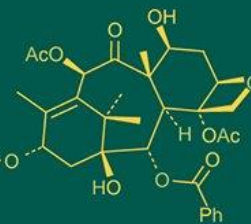
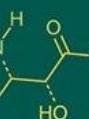
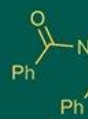


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
IJABR 2026; SP-10(9): 1705-1709
www.biochemjournal.com
Received: 25-06-2026
Accepted: 29-07-2026

Kirti Sharma
Department of Soil Science,
VNМКV, Parbhani,
Maharashtra, India

Pravin Vaidya
Department of Soil Science,
VNМКV, Parbhani,
Maharashtra, India

Swati Zade
Department of Soil Science,
VNМКV, Parbhani,
Maharashtra, India

Hrushikesh Bhambere
Department of Agronomy,
VNМКV, Parbhani,
Maharashtra, India

Vishwajeet Avhale
Department of Agronomy,
VNМКV, Parbhani,
Maharashtra, India

Salman Shaikh
Department of Soil Science,
VNМКV, Parbhani,
Maharashtra, India

Corresponding Author:
Pravin Vaidya
Department of Soil Science,
VNМКV, Parbhani,
Maharashtra, India

Assessment of cations and anions in irrigation water of farm VNМКV, Parbhani

Kirti Sharma, Pravin Vaidya, Swati Zade, Hrushikesh Bhambere, Vishwajeet Avhale and Salman Shaikh

DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i9Su.10068>

Abstract

Groundwater is an important source of irrigation water in semi-arid agricultural regions, where its chemical composition can influence soil properties and crop productivity. The present study was undertaken to assess the concentration and variability of selected major cations and anions in irrigation water of the Vasantao Naik Marathwada Krishi Vidyapeeth (VNМКV) Agricultural Farm, Parbhani, Maharashtra. Groundwater samples collected from different locations of the farm were analysed for calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), potassium (K^+), carbonate (CO_3^{2-}), bicarbonate (HCO_3^-) and nitrate (NO_3^-). The concentration of calcium ranged from 1.20 to 5.40 meq L^{-1} , with an average of 3.216 meq L^{-1} , whereas magnesium varied from 2.80 to 5.40 meq L^{-1} , with an average of 3.820 meq L^{-1} . Sodium concentration ranged from 1.52 to 6.81 meq L^{-1} , with an average of 3.8276 meq L^{-1} , while potassium ranged from 0.12 to 0.67 meq L^{-1} , with an average of 0.3444 meq L^{-1} . Among the anions, carbonate concentration varied from 0.00 to 0.50 meq L^{-1} , with an average of 0.242 meq L^{-1} . Bicarbonate concentration ranged from 5.25 to 8.50 meq L^{-1} , with an average of 6.626 meq L^{-1} , whereas nitrate concentration ranged from 0.56 to 3.36 meq L^{-1} , with an average of 2.0832 meq L^{-1} . The results indicated considerable variation in the concentration of major ions in irrigation water across the farm. Among the cations, sodium and magnesium recorded the highest average concentrations, whereas bicarbonate was the dominant anion among the selected constituents. The variation in nitrate concentration may reflect differences in agricultural activities, fertilizer application, irrigation and groundwater recharge. The study provides useful information on the ionic composition of irrigation water and emphasizes the importance of regular monitoring for sustainable agricultural water management.

Keywords: Calcium, magnesium, carbonate, bicarbonate, nitrate, VNМКV

Introduction

Water is an essential natural resource for agricultural production and sustainable development. Groundwater plays a particularly important role in regions where rainfall is variable and irrigation is necessary to maintain crop production. In India, increasing agricultural demand and dependence on irrigation have enhanced the importance of groundwater resources. However, intensive groundwater utilization and agricultural activities can influence both the quantity and quality of available groundwater [1].

The quality of irrigation water is important because its continuous application can influence soil chemical and physical properties and, consequently, crop growth and long-term agricultural productivity. Groundwater chemistry is controlled by several natural processes, including mineral dissolution, weathering and water-rock interaction, while agricultural activities such as fertilizer application and irrigation may also contribute to changes in groundwater composition [2, 3]. Therefore, assessment of the concentration of major dissolved ions is important for understanding the chemical characteristics of irrigation water.

Major cations such as calcium, magnesium, sodium and potassium constitute important components of groundwater chemistry. Calcium contributes to the maintenance of soil aggregate stability and can counteract the dispersive effect of sodium. Magnesium also contributes substantially to the ionic composition of groundwater and may influence soil physical conditions depending on its relative abundance. Sodium is particularly important from an irrigation perspective because its accumulation in soil can adversely affect soil structure, infiltration and permeability.

Potassium generally occurs in lower concentrations in groundwater compared with calcium, magnesium and sodium.

