



Physicochemical parameters of groundwater collected from different villages of Sikar district, Rajasthan

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Abstract

The current study aims to evaluate the seasonal variation in groundwater quality across five different sites in the Sikar district, namely, Piprali (Site 1), Dadiya (Site 2), Yalsar (Site 3), Sabalpura (Site 4), and Gokulpura (Site 5), over a period of one year. The results of the study showcased a seasonal variation in the physicochemical parameters of the water samples collected from different sites, namely, Temperature, pH, EC (Electrical Conductivity), Turbidity, TA (Total Alkalinity), DO (Dissolved Oxygen), BOD (Biochemical Oxygen Demand), COD (Chemical Oxygen Demand), TH (Total Hardness), Chloride, Calcium and Magnesium. The results showed that TA, TH, Calcium, BOD and COD were highest in summer season while temperature and turbidity were highest in monsoon season. On the contrary, winter season showed highest levels of pH, DO, chloride and magnesium. Nonetheless, the groundwater from all the tested sites was found to be within the acceptable limits for drinking purposes.

Keywords: Groundwater, Sikar district, physicochemical, seasonal variation etc

Introduction

Human existence on this earth has been possible because of ample availability of groundwater and plants, to whom we owe the oxygen that we breathe. In this regard, groundwater is one of the most indispensable resources to which we owe our existence to fulfil various needs related to drinking, domestic, agricultural, as well as industrial purposes. The essence of groundwater is particularly beneficial in semi-arid regions of the world, wherein, availability of surface water is scarce. In countries like India with a developing economy, a significant proportion of the country's population is dependent on groundwater for fulfilment of daily needs, making its quality a critical public health concern. However, groundwater quality is dynamic and is affected by a complex interplay of natural processes such as geological formations, mineral dissolution, and seasonal recharge, along with other anthropogenic activities such as agriculture, urbanization, and waste disposal (Kumar *et al.*, 2022; Jaffar *et al.*, 2020; Tigga *et al.*, 2023; Jain *et al.*, 2022) [1, 2, 3, 4].

The physicochemical characteristics of groundwater including pH, electrical conductivity (EC), total alkalinity (TA), dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total hardness (TH), as well as composition of major ions including calcium, magnesium, and chloride, provide evidence for determining the quality of groundwater. According to the guidelines issued by the World Health Organization and the Bureau of Indian Standards, all these parameters must fall within the permissible limits to ensure safe water consumption (Nirmala *et al.*, 2022; Adesakin *et al.*, 2020; Tadesse *et al.*, 2018) [5, 6, 7].

The physicochemical parameters of water are largely influenced by seasonal variations, all of which play a crucial role in determining the groundwater quality. The summer season is marked by increased temperature, leading to evaporation, which can lead to the concentration of dissolved ions. It causes an increase in electrical conductivity, water hardness, and alkalinity. On the contrary, the monsoon season causes dilution of solutes,

leading to changes in ionic composition and water turbidity. In contrast to the above two, winter leads to an increased amount of dissolved oxygen in water, leading to increased microbial growth. This leads to increase in values of parameters such as higher values of EC, hardness, and alkalinity. Such seasonal fluctuations have been widely reported in hydrogeochemical studies and are essential for understanding temporal dynamics in groundwater systems (Islam *et al.*, 2018; Leta *et al.*, 2019) [9, 21].

A number of previous studies have shown that groundwater quality in rural as well as semi-urban regions is controlled by a number of natural geochemical processes rather than severe contamination. Therefore, periodic monitoring of groundwater quality across different seasons as well as locations is critical in order to assess its suitability for drinking (Rashad *et al.*, 2020; Dey *et al.*, 2021) [13, 14].

In this context, the current study aims to evaluate the seasonal variation in physicochemical parameters of groundwater collected from five different sites in Sikar district, namely, Piprali, Dadiya, Yalsar, Sabalpura, and Gokulpura over a period of one year. By analysing the physico-chemical parameters of water collected from different sources, the study seeks to understand the influence of seasonal dynamics on groundwater chemistry and to assess its suitability for drinking purposes.

