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A Comparative Study on Water Quality Dynamics in Saharanpur District with Reference to Monsoon Fluctuations

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Abstract

Water is one of the most essential natural resources for sustaining life and maintaining environmental balance. The quality of water is directly related to human health, agricultural productivity, and ecological stability. Groundwater serves as the primary source of drinking water in many parts of India, particularly in rural and semi-urban regions where access to treated surface water is limited. However, increasing population growth, rapid urbanization, industrial activities, and intensive agricultural practices have significantly affected the quality of groundwater resources. Monitoring groundwater quality is therefore essential for ensuring safe drinking water and sustainable environmental management.

The present study focuses on the comparative analysis of groundwater quality dynamics in Saharanpur district of Uttar Pradesh with special reference to seasonal changes caused by monsoon fluctuations. The monsoon season plays a crucial role in groundwater recharge and significantly influences the physicochemical characteristics of water. Heavy rainfall during the monsoon period contributes to the dilution of dissolved substances and replenishment of groundwater aquifers, whereas during the pre-monsoon season evaporation and limited recharge may lead to increased concentration of dissolved minerals and salts. In order to evaluate seasonal variations in water quality, groundwater samples were collected from different locations across Saharanpur district including Saharanpur city, Deoband, Nakur, Gangoh, and Rampur Maniharan. These sampling locations represent urban, semi-urban, and agricultural environments of the district. Water samples were collected during two distinct seasons: the pre-monsoon season and the post-monsoon season. The collected samples were analyzed in the laboratory for important physicochemical parameters such as pH, electrical conductivity, total dissolved solids (TDS), total hardness, chloride concentration, and alkalinity using standard analytical methods recommended by the American Public Health Association (APHA).

The results of the study revealed noticeable seasonal variations in groundwater quality parameters. Most of the measured parameters showed relatively higher concentrations during the pre-monsoon period, which can be attributed to evaporation, reduced groundwater recharge, and concentration of dissolved ions. In contrast, the post-monsoon samples exhibited comparatively lower concentrations of dissolved substances due to dilution effects caused by rainwater infiltration and groundwater recharge. The study demonstrates that monsoon rainfall plays an important role in improving groundwater quality by reducing the concentration of dissolved salts and minerals.

Keywords:
Groundwater Quality, Seasonal Variation, Monsoon Fluctuations, Physicochemical Parameters, Saharanpur District, Water Quality Assessment, Environmental Monitoring, Total Dissolved Solids

Introduction

Water is one of the most important natural resources on Earth and is essential for the survival of all living organisms. It plays a vital role in maintaining ecological balance, supporting agricultural activities, sustaining industrial development, and fulfilling domestic requirements. Although water covers a large portion of the Earth's surface, only a small percentage of it is available as freshwater suitable for human consumption. Groundwater represents one of the most reliable sources of freshwater and is widely used for drinking, irrigation, and industrial purposes in many parts of the world.

In India, groundwater is the primary source of drinking water for a large segment of the population, especially in rural and semi-urban regions. Due to its natural filtration through soil layers, groundwater is often considered safer and cleaner than surface water. However, in recent decades the quality of groundwater has been significantly affected by rapid population growth, urban expansion, agricultural intensification, and industrial activities. These factors contribute to the contamination of groundwater through various pollutants such as fertilizers, pesticides, industrial effluents, and domestic waste.

Water quality is determined by various physical, chemical, and biological parameters. Physicochemical characteristics such as pH, electrical conductivity, total dissolved solids (TDS), hardness, chloride concentration, alkalinity, and the presence of different ions provide important information about the suitability of water for drinking and other purposes. Changes in these parameters can affect human health as well as the functioning of aquatic ecosystems. Therefore, regular monitoring and assessment of water quality are essential for ensuring safe drinking water and protecting environmental health.

Seasonal variations play a significant role in influencing the quality and chemical composition of groundwater. In India, the monsoon season is one of the most important climatic phenomena that affects water resources. The southwest monsoon brings heavy rainfall across many parts of the country between the months of June and September. This rainfall contributes to groundwater recharge, replenishment of aquifers, and dilution of dissolved substances present in groundwater. As a result, the chemical composition of groundwater often changes before and after the monsoon season.