The carbonate and bicarbonate system represents an important component of groundwater chemistry. Bicarbonate can interact with calcium and magnesium and influence their precipitation, thereby modifying the relative ionic composition of irrigation water and soil solution. The importance of bicarbonate in evaluating irrigation-water chemistry has been highlighted by Gupta and Kumar [4]. Carbonate and bicarbonate concentrations are therefore important for understanding the alkalinity characteristics of irrigation water.

Nitrate is another important constituent of groundwater in agricultural areas. It is highly mobile and may reach groundwater through fertilizer leaching, irrigation return flow and rainfall infiltration. Agricultural practices, fertilizer application, cropping intensity, soil permeability and groundwater recharge can contribute to spatial differences in groundwater nitrate concentration [5-7]. Consequently, nitrate assessment is particularly relevant in intensively cultivated agricultural landscapes.

The Vasantrao Naik Marathwada Krishi Vidyapeeth (VNMKV) Agricultural Farm, Parbhani, represents an important agricultural landscape in the semi-arid Marathwada region of Maharashtra. The region experiences variable monsoon rainfall and periodic water scarcity, resulting in substantial dependence on available groundwater resources [8]. Understanding the chemical composition of irrigation water is therefore important for sustainable utilization of groundwater resources at the farm scale.

Previous investigations have demonstrated considerable variability in groundwater chemistry in Maharashtra and the Godavari basin. Marghade *et al.* [2] identified carbonate and silicate weathering as important processes governing groundwater chemistry in the Godavari basin of Maharashtra. Similarly, Wagh *et al.* [9] reported variability in groundwater quality in Maharashtra. These studies demonstrate the importance of evaluating major ions when characterizing groundwater resources.

Therefore, the present study was undertaken to assess the concentration and variability of selected major cations, namely Ca^{2+} , Mg^{2+} , Na^+ and K^+ , and selected anions, namely CO_3^{2-} , HCO_3^- and NO_3^- , in irrigation water of the VNMKV Agricultural Farm, Parbhani.

Materials and Methods

Study area and groundwater sampling

The study was conducted at the Vasantrao Naik Marathwada Krishi Vidyapeeth (VNMKV) Agricultural Farm, Parbhani, Maharashtra, India. The farm is located in the semi-arid region of the Godavari basin. The region is characterized by variable rainfall and substantial dependence on groundwater for agricultural activities.

A total of 50 groundwater samples were collected from open wells and bore wells distributed across the VNMKV Agricultural Farm and surrounding study locations. The geographical coordinates of the sampling locations were recorded using GPS. Groundwater samples were collected in clean one-litre plastic bottles and transported to the laboratory for chemical analysis following standard procedures [10].

Chemical analysis

The groundwater samples were analysed for calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), potassium (K^+), carbonate (CO_3^{2-}), bicarbonate (HCO_3^-) and nitrate (NO_3^-).

Sodium and potassium were estimated using a flame photometer, whereas calcium and magnesium were determined by EDTA titration. Carbonate and bicarbonate were determined by titration. Nitrate was determined using the Devarda's alloy distillation method. The analytical procedures were based on standard methods described by Richards [10] and Jackson [11, 12].

Statistical analysis

Descriptive statistics were used to determine the minimum, maximum and average concentrations of the selected cations and anions. The relative abundance of individual ions was interpreted using their average concentrations to characterize the ionic composition of the irrigation water.

Results and Discussion

Concentration of selected cations and anions

The groundwater samples showed variation in the concentration of all selected cations and anions. The minimum, maximum and average concentrations are presented in Table 1.

Table 1: Concentration of selected cations and anions in irrigation water of VNMKV Agricultural Farm, Parbhani

Category	Parameter	Minimum (meq L ⁻¹)	Maximum (meq L ⁻¹)	Average (meq L ⁻¹)
Cations	Ca^{2+}	1.20	5.40	3.2160
	Mg^{2+}	2.80	5.40	3.8200
	Na^+	1.52	6.81	3.8276
	K^+	0.12	0.67	0.3444
Anions	CO_3^{2-}	0.00	0.50	0.2420
	HCO_3^-	5.25	8.50	6.6260
	NO_3^-	0.56	3.36	2.0832

The average concentration of the selected cations followed the order $\text{Na}^+ > \text{Mg}^{2+} > \text{Ca}^{2+} > \text{K}^+$, while the selected anions followed the order $\text{HCO}_3^- > \text{NO}_3^- > \text{CO}_3^{2-}$. The relatively high concentration of bicarbonate indicates its predominance among the selected anions, whereas sodium and magnesium represented the major cationic constituents based on their average concentrations.

Calcium concentration

Calcium concentration ranged from 1.20 to 5.40 meq L⁻¹, with an average concentration of 3.216 meq L⁻¹. The observed variation indicates differences in calcium concentration among groundwater sources across the farm.