Materials and Methods

During the present study, groundwater samples used for drinking purpose were collected from different villages of Sikar district. Those were- Sikar district, namely, Piprali (Site 1), Dadiya (Site 2), Yalsar (Site 3), Sabalpura (Site 4), and Gokulpura (Site 5). Water samples were collected during all months of the year to determine seasonal variations. Physico-chemical parameters of the collected water samples such as Temperature, pH, EC (Electrical Conductivity), Turbidity, TA (Total Alkalinity), DO (Dissolved Oxygen), BOD (Biochemical Oxygen Demand), COD (Chemical Oxygen Demand), TH (Total Hardness), Chloride, Calcium and Magnesium were determined using standard methods. Those were compared with standards of BSI for drinking purposes.

Results

Temperature

The results show the seasonal variation in water temperature in 5 different sites of district Sikar, namely, Site 1 (Piprali), Site 2 (Dadiya), Site 3 (Yalsar), Site 4 (Sabalpura) and Site 5 (Gokulpura) over a period of 1 year (March 2025-February 2026) across three different seasons: Summer (March-June), Monsoon (July-October) and Winter (November-February). For all the sites, the highest temperature was recorded in monsoon season (28.15 C) while lowest temperature was observed in winter season (16.22 C). The average temperature of all the five sites ranged between 16 C-28 C.

pH

The results show the seasonal variation in water pH in 5 different sites of district Sikar, namely, Site 1 (Piprali), Site 2 (Dadiya), Site 3 (Yalsar), Site 4 (Sabalpura) and Site 5 (Gokulpura) over a period of 1 year (March 2025- February 2026) across three different seasons: Summer (March-June), Monsoon (July-October) and Winter (November-February). For all the sites, the highest pH was recorded in winter season (9.3) while lowest pH was observed in summer season (7.95). The average pH of all the five sites ranged between 7.95-9.3.

Electrical conductivity

The results show the seasonal variation in water electrical conductivity in 5 different sites of district Sikar, namely, Site 1 (Piprali), Site 2 (Dadiya), Site 3 (Yalsar), Site 4 (Sabalpura) and Site 5 (Gokulpura) over a period of 1 year (March 2025- February 2026) across three different seasons: Summer (March-June), Monsoon (July-October) and Winter (November-February). For all the sites, the highest Electrical conductivity was recorded in summer season (581) while lowest Electrical conductivity was observed in monsoon season (567). The average Electrical conductivity of all the five sites ranged between 567-581.

Turbidity

The results show the seasonal variation in water turbidity in 5 different sites of district Sikar, namely, Site 1 (Piprali), Site 2 (Dadiya), Site 3 (Yalsar), Site 4 (Sabalpura) and Site 5 (Gokulpura) over a period of 1 year (March 2025-February 2026) across three different seasons: Summer (March-June), Monsoon (July-October) and Winter (November-February). For all the sites, the highest turbidity was recorded in monsoon season (10.77) while lowest turbidity was observed in winter season (7.65). The average turbidity of all the five sites ranged between 7.65-10.77

Total alkalinity

The results show the seasonal variation in water total alkalinity in 5 different sites of district Sikar, namely, Site 1 (Piprali), Site 2 (Dadiya), Site 3 (Yalsar), Site 4 (Sabalpura) and Site 5 (Gokulpura) over a period of 1 year (March 2025-February 2026) across three different seasons: Summer (March-June), Monsoon (July-October) and Winter (November-February). For all the sites, the highest total alkalinity was recorded in summer season (96.5) while lowest total alkalinity was observed in monsoon season (59.75). The average total alkalinity of all the five sites ranged between 59.75-96.5.

