Additionally, Residual Sodium Carbonate (RSC) and Sodium Adsorption Ratio (SAR) were calculated to assess the water's suitability for irrigation.

Results & Discussion

The results of the present study outline the criteria for assessing the suitability of tube well water for both irrigation and domestic use. Water quality monitoring involved the chemical analysis of samples collected from tube wells and open wells during December 2021. The samples were obtained from ten villages across three sites within the Morar block of Gwalior district, Madhya Pradesh, with the objective of evaluating the water quality and identifying appropriate management strategies. The analysis focused on determining the ionic composition of the water, including cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}) and anions (CO_3^{2-}, HCO_3^{-}, Cl^{-}, SO_4^{2-}). In addition, pH and electrical conductivity (EC) were measured, and key parameters

such as the Sodium Adsorption Ratio (SAR) and Residual Sodium Carbonate (RSC) were calculated to assess water suitability. The data from the chemical analysis of tube well water is summarized in Table 1 and discussed in detail below.

Ionic composition of tube well water

The analysis of tube well water samples from the Morar block revealed the following ionic composition, as presented in Table 3. The concentrations of soluble cations Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Sodium (Na^{+}), and Potassium (K^{+}) were measured in milliequivalents per liter (me L^{-1}). The observed ranges, means, standard deviations (SD), and coefficients of variation (CV%) for these cations were as follows:

- Calcium (Ca^{2+}): Ranged from 0.17 to 4.36 (mean: 2.51, SD: 1.15, CV: 45.87%)
- Magnesium (Mg^{2+}): Ranged from 0.05 to 1.24 (mean: 0.40, SD: 0.30, CV: 74.00%)
- Sodium (Na^{+}): Ranged from 1.18 to 5.98 (mean: 3.02, SD: 1.52, CV: 50.23%)
- Potassium (K^{+}): Ranged from 0.02 to 0.09 (mean: 0.06, SD: 0.02, CV: 30.69%)

Among the villages sampled, the highest concentration of Calcium (4.36 me L^{-1}) was recorded in Rora at Field 1, while the lowest (0.17 me L^{-1}) was found in Baderafutker at Field 2. For Magnesium, the maximum value (1.24 me L^{-1}) was observed in Tankoli at Field 1, whereas the minimum (0.05 me L^{-1}) was noted in Baderafutker at Field 2. The highest level of Sodium (5.98 me L^{-1}) was detected in Laxmangarh at Field 2, while the lowest (1.18 me L^{-1}) was recorded in Sonsa at Field 1. For Potassium, the highest concentration (0.09 me L^{-1}) was found in Rora at Field 2, and the lowest (0.02 me L^{-1}) was observed in Sonsa at Field 3.

In terms of soluble anions, the analyzed parameters included Carbonate (CO_3^{2-}), Bicarbonate (HCO_3^{-}), Chloride (Cl^{-}), and Sulfate (SO_4^{2-}), with the following ranges, means, SD, and CV%:

- Carbonate (CO_3^{2-}): Ranged from 0.08 to 0.66 (mean: 0.36, SD: 0.14, CV: 37.35%)
- Bicarbonate (HCO_3^{-}): Ranged from 1.11 to 4.91 (mean: 3.34, SD: 1.04, CV: 31.04%)
- Chloride (Cl^{-}): Ranged from 0.28 to 3.11 (mean: 1.82, SD: 0.73, CV: 40.38%)
- Sulfate (SO_4^{2-}): Ranged from 0.10 to 0.90 (mean: 0.36, SD: 0.23, CV: 62.38%)

The maximum concentration of Carbonate (0.66 me L^{-1}) was recorded in Maharajpura at Field 2, while the minimum (0.08 me L^{-1}) was found in Tankoli at the same field. For Bicarbonate, the highest level (4.91 me L^{-1}) was observed in Baderafutker at Field 1, whereas the lowest (1.11 me L^{-1}) was noted in Sonsa at Field 2. The maximum concentration of Chloride (3.11 me L^{-1}) was detected in Tankoli at Field 1, while the minimum (0.28 me L^{-1}) was recorded in Baderafutker at Field 3. Lastly, the highest level of Sulfate (0.90 me L^{-1}) was observed in Rora at Field 1, and the lowest (0.10 me L^{-1}) was found in Sonsa at Field 3.