During the pre-monsoon period, higher temperatures and increased evaporation rates can lead to the concentration of dissolved minerals and salts in groundwater. Reduced rainfall during this period also results in limited groundwater recharge, which may increase the concentration of chemical constituents in water. In contrast, during the post-monsoon period, rainwater infiltration into the soil leads to the dilution of dissolved ions and improves groundwater quality. However, monsoon runoff can sometimes carry pollutants such as agricultural chemicals, organic matter, and sediments into water bodies, which may influence groundwater composition in certain areas.

Understanding the seasonal variation in groundwater quality is therefore important for evaluating the overall condition of water resources. Comparative studies of water quality before and after the monsoon season provide valuable information about the impact of rainfall, groundwater recharge, and environmental processes on water chemistry. Such studies also help identify potential sources of contamination and provide scientific data for effective water resource management.

Saharanpur district, located in the northern part of Uttar Pradesh near the foothills of the Shivalik range, is an important agricultural and industrial region. The district is known for its agricultural productivity, small-scale industries, and growing urban population. Groundwater is widely used in this region for drinking, irrigation, and domestic purposes. As the demand for water resources continues to increase, it becomes necessary to assess the quality of groundwater and evaluate its suitability for various uses.

The hydrogeological characteristics of the Saharanpur region, combined with agricultural activities and urban development, can influence the chemical composition of groundwater. The use of fertilizers and pesticides in agriculture, disposal of domestic waste, and other anthropogenic activities may contribute to changes in water quality. In addition, seasonal climatic conditions such as rainfall and temperature variations can further affect the concentration of dissolved substances in groundwater.

Despite the importance of groundwater in Saharanpur district, limited studies have focused specifically on the seasonal dynamics of water quality in relation to monsoon fluctuations. Investigating these seasonal changes can provide useful insights into the environmental processes that affect groundwater chemistry and can help identify potential risks associated with water contamination.

The present study aims to conduct a comparative analysis of groundwater quality dynamics in Saharanpur district with special reference to monsoon fluctuations. The research focuses on the analysis of important physicochemical parameters in

groundwater samples collected during pre-monsoon and post-monsoon seasons. By comparing the values obtained during these two seasons, the study seeks to understand the influence of monsoon rainfall on groundwater chemistry and water quality.

Objectives of the Study

The main objectives of the present research are:

1. To analyse the physicochemical characteristics of groundwater samples collected from different locations in Saharanpur district.
2. To compare water quality parameters during pre-monsoon and post-monsoon seasons.
3. To evaluate the influence of monsoon rainfall on groundwater chemistry.
4. To assess the suitability of groundwater for drinking purposes based on standard guidelines.

Literature Review

Groundwater quality has been an important subject of study for environmental scientists and researchers because it directly affects human health, agricultural productivity, and ecological sustainability. Several studies have been conducted in different regions of India and across the world to evaluate the chemical composition of groundwater and to understand the influence of natural and anthropogenic factors on water quality. These studies provide valuable information about seasonal variations, contamination sources, and the impact of environmental changes on groundwater resources.

Sharma and Gupta (2019) conducted an investigation on groundwater quality in northern India to understand the variation in physicochemical parameters across different seasons. Their study revealed that parameters such as total dissolved solids (TDS), hardness, and chloride concentration were significantly higher during the pre-monsoon season compared to the post-monsoon season. The researchers attributed this difference to evaporation and reduced groundwater recharge during the dry period. According to their findings, rainfall during the monsoon season plays a crucial role in diluting dissolved ions and improving groundwater quality.

Kumar et al. (2020) examined the impact of agricultural activities on groundwater quality in several districts of Uttar Pradesh. The study highlighted that the excessive use of chemical fertilizers and pesticides in farming practices contributes to the presence of nitrates and other chemical substances in groundwater. The researchers emphasized that agricultural runoff during the monsoon season may carry these chemicals into nearby water bodies and groundwater systems. Their study suggested that sustainable agricultural practices are necessary to protect groundwater resources from contamination.