Dissolved oxygen

The results show the seasonal variation in water Dissolved oxygen in 5 different sites of district Sikar, namely, Site 1 (Piprali), Site 2 (Dadiya), Site 3 (Yalsar), Site 4 (Sabalpura)

and Site 5 (Gokulpura) over a period of 1 year (March 2025-February 2026) across three different seasons: Summer (March-June), Monsoon (July-October) and Winter (November-February). For all the sites, the highest Dissolved oxygen was recorded in winter season (7.52) while lowest dissolved oxygen was observed in summer season (4.77). The average dissolved oxygen of all the five sites ranged between 4.77-7.52.

Biological Oxygen Demand (BOD)

The results show the seasonal variation in water Biological Oxygen Demand (BOD) in 5 different sites of district Sikar, namely, Site 1 (Piprali), Site 2 (Dadiya), Site 3 (Yalsar), Site 4 (Sabalpura) and Site 5 (Gokulpura) over a period of 1 year (March 2025- February 2026) across three different seasons: Summer (March-June), Monsoon (July-October) and Winter (November-February). For all the sites, the highest BOD was recorded in summer season (4.52) while lowest BOD was observed in winter season (3.05). The average BOD of all the five sites ranged between 3.05-4.52.

Chemical Oxygen Demand (COD)

The results show the seasonal variation in water Chemical Oxygen Demand (COD) in 5 different sites of district Sikar, namely, Site 1 (Piprali), Site 2 (Dadiya), Site 3 (Yalsar), Site 4 (Sabalpura) and Site 5 (Gokulpura) over a period of 1 year (March 2025- February 2026) across three different seasons: Summer (March-June), Monsoon (July-October) and Winter (November-February). For all the sites, the highest COD was recorded in summer season (3.1) while lowest COD was observed in monsoon season (1.455). The average COD of all the five sites ranged between 1.455-3.1.

Total Hardness (TH)

The results show the seasonal variation in water Total Hardness (TH) in 5 different sites of district Sikar, namely, Site 1 (Piprali), Site 2 (Dadiya), Site 3 (Yalsar), Site 4 (Sabalpura) and Site 5 (Gokulpura) over a period of 1 year (March 2025- February 2026) across three different seasons: Summer (March-June), Monsoon (July-October) and Winter (November-February). For all the sites, the highest TH was recorded in summer season (89.5) while lowest TH was observed in monsoon season (55.5). The average TH of all the five sites ranged between 55.5-89.5.

Chloride

The results show the seasonal variation in water chloride levels in 5 different sites of district Sikar, namely, Site 1 (Piprali), Site 2 (Dadiya), Site 3 (Yalsar), Site 4 (Sabalpura) and Site 5 (Gokulpura) over a period of 1 year (March 2025-February 2026) across three different seasons: Summer (March-June), Monsoon (July-October) and Winter (November-February). For all the sites, the highest chloride content was recorded in winter season (49.5) while lowest chloride was observed in monsoon season (31.75). The average chloride content of all the five sites ranged between 16 C-28 C.

Calcium

The results show the seasonal variation in water calcium levels in 5 different sites of district Sikar, namely, Site 1 (Piprali), Site 2 (Dadiya), Site 3 (Yalsar), Site 4 (Sabalpura) and Site 5 (Gokulpura) over a period of 1 year (March 2025-February 2026) across three different seasons: Summer (March-June), Monsoon (July-October) and Winter (November-February). For all the sites, the highest calcium content was recorded in summer season (38.5) while lowest

calcium was observed in monsoon season (19.67). The average calcium content of all the five sites ranged between 19.67-38.5

Magnesium

The results show the seasonal variation in water magnesium levels in 5 different sites of district Sikar, namely, Site 1 (Piprali), Site 2 (Dadiya), Site 3 (Yalsar), Site 4 (Sabalpura)

and Site 5 (Gokulpura) over a period of 1 year (March 2025-February 2026) across three different seasons: Summer (March-June), Monsoon (July-October) and Winter (November-February). For all the sites, the highest magnesium content was recorded in winter season (29.62) while lowest magnesium was observed in monsoon season (20.12). The average magnesium content of all the five sites ranged between 20.12-29.62.