Table 1 : Ionic composition of tube well water in Morar block of Gwalior

Morar Block	Ionic composition (me L^{-1})							
	Cations (me L^{-1})				Anions (me L^{-1})			
	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{2-}	HCO_3^{-}	Cl^{-}	SO_4^{2-}
Range	0.17-4.36	0.05-1.24	1.18-5.98	0.02-0.09	0.08-0.66	1.11-4.91	0.28-3.11	0.10-0.90
Mean	2.51	0.40	3.02	0.06	0.36	3.34	1.82	0.36
SD	1.15	0.30	1.52	0.02	0.14	1.04	0.73	0.23
CV (%)	45.87	74.00	50.23	30.69	37.35	31.04	40.38	62.38

Characteristics of sewage water

The analysis of sewage water samples collected from tube wells and open wells was conducted to assess the quality of the sewage water. Samples were gathered in December 2021 from ten villages across three fields within the selected block. The water samples were evaluated for their ionic composition, including cations (Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+}) and anions (CO_3^{2-}, HCO_3^{-}, Cl^{-}, and SO_4^{2-}). Additionally, parameters such as pH**,** electrical conductivity (EC)**,** Sodium Adsorption Ratio (SAR)**,** and Residual Sodium Carbonate (RSC) were calculated. The data pertaining to the chemical analysis of the sewage water are summarized in Table 2.

Ionic composition of sewage water

The analysis of the ionic composition of sewage water revealed the following findings regarding the soluble cations and anions present in the samples.

Cations

The soluble cations Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Sodium (Na^{+}), and Potassium (K^{+}) were measured in me L^{-1}. The concentration ranges, mean values, standard deviations (SD), and coefficients of variation (CV%) for these cations are presented below:

- Calcium (Ca^{2+}): Values ranged from 2.73 to 5.39 (mean: 3.95; SD: 1.03; CV: 26.06%)
- Magnesium (Mg^{2+}): Values ranged from 0.19 to 1.79 (mean: 0.88; SD: 0.64; CV: 73.22%)
- Sodium (Na^{+}): Values ranged from 1.34 to 4.34 (mean: 2.70; SD: 1.44; CV: 53.49%)
- Potassium (K^{+}): Values ranged from 0.10 to 0.20 (mean: 0.15; SD: 0.04; CV: 28.18%)

The maximum concentration of Calcium (Ca^{2+}) was recorded in village Jamahar (5.39 me L^{-1}) at field-1, while the minimum concentration was found in village Jalalpur (2.73 me L^{-1}) at field-2. The highest Magnesium (Mg^{2+}) concentration was also in village Jamahar (1.79 me L^{-1}) at field-3, with the lowest in village Jalalpur (0.19 me L^{-1}) at field-1.

For Sodium (Na^{+}), the maximum value was observed in village Jamahar (4.34 me L^{-1}) at field-2, while the minimum was noted in village Jalalpur (1.34 me L^{-1}) at field-3. The maximum concentration of Potassium (K^{+}) was recorded in village Jalalpur (0.20 me L^{-1}) at field-3, whereas the minimum was again in village Jalalpur (0.10 me L^{-1}) at field-1.

Anions:

The soluble anions Carbonate (CO_3^{2-}), Bicarbonate (HCO_3^{-}), Chloride (Cl^{-}), and Sulfate (SO_4^{2-}) were similarly measured in me L^{-1}. Their ranges, mean values, SDs, and CVs are as follows:

- Carbonate (CO_3^{2-}): Values ranged from 0.37 to 0.44 (mean: 0.40; SD: 0.03; CV: 6.70%)
- Bicarbonate (HCO_3^{-}): Values ranged from 2.27 to 4.78 (mean: 3.79; SD: 1.08; CV: 28.62%)
- Chloride (Cl^{-}): Values ranged from 1.58 to 2.78 (mean: 2.26; SD: 0.49; CV: 21.92%)
- Sulfate (SO_4^{2-}): Values ranged from 0.90 to 1.30 (mean: 1.12; SD: 0.13; CV: 11.90%)

The maximum concentration of Carbonate (CO_3^{2-}) was noted in village Jalalpur (0.44 me L^{-1}) at field-3, while the minimum was in village Jamahar (0.37 me L^{-1}) at field-2. The highest concentration of Bicarbonate (HCO_3^{-}) was recorded in village Jamahar (4.78 me L^{-1}) at field-3, with the minimum found in village Jalalpur (2.27 me L^{-1}) at field-3. For Chloride (Cl^{-}), the maximum was observed in village Jamahar (2.78 me L^{-1}) at field-2, while the minimum was noted in village Jamahar (1.58 me L^{-1}) at field-1. Finally, the maximum concentration of Sulfate (SO_4^{2-}) was found in village Jamahar (1.30 me L^{-1}) at field-1, and the minimum was recorded in village Jalalpur (0.90 me L^{-1}) at field-3.