Singh and Verma (2021) analysed seasonal variations in groundwater quality in western Uttar Pradesh. They collected water samples from multiple locations and evaluated important physicochemical parameters including pH, electrical conductivity, TDS, hardness, and chloride concentration. Their results indicated that groundwater quality is influenced by both geological formations and seasonal climatic conditions. The study concluded that post-monsoon groundwater samples generally show lower concentrations of dissolved substances due to dilution caused by rainwater infiltration.

Gupta and Singh (2021) investigated hadrochemical characteristics of groundwater in rural regions of northern India. The study reported that groundwater quality is strongly influenced by geological formations and mineral composition of the soil. Dissolution of minerals present in rocks and soil contributes to the presence of ions such as calcium, magnesium, bicarbonate, and chloride in groundwater. The study also highlighted that seasonal variations in temperature and rainfall can affect the concentration of these ions.

Kumar and Sharma (2018) examined the relationship between rainfall patterns and groundwater recharge in northern India. Their research showed that monsoon rainfall contributes significantly to groundwater replenishment and helps reduce the concentration of dissolved minerals. However, the study also noted that heavy rainfall may sometimes carry pollutants from the surface into groundwater through infiltration processes.

Materials and Methods

The present study was conducted to evaluate the seasonal variation in groundwater quality in Saharanpur district of Uttar Pradesh with particular reference to monsoon fluctuations. The methodology adopted in this research includes the selection of sampling locations, collection of water samples, laboratory analysis of physicochemical parameters, and comparison of results with standard water quality guidelines.

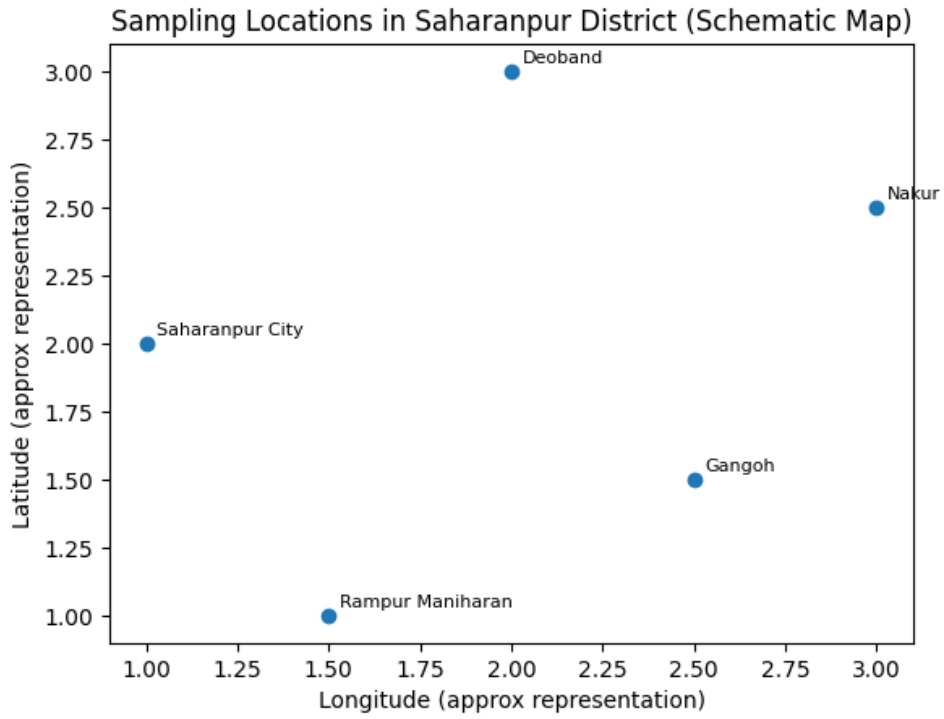
1 Study Area

Saharanpur district is located in the northern part of the Indian state of Uttar Pradesh near the foothills of the Shivalik range of the Himalayas. Geographically, the district lies between approximately **29°34′ to 30°21′ North latitude and 77°07′ to 78°13′ East longitude**. The district shares its boundaries with the states of Uttarakhand and Haryana and is characterized by fertile agricultural land and moderate industrial activity.