Table 1: Physico-chemical parameters of water collected from different sites of Sikar district during various seasons.

Name of parameter	Site 1			Site 2			Site 3			Site 4			Site 5		
	Summer	Monsoon	Winter	Summer	Monsoon	Winter	Summer	Monsoon	Winter	Summer	Monsoon	Winter	Summer	Monsoon	Winter
Temperature (°C)	25.92	27.87	16.47	26.27	28.15	16.7	26.22	28	16.85	25.75	27.72	16.425	25.52	27.6	16.22
pH	8.07	8.16	9.262	8.06	8.1	9.15	8.15	8.27	9.3	8.05	8.07	9.17	7.95	7.97	9.05
EC (µS/cm)	579.25	571.6	573.37	581.75	569.75	575.5	581.5	573.25	577.5	578.5	570.5	573	576.5	567.5	570.5
Turbidity (NTU)	8.6	10.52	7.85	8.825	10.77	8.05	8.7	10.7	7.95	8.5	10.37	7.8	8.4	10.17	7.65
TA (mg/L)	95.25	61.5	79.75	96.5	62.5	81.75	96.25	62.75	81.25	94.5	60.75	79.75	93.25	59.75	77.75
DO (mg/L)	4.87	5.75	7.32	4.77	5.87	7.42	4.77	5.92	7.52	4.87	5.8	7.32	4.97	5.75	7.22
BOD (mg/L)	4.42	3.4	3.15	4.52	3.45	3.25	4.52	3.5	3.25	4.42	3.4	3.15	4.32	3.3	3.05
COD (mg/L)	3	1.45	2.45	3.1	1.52	2.55	3.1	1.52	2.55	3	1.45	2.45	2.9	1.37	2.35
TH (mg/L)	87.5	57.5	65	89.5	59.5	67	89.5	59.5	70	87.5	57.5	65	85.5	55.5	63
Chloride (mg/L)	42.5	33.7	47.5	44.75	34.75	49.5	43.75	34.75	49.5	42.75	33.25	47.5	40.5	31.75	45.5
Calcium (mg/L)	37.8	20.35	27.8	38.5	21.32	28.55	38.5	21.37	29.62	37.5	20.2	27.37	37	19.67	26.87
Magnesium (mg/L)	20.4	20.32	27.85	20.6	20.5	28.55	20.6	20.5	29.62	20.35	20.25	27.37	20.2	20.12	27

Discussion

The current study aims to evaluate the seasonal variation in groundwater quality across five different sites in the Sikar district, namely, Piprali (Site 1), Dadiya (Site 2), Yalsar (Site 3), Sabalpura (Site 4), and Gokulpura (Site 5), over a period of one year. The results of the study unveiled a seasonal variation in the physicochemical parameters of the water samples collected from different sites. Nonetheless, the groundwater from all the tested sites was found to be within the acceptable limits for drinking purposes. All these findings are in complete correlation with previously published studies showcasing that groundwater quality in arid regions is largely affected by seasonal hydrogeochemical processes rather than severe anthropogenic contamination.

The results show that temperature exhibited a typical seasonal pattern across all the studied sites, with highest value in monsoon season while lowest in winter season. This may be attributed to the prevalent atmospheric conditions and directly influences other water parameters including dissolved oxygen (DO), biochemical oxygen demand (BOD), as well as chemical oxygen demand (COD). Increased temperature is associated with augmented microbial activity and accelerated organic matter decomposition, as a consequence of which, there is increase in both BOD and COD values. On the contrary, lower winter temperatures in winter is associated with improved oxygen solubility, leading to increased DO levels (Rashad *et al.*, 2020; Dey *et al.*, 2021; Kumar *et al.*, 2019) [13, 14, 15].