Table 2: Ionic composition of sewage irrigation water in Morar block of Gwalior

Morar Block	Ionic composition (me L^{-1})							
	Cations (me L^{-1})				Anions (me L^{-1})			
	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{2-}	HCO_3^{-}	Cl^{-}	SO_4^{2-}
Range	2.73-5.39	0.19-1.79	1.34-4.34	0.10-0.20	0.37-0.44	2.27-4.78	1.58-2.78	0.90-1.30
Mean	3.95	0.88	2.70	0.15	0.40	3.79	2.26	1.12
SD	1.03	0.64	1.44	0.04	0.03	1.08	0.49	0.13
CV (%)	26.06	73.22	53.49	28.18	06.70	28.62	21.92	11.90

Characteristics of tube well irrigation water in Morar block of Gwalior

pH

The pH of the tube well water samples ranged from 7.30 to 8.30, with an average value of 7.80**.** The standard deviation (SD) was 0.31, and the coefficient of variation (CV%) was 3.91%**.** The lowest pH value was observed in village Sunarpura (pH 7.30) at field-2, while the highest pH value was recorded in village Baderafutker (pH 8.30) at field-1.

Electrical Conductivity (EC)

The electrical conductivity (EC) of the water samples varied between 0.32 dS m^{-1} to 0.79 dS m^{-1}, with an average value of 0.60 dS m^{-1}. The SD was 0.12, and the CV% was 20.53%**.** The lowest EC was recorded in village Sonsa (0.32 dS m^{-1}) at field-1,

while the highest EC was observed in village Laxmangarh (0.79 dS m^{-1}) at field-2.

Residual Sodium Carbonate (RSC)

The residual sodium carbonate (RSC) values ranged from Nil to 4.57 me L^{-1}**,** with an average value of 1.23 me L^{-1}. The SD was 1.56, and the CV% was 127.25%. The highest RSC value was recorded in village Baderafutker (4.57 me L^{-1}) at field-2**.**

Sodium Adsorption Ratio (SAR)

The sodium adsorption ratio (SAR) varied from 2.04 to 8.21, with an average value of 3.99. The SD was 1.75**,** and the CV% was 43.90%. The highest SAR value was observed in village Baderafutker (8.21) at field-2, while the lowest SAR value was recorded in village Tankoli (2.04) at field-1.

Relationship Between pH, EC, and SAR

The increase in SAR values in tube well water appears to correlate with higher pH and EC levels. This trend could be attributed to the dominance of soluble sodium ions (Na^+) over calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions.

Table 3: Characteristics of tube well irrigation water of Morar block of Gwalior

Morar Block	pH	EC (dSm^{-1})	RSC (me L^{-1})	SAR
Range	7.30-8.30	0.32-0.79	Nil-4.57	2.04-8.21
Mean	7.80	0.60	1.23	3.99
SD	0.31	0.12	1.56	1.75
CV (%)	3.91	20.53	127.25	43.90

Nil-Negative RSC values

Characteristics of sewage irrigation water of Morar block of Gwalior

pH

The pH of sewage water samples ranged from 7.40 to 7.90, with an average of 7.71. The standard deviation (SD) was 0.19, and the coefficient of variation (CV%) was 2.49%**.** The lowest pH was observed in village Jamahar (7.40) at field-3, and the highest in the same village (7.90) at field-1.

EC

The EC values ranged from 0.63 to 0.90 dS m^{-1}, with an average of 0.77 dS m^{-1}. The SD was 0.12, and the CV% was 15.40%**.** The lowest EC was recorded in village Jalalpur (0.63 dS m^{-1}) at field-3, while the highest was in village Jamahar (0.90 dS m^{-1}) at field-2.

Residual sodium carbonate

RSC measures excess carbonate and bicarbonate over calcium and magnesium. The RSC values ranged from Nil to 1.28 me L^{-1}, with an average of 0.30 me L^{-1}. The SD was 0.52, with a high CV% of 173.06%. The highest RSC value was observed in village Jamahar (1.28 me L^{-1}) at field-1.

Sodium adsorption ratio

SAR values ranged between 2.62 and 3.15, with an average of 2.87. The SD was 0.20, and the CV% was 6.96%. The highest SAR was recorded in village Jamahar (3.15) at field-2, while the lowest was observed in village Jalalpur (2.62) at field-1.

Trends and Observations

Higher SAR values were associated with increased pH and EC levels, likely due to the dominance of sodium ions (Na^+) over calcium (Ca^{2+}) and magnesium (Mg^{2+}).

Table 4: Characteristics of sewage irrigation water of Morar block of Gwalior

Morar Block	pH	EC (dSm^{-1})	RSC (me L^{-1})	SAR
Range	7.40-7.90	0.63-0.90	Nil-1.28	2.62-3.15
Mean	7.71	0.77	0.30	2.87
SD	0.19	0.12	0.52	0.20
CV (%)	2.49	15.40	173.06	6.96

Nil-Negative RSC values

Conclusion

The assessment of irrigation water quality in the Morar block of Gwalior district revealed that both groundwater and sewage water contain varying levels of essential ions. Groundwater in some villages exhibited high sodium concentrations, posing a risk for

soil salinity. Similarly, sewage water showed elevated cation levels, which, if used without adequate management, may degrade soil health over time. The SAR and RSC analysis further highlighted the potential hazards of long-term water use in agriculture.

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