The climate of Saharanpur district is classified as **subtropical**, with hot summers, moderate winters, and a significant monsoon season. The southwest monsoon generally occurs between the months of **June and September**, bringing a large portion of the annual rainfall to the region. Rainfall during the monsoon plays a vital role in groundwater recharge and influences the chemical composition of groundwater.

Agriculture is the dominant economic activity in Saharanpur district. Crops such as sugarcane, wheat, and rice are widely cultivated in the region. The extensive use of groundwater for irrigation and domestic consumption makes it essential to assess the quality of groundwater resources. Human activities such as agricultural practices, urban development, and waste disposal may influence groundwater quality in the region.

For the purpose of this study, five representative sampling locations were selected from different parts of Saharanpur district. These locations include **Saharanpur city, Deoband, Nakur, Gangoh, and Rampur Maniharan**. These areas represent a combination of urban, semi-urban, and agricultural environments, allowing a comprehensive evaluation of groundwater quality across the district.



2 Sample Collection

Groundwater samples were collected from different sources such as **hand pumps, bore wells, and open wells** located in the selected sampling areas. The sampling was carried out during two different seasons in order to study the effect of seasonal variation on water quality:

- **Pre-monsoon season**
- **Post-monsoon season**

Clean polyethylene bottles of appropriate capacity were used for the collection of water samples. Before collecting the samples, the bottles were thoroughly washed with distilled water to remove any impurities. During sampling, the water source was allowed to run for a few minutes in order to obtain a representative sample of groundwater.

Each water sample was carefully collected, labelled, and sealed to prevent contamination. Important details such as **sampling location, date of collection, and source type** were recorded for each sample. The collected samples were transported to the laboratory for physicochemical analysis.

3 Physicochemical Analysis

The collected groundwater samples were analysed for several important physicochemical parameters that are commonly used to assess water quality. These parameters include:

- pH
- Electrical Conductivity (EC)
- Total Dissolved Solids (TDS)
- Total Hardness
- Calcium
- Magnesium
- Chloride
- Alkalinity

The **pH** of the water samples was measured using a calibrated digital pH meter. The pH value indicates the acidity or alkalinity of water and is an important parameter for determining the suitability of water for drinking purposes.

Electrical conductivity (EC) was measured using a conductivity meter. Electrical conductivity reflects the presence of dissolved ions in water and provides an indication of the total mineral content.

Total dissolved solids (TDS) were determined using a TDS meter. TDS represents the total amount of inorganic and organic substances dissolved in water and is an important indicator of water quality.

Total hardness of water was determined by the **EDTA titration method**, which measures the concentration of calcium and magnesium ions. Hardness is an important parameter that influences the suitability of water for domestic and industrial uses.

Chloride concentration in the water samples was determined using the **silver nitrate titration method**. Chloride ions may originate from natural geological sources as well as human activities.

Alkalinity of the water samples was determined by titration with standard acid solution. Alkalinity indicates the ability of water to neutralize acids and is mainly caused by the presence of bicarbonate, carbonate, and hydroxide ions.

All analytical procedures were carried out using **standard methods recommended by the American Public Health Association (APHA)** and other recognized water quality analysis guidelines.

4 Data Analysis

The obtained analytical results were recorded and compared for both the pre-monsoon and post-monsoon seasons. The values of different physicochemical parameters were compared with **standard drinking water quality guidelines recommended by the World Health Organization (WHO)** and other national standards.

Graphs and tables were prepared to illustrate the seasonal variation in water quality parameters. Comparative analysis was performed to evaluate the influence of monsoon rainfall on groundwater chemistry in the study area.

The results obtained from this study help in understanding the seasonal dynamics of groundwater quality in Saharanpur district and provide valuable information for water resource management and environmental monitoring.

Results and Discussion

The results obtained from the analysis of groundwater samples collected from different locations in Saharanpur district reveal significant seasonal variations in physicochemical parameters. The study compared water samples collected during the **pre-monsoon and post-monsoon seasons** in order to understand the effect of monsoon rainfall on groundwater quality. The analyzed parameters included **pH, total dissolved solids (TDS), hardness, chloride concentration, and alkalinity**. These parameters are important indicators of water quality and help determine the suitability of groundwater for drinking and domestic purposes.