The pH values across all the studied sites indicated slightly alkaline conditions throughout the year. The results showed that both summer and monsoon seasons showed moderate alkalinity while winter values were relatively higher. This increase in pH in the winter season may be attributed to decrease in water dilution in the winter season along with higher photosynthetic activity, leading to decreased dissolved CO₂ levels and higher dissolved oxygen (Sharma *et al.*, 2018; Jain *et al.*, 2018; Cruz *et al.*, 2019) [16, 17, 18].

The highest value of Total alkalinity (TA) was observed in summer season while lowest in the monsoon season, which may be attributed to dilution effect of the monsoon due to rainwater recharge followed by concentration during summers. Similarly, Electrical conductivity (EC), which is a measure of the dissolved ionic content in water bodies, showed higher values during summer season as well as winter season with a slight decline in the monsoon season, which maybe attributed to dilution-concentration mechanism reported in hydrogeochemical studies (Bharati *et al.*, 2018; Umer *et al.*, 2020; Saxena *et al.*, 2018) [20, 21].

The highest value of turbidity was observed in monsoon season, followed by the lowest values in winter season. The increase in turbidity in the monsoon season is indicative of increased surface runoff, which along with it carries huge amount of suspended particles, silt, as well as organic debris into the groundwater (Beniwal *et al.*, 2024; Joshi *et al.*, 2024) [22, 23].

As explained above, Dissolved oxygen showcases an antagonistic relationship with water temperature. Following this notion, the results showed that the lowest DO values were observed during summer while highest in the winter season. BOD and COD values, which are the indicators of organic pollution, were found to be the highest during summer's season, indicating increased organic load along with higher microbial activity in the season. All these findings are in concordance with previously published literature, where too, the researchers showed increased microbial degradation under summer conditions. The decline in both BOD as well as COD during the monsoon season maybe attributed to increased dilution of the water bodies by rainwater. On the contrary, lowest values in winter are reflective of decreased biological activity along with improved quality of water.

Thereafter, the researchers analysed seasonal variation in other parameters such as Total hardness (TH), calcium, as well as magnesium levels. All of these showed consistent seasonal trends across all the studied sites. The results showed that higher values of all these parameters were

observed during the summer season while lowest values were observed during the monsoon season and moderate values during winter season. Calcium and magnesium followed similar patterns, showcasing their major contribution to overall hardness of water. The decline in hardness of water during the monsoon season is indicative of dilution from rainwater. On the contrary, higher summer values of all these ionic parameters is a direct consequence of evaporation and concentration of dissolved minerals. Previous studies have also reported similar seasonal trends in hardness (Chouhan *et al.*, 2019; Nama *et al.*, 2023; Bairwa *et al.*, 2024; Choudhary *et al.*, 2023; Sharma *et al.*, 2018) [16, 24, 25, 26, 27].

The levels of chloride levels showed very slight seasonal variation, with slightly higher values during the summer season and winter and lower levels during the monsoon season. This is indicative of the fact that a balance exists between the evaporation-driven concentration as well as dilution effects of water sources. Nonetheless, trends in physico-chemical parameter of water from all the five sites were remarkably consistent, indicating a uniform hydrogeological setting across the study area. Slight variations in the parameters maybe have occurred owing to factors such as soil composition, groundwater recharge rate, as well as land-use practices (Singodia *et al.*, 2023; Ojha *et al.*, 2019) [29, 30].

Concluding the findings of the study in a nutshell, it would be appropriate to quite here that physicochemical parameters of the studied sites lie within the acceptable limits for drinking purposes. Furthermore, seasonal variations observed in the parameters are primarily governed by natural processes such as temperature fluctuations, dilution induced by rainfall as well as the geochemical interactions occurring inside water bodies. The fact that all the analysed parameters such as BOD, COD, chloride, as well as electrical conductivity lie within the BIS limits, is indicative of minimal effect of pollution on the analysed parameters. However, continuous monitoring is needed in order to ensure long-term sustainability, particularly in light of increasing anthropogenic pressures and climate variability.

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