Calcium is an important divalent cation in irrigation water and plays an important role in maintaining soil aggregate stability. Adequate calcium in the soil solution can also counteract the dispersive influence of sodium. Consequently, the concentration of calcium should be considered together with sodium and magnesium when evaluating irrigation-water chemistry.

The presence and variation of calcium in groundwater may be related to mineral dissolution and water-rock interaction. Marghade *et al.* [2] reported that carbonate and silicate weathering were important processes controlling groundwater chemistry in the Godavari basin of Maharashtra. The calcium concentration observed in the

present study therefore represents an important component of the natural ionic composition of groundwater.

Magnesium concentration

Magnesium concentration ranged from 2.80 to 5.40 meq L⁻¹, with an average concentration of 3.820 meq L⁻¹. Magnesium recorded the second-highest average concentration among the selected cations, being only slightly lower than sodium. Magnesium is an important constituent of groundwater and contributes to its overall cationic composition. Its effect on irrigation-water quality is better understood when considered in relation to calcium and sodium rather than as an isolated parameter. Wagh *et al.* [9] reported variation in groundwater quality parameters in Maharashtra, highlighting the importance of major-ion composition in groundwater assessment.

The relatively high average magnesium concentration observed in the present study indicates that Mg²⁺ made a substantial contribution to the cationic composition of irrigation water at the VNMKV Agricultural Farm.

Sodium concentration

Sodium concentration ranged from 1.52 to 6.81 meq L⁻¹, with an average concentration of 3.8276 meq L⁻¹. Sodium recorded the highest average concentration among the selected cations.

Sodium is particularly important in irrigation-water assessment because prolonged application of sodium-rich water may contribute to sodium accumulation in soil. Excessive sodium relative to calcium and magnesium can adversely influence soil structure, infiltration and permeability. Therefore, the relatively high average concentration of sodium observed in the present study warrants consideration when evaluating the long-term use of groundwater for irrigation.

The occurrence of sodium in groundwater may result from natural geochemical processes as well as ion exchange and mineral weathering. Marghade *et al.* [2] identified mixed Ca-Na-HCO₃ groundwater types in parts of the Godavari basin and reported the importance of geochemical processes in controlling groundwater composition. Pondkule and Jadhao [13] also demonstrated the importance of irrigation-related changes in soil and groundwater environments in Maharashtra.

The relatively high sodium concentration observed in the present study emphasizes the need to consider sodium along with calcium, magnesium and bicarbonate when interpreting the ionic composition of irrigation water.

Potassium concentration

Potassium concentration ranged from 0.12 to 0.67 meq L⁻¹, with an average concentration of 0.3444 meq L⁻¹. Potassium recorded the lowest average concentration among the selected cations.

The comparatively low concentration of potassium indicates that it contributed less to the overall cationic composition of the groundwater than sodium, magnesium and calcium. Potassium generally occurs at relatively lower concentrations in groundwater because it is more readily retained by soil minerals and participates in mineral exchange processes.

Gupta and Kumar [4] emphasized that potassium should not be completely overlooked while assessing irrigation-water chemistry, despite the relatively lower concentration of

potassium compared with other major cations. In the present study, however, potassium represented a comparatively minor component of the selected cations.

Carbonate concentration

Carbonate concentration ranged from 0.00 to 0.50 meq L⁻¹, with an average concentration of 0.242 meq L⁻¹. Carbonate was absent in some groundwater samples, whereas the maximum observed concentration was 0.50 meq L⁻¹.

The relatively low average carbonate concentration compared with bicarbonate indicates that carbonate represented a smaller component of the selected anions. Carbonate concentration is influenced by the carbonate-bicarbonate equilibrium of groundwater and is associated with the overall alkalinity characteristics of irrigation water. The carbonate-bicarbonate system is also closely related to the behaviour of calcium and magnesium in irrigation water. Changes in carbonate and bicarbonate concentrations can influence the precipitation and dissolution of calcium-and magnesium-bearing minerals, thereby affecting the relative composition of other cations in groundwater [2, 4].

Bicarbonate concentration

Bicarbonate concentration ranged from 5.25 to 8.50 meq L⁻¹, with an average concentration of 6.626 meq L⁻¹. Bicarbonate was the dominant anion among the selected constituents.

The higher concentration of bicarbonate compared with carbonate demonstrates the importance of bicarbonate in the anionic composition of groundwater at the VNMKV Agricultural Farm. Bicarbonate is an important component of irrigation-water chemistry because it can interact with calcium and magnesium and influence their precipitation. Such processes can subsequently modify the relative concentration of sodium in the soil solution.