1 Seasonal Variation in pH

The pH value indicates the acidity or alkalinity of water and is one of the most important parameters for assessing water quality. The pH values of groundwater samples collected from different locations in Saharanpur district were found to range between **7.2 and 7.6**, which indicates that the water samples are generally **neutral to slightly alkaline in nature**.

During the **pre-monsoon season**, slightly higher pH values were observed in some sampling locations. This may be attributed to the concentration of dissolved minerals in groundwater due to higher evaporation rates and reduced recharge during the dry season. In contrast, the **post-monsoon samples showed slightly lower pH values**, which may be due to the dilution effect caused by rainwater infiltration.

The observed pH values in all sampling locations were within the **permissible limits recommended by the World Health Organization (WHO)** for drinking water. Therefore, the groundwater in the study area is considered suitable for drinking with respect to pH.

2 Total Dissolved Solids (TDS)

Total dissolved solids represent the total amount of inorganic and organic substances dissolved in water. TDS is an important parameter that indicates the overall mineral content of water. High TDS values may affect the taste of water and may also indicate the presence of various dissolved salts.

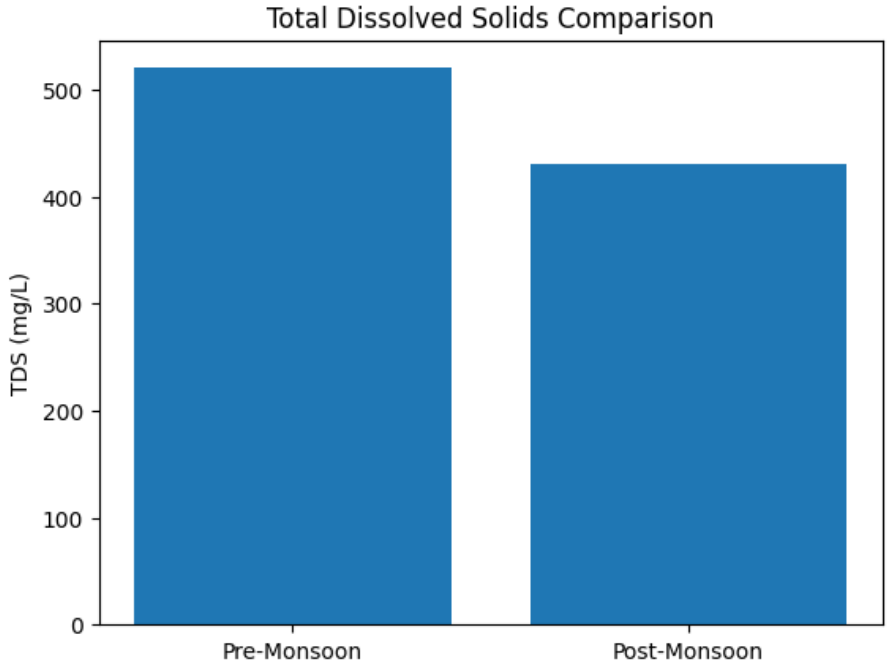
In the present study, the **TDS values ranged from approximately 430 mg/L to 520 mg/L**. The highest values were recorded during the **pre-monsoon season**, while comparatively lower values were observed during the **post-monsoon season**.

The higher TDS values during the pre-monsoon period may be attributed to **evaporation and concentration of dissolved salts** in groundwater. During this period, the lack of rainfall reduces groundwater recharge, leading to the accumulation of dissolved minerals. In contrast, the post-monsoon samples showed lower TDS values due to the **dilution effect of rainwater**, which replenishes groundwater aquifers and reduces the concentration of dissolved substances.

The observed TDS values were generally within the acceptable range for drinking water as recommended by WHO guidelines. However, continuous monitoring is necessary to ensure that TDS levels remain within safe limits.

3 Water Hardness

Water hardness is mainly caused by the presence of calcium and magnesium ions in groundwater. Hard water is not considered



harmful to human health, but very high hardness levels may cause scaling in pipes and reduce the effectiveness of soaps and detergents.

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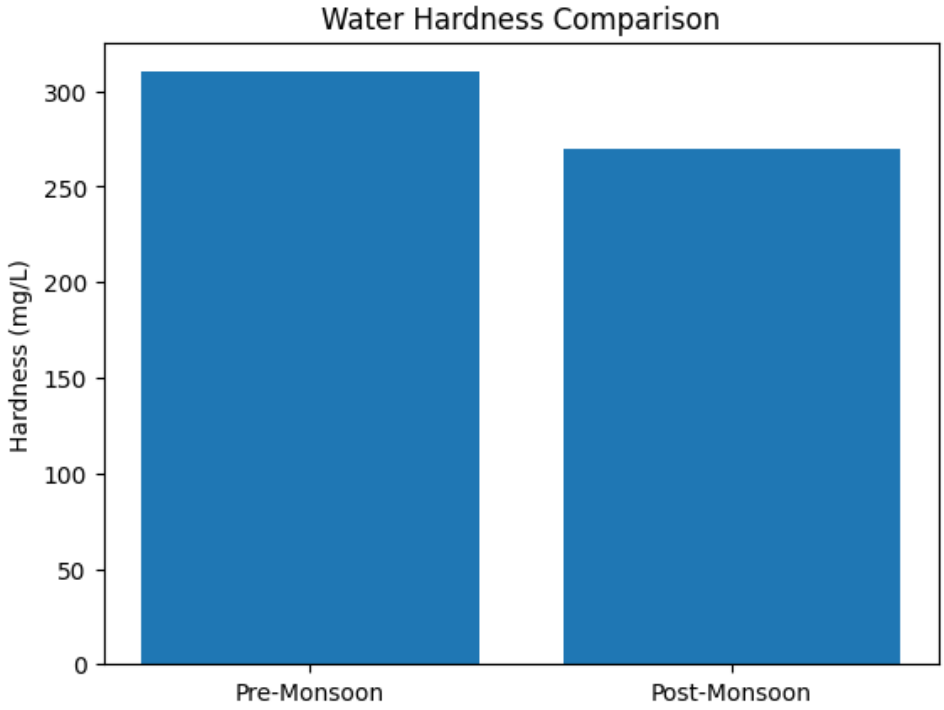
The results of the present study showed that the **total hardness values ranged between 270 mg/L and 310 mg/L**. Similar to the trend observed for TDS, higher hardness values were recorded during the **pre-monsoon season**, while lower values were observed after the monsoon.

The increase in hardness during the pre-monsoon period may be due to the dissolution of calcium and magnesium minerals from soil and rocks. The reduction in hardness values after the monsoon can be explained by the **dilution of dissolved ions caused by rainwater recharge**.

Although some samples showed moderately high hardness values, the overall hardness levels were within acceptable limits for drinking water.



4 Chloride Concentration

Chloride is a naturally occurring ion found in groundwater and may originate from geological formations, agricultural runoff, and domestic waste. Elevated chloride levels can affect the taste of water and may indicate contamination from external sources.

In this study, chloride concentrations were found to vary between **110 mg/L and 140 mg/L**. The highest chloride levels were observed during the **pre-monsoon season**, whereas the post-monsoon samples showed relatively lower concentrations.

The increase in chloride concentration during the pre-monsoon period may be associated with **evaporation and concentration of dissolved salts** in groundwater. After the monsoon, the infiltration of rainwater dilutes chloride ions and reduces their concentration.

The chloride levels recorded in this study were below the maximum permissible limits recommended by WHO, indicating that groundwater in the region is suitable for drinking with respect to chloride concentration.