Gupta and Kumar [4] highlighted the importance of bicarbonate in irrigation-water assessment and its relationship with sodium and calcium-magnesium chemistry. Similar importance of carbonate-bicarbonate processes has been reported in groundwater studies of Maharashtra and the Godavari basin [2, 14].

The predominance of bicarbonate observed in the present study therefore represents an important characteristic of the irrigation-water chemistry of the VNMKV Agricultural Farm.

Nitrate concentration

Nitrate concentration ranged from 0.56 to 3.36 meq L⁻¹, with an average concentration of 2.0832 meq L⁻¹. The range indicates variation in nitrate concentration among groundwater sampling locations.

Nitrate is highly mobile in the soil-water system and can move towards groundwater through leaching. In agricultural areas, fertilizer application is an important potential source of nitrate enrichment. Other processes, including irrigation return flow, rainfall infiltration, cropping intensity and groundwater recharge, can also contribute to differences in nitrate concentration.

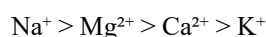
Khan *et al.* [5] discussed the potential contribution of fertilizers to contamination of soil, surface water and groundwater. Natraj *et al.* [6] reported groundwater contamination associated with agricultural activity in Maharashtra, while Patil *et al.* [7] highlighted the importance of anthropogenic activities in nitrate contamination of groundwater in North Maharashtra.

The observed nitrate concentration in the present study may therefore reflect the combined influence of agricultural practices and natural groundwater processes. Because nitrate is mobile and can respond relatively quickly to changes in fertilizer and irrigation management, periodic monitoring is important in intensively cultivated agricultural areas.

Relative abundance of selected cations and anions

The average concentrations of the selected ions showed clear differences in their contribution to the ionic composition of groundwater. Among the cations, sodium recorded the highest average concentration (3.8276 meq L⁻¹), followed very closely by magnesium (3.8200 meq L⁻¹), followed by calcium (3.2160 meq L⁻¹) and potassium (0.3444 meq L⁻¹).

Thus, the order of average cation concentration was:



Among the anions, bicarbonate recorded the highest average concentration (6.6260 meq L⁻¹), followed by nitrate (2.0832 meq L⁻¹) and carbonate (0.2420 meq L⁻¹).

Thus, the order of average anion concentration was:



The predominance of sodium and magnesium among the selected cations and bicarbonate among the selected anions indicates that these ions represent major components of the measured groundwater chemistry. The observed composition is consistent with the importance of weathering and hydrogeochemical processes in the Godavari basin reported by Marghade *et al.* [2]. At the same time, the presence of nitrate reflects the potential influence of agricultural activities and fertilizer use, as reported in groundwater studies from Maharashtra [5-7].

The ionic composition should therefore be interpreted as the combined outcome of natural hydrogeochemical processes and agricultural influences. Regular monitoring of these major ions can provide useful information for maintaining the quality of irrigation water and supporting sustainable agricultural water management.

Conclusion

The present study assessed the concentration and variability of selected major cations and anions in irrigation water of the VNMKV Agricultural Farm, Parbhani. Calcium concentration ranged from 1.20 to 5.40 meq L⁻¹, magnesium from 2.80 to 5.40 meq L⁻¹, sodium from 1.52 to 6.81 meq L⁻¹ and potassium from 0.12 to 0.67 meq L⁻¹. Among the selected cations, sodium recorded the highest average concentration (3.8276 meq L⁻¹), followed closely by magnesium (3.8200 meq L⁻¹) and calcium (3.2160 meq L⁻¹), whereas potassium recorded the lowest average concentration (0.3444 meq L⁻¹).

Among the selected anions, carbonate ranged from 0.00 to 0.50 meq L⁻¹, bicarbonate from 5.25 to 8.50 meq L⁻¹ and nitrate from 0.56 to 3.36 meq L⁻¹. Bicarbonate recorded the highest average concentration (6.6260 meq L⁻¹), followed by nitrate (2.0832 meq L⁻¹) and carbonate (0.2420 meq L⁻¹). The ionic composition therefore followed the order $\text{Na}^+ >$

$\text{Mg}^{2+} > \text{Ca}^{2+} > \text{K}^+$ among cations and $\text{HCO}_3^- > \text{NO}_3^- > \text{CO}_3^{2-}$ among anions.

The observed variation in major ions reflects the influence of groundwater geochemistry and agricultural activities. Calcium, magnesium and sodium represent important components of the cationic composition, while bicarbonate was the predominant selected anion. The variation in nitrate is particularly relevant in an agricultural environment because fertilizer application, irrigation practices, leaching and groundwater recharge can influence nitrate movement. Regular monitoring of major cations and anions is therefore recommended for sustainable irrigation-water management and for maintaining long-term soil and groundwater quality at the VNMKV Agricultural Farm.

Declaration

Authors declare no conflict of interest.

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