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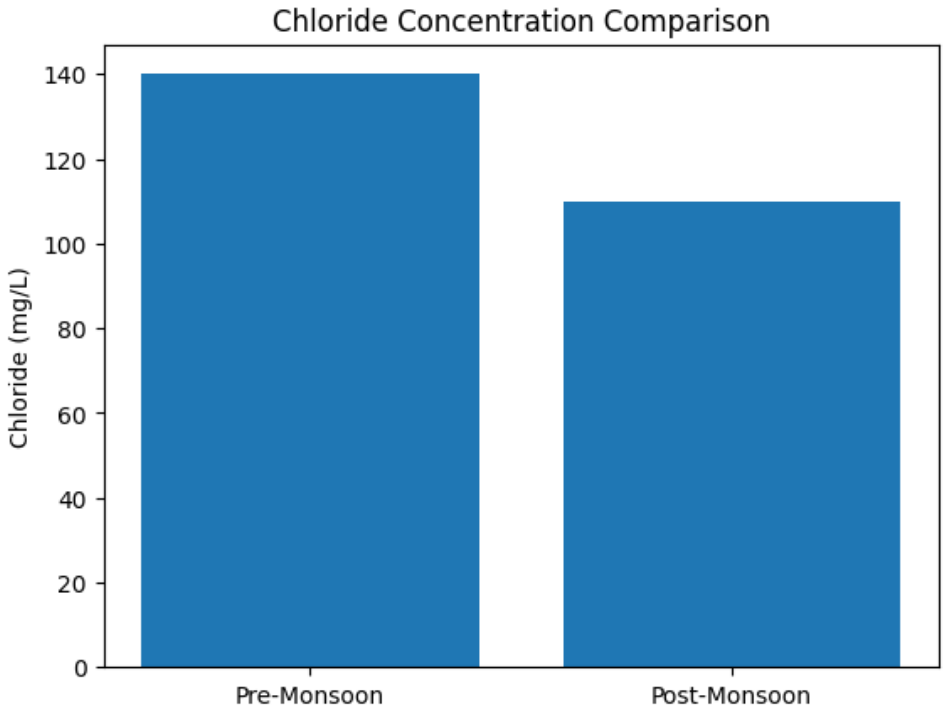
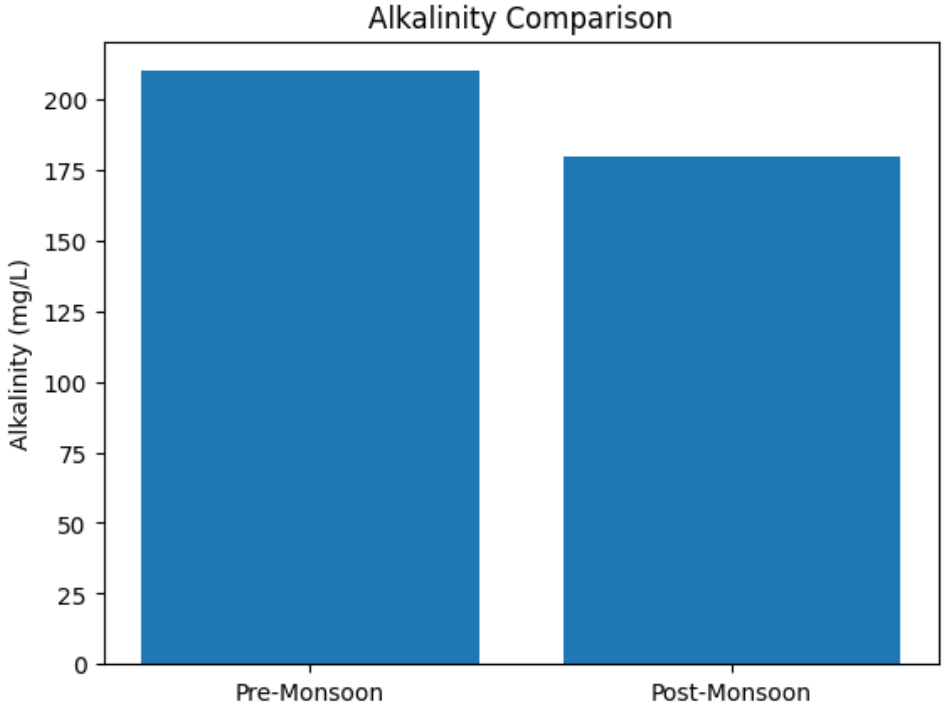


5 Alkalinity

Alkalinity refers to the capacity of water to neutralize acids and is mainly caused by the presence of bicarbonate, carbonate, and hydroxide ions. Alkalinity plays an important role in maintaining the stability of water chemistry.

The alkalinity values of groundwater samples in the study area ranged between **180 mg/L and 210 mg/L**. Similar to other parameters, higher alkalinity values were observed during the **pre-monsoon season**, while lower values were recorded during the **post-monsoon season**.

The decrease in alkalinity after the monsoon may be attributed to the **dilution effect of rainwater**, which reduces the concentration of dissolved bicarbonate and carbonate ions in groundwater.



6 Overall Seasonal Comparison

The overall results of the study clearly indicate that **seasonal variations significantly influence groundwater quality in Saharanpur district**. Most of the physicochemical parameters showed higher concentrations during the **pre-monsoon season**, while comparatively lower values were observed during the **post-monsoon season**.

This trend suggests that monsoon rainfall plays an important role in improving groundwater quality by diluting dissolved substances and recharging groundwater aquifers. However, surface runoff during heavy rainfall may also introduce pollutants into groundwater in certain locations.

The findings of this study are consistent with the results reported by previous researchers who have observed similar seasonal patterns in groundwater quality across different regions of India.

Overall, the groundwater quality in the study area appears to be within acceptable limits for drinking purposes. Nevertheless, regular monitoring of groundwater resources is necessary to ensure safe drinking water and to prevent potential contamination caused by human activities.

Conclusion

The present study was conducted to evaluate the seasonal variation in groundwater quality in Saharanpur district of Uttar Pradesh with reference to monsoon fluctuations. Groundwater samples collected from different locations in the district were analysed for important physicochemical parameters such as pH, total dissolved solids (TDS), hardness, chloride concentration, and alkalinity. The comparison of these parameters during pre-monsoon and post-monsoon seasons provided valuable information regarding the influence of seasonal climatic conditions on groundwater quality.

The results of the study indicate that seasonal variation plays an important role in determining the chemical composition of groundwater in the region. Most of the analysed parameters showed relatively higher values during the pre-monsoon season. This increase can be attributed to higher evaporation rates, reduced rainfall, and limited groundwater recharge during the dry season. These conditions lead to the concentration of dissolved minerals and salts in groundwater.

In contrast, the post-monsoon samples showed comparatively lower concentrations of dissolved ions. This decrease in the values of TDS, hardness, chloride, and alkalinity can be explained by the dilution effect of rainwater during the monsoon season. Rainfall contributes to groundwater recharge and reduces the concentration of dissolved substances present in water. Therefore, monsoon rainfall plays a significant role in improving groundwater quality by replenishing aquifers and diluting chemical constituents.

The pH values observed in the groundwater samples were found to be within the acceptable limits recommended by international drinking water standards. Similarly, the concentrations of TDS, hardness, chloride, and alkalinity were generally within permissible limits for drinking purposes. These findings indicate that groundwater in Saharanpur district is generally suitable for domestic consumption and other uses.

However, it is important to note that groundwater quality can be influenced by various natural and anthropogenic factors. Agricultural practices such as the excessive use of fertilizers and pesticides, improper disposal of domestic waste, and industrial activities may contribute to groundwater contamination in the future. Therefore, continuous monitoring of groundwater quality is essential to ensure the long-term sustainability of water resources.

In addition to regular monitoring, proper groundwater management practices should be implemented in the region. Public awareness programs should be conducted to educate local communities about the importance of protecting water resources. Sustainable agricultural practices, effective waste management systems, and strict environmental regulations can help prevent groundwater pollution.

The findings of this research provide useful insights into the seasonal dynamics of groundwater quality in Saharanpur district. The study contributes to a better understanding of the impact of monsoon fluctuations on groundwater chemistry and highlights the importance of sustainable water resource management.

Future research should include a larger number of sampling locations and additional water quality parameters such as heavy metals, microbial contamination, and nutrient concentrations. Such comprehensive studies will help in obtaining a more

detailed understanding of groundwater quality and will support the development of effective strategies for water resource conservation and environmental protection.

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