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Comparative assessment of ground water quality in Kokrajhar, India.

Evaluación comparativa de la calidad del agua subterránea en Kokrajhar, India

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ABSTRACT

A study was undertaken to understand the comparative assessment of ground water quality of Kokrajhar in both pre and post monsoon seasons. Kokrajhar is witnessing a considerable growth in terms of population and urbanization. Ground water plays a crucial role for consumption and in supporting daily activities of the local population. With the potential risk of groundwater contamination due to various activities, it is essential to assess the quality of this vital resource in order to meet the needs of the local population. In this study, ground water samples were collected from 20 different locations during both pre and post monsoon periods. The ground water samples were tested for 12 different parameters. The geo-locations of the sample points were mapped using GIS software and contour maps were generated for various test parameters. The ground water quality was determined using two methods: The Weighted Arithmetic Index method and the Canadian Council of Ministers of the Environment Water Quality Index method. The result obtained from both the methods have been compared. A very small to some significant changes in different parameters were noted when both pre and post monsoon ground water samples were considered.

Keywords: Ground water Quality, Ground water contamination, CCME and WAI WQI methods, GIS, Laboratory tests of ground water

RESUMEN

Se llevó a cabo un estudio para comprender la evaluación comparativa de la calidad del agua subterránea de Kokrajhar tanto antes como después de la temporada de monzones. Kokrajhar está presenciando un crecimiento considerable en términos de población y urbanización. El agua subterránea desempeña un papel crucial para el consumo y para sustentar las actividades diarias de la población local. Con el riesgo potencial de contaminación de las aguas subterráneas debido a diversas actividades, es esencial evaluar la calidad de este recurso vital para satisfacer las necesidades de la población local. En este estudio, se recolectaron muestras de agua subterránea de 20 lugares diferentes durante los períodos previo y posterior al monzón. Las muestras de agua subterránea se analizaron para determinar 12 parámetros diferentes. Las ubicaciones geográficas de los puntos de muestra se mapearon utilizando software GIS y se generaron mapas de contorno para varios parámetros de prueba. La calidad del agua subterránea se determinó mediante dos métodos: el método del índice aritmético ponderado y el método del índice de calidad del agua del Consejo Canadiense de Ministros de Medio Ambiente. Se han comparado los resultados obtenidos con ambos métodos. Se observaron cambios desde muy pequeños a algunos significativos en diferentes parámetros cuando se consideraron muestras de agua subterránea tanto antes como después del monzón.

Palabras clave: Calidad de las aguas subterráneas, Contaminación de las aguas subterráneas, Métodos CCME y WAI WQI, SIG, Pruebas de laboratorio de aguas subterráneas.

INTRODUCTION

In order to determine the presence of various chemical and physical properties, groundwater samples are often collected from wells or other sources and then subjected to laboratory analysis using a variety of procedures. Studies have shown that the most frequently examined parameters are pH, total dissolved solids (TDS), conductivity, and main cations and anions such calcium, magnesium, sodium, chloride, sulphate, and nitrate [1]. Many human activities can have an impact on groundwater, including residential, municipal, commercial, industrial, and agricultural activity [2]. In recent years, India's reliance on groundwater has grown dramatically [3]. Because of the increased use of fertilisers, pesticides, and other chemicals in agriculture as well as the release of contaminants from industrial and sewage disposal practises, there is growing concern about how human activities affect groundwater quality. Regular groundwater quality monitoring is required to solve these problems, and efficient management methods must be created to reduce the danger of contamination and safeguard this priceless resource. Understanding the condition and health of groundwater resources and ensuring that this priceless resource is maintained sustainably depend on groundwater quality studies.

Several studies have been conducted using GIS for groundwater quality assessment [4], [5] in recent years to create new and improved methods for analysing groundwater quality. [6], for example, provided a fuzzy comprehensive evaluation approach to assess groundwater quality in China. To provide an integrated and comprehensive assessment of groundwater quality, the technique takes into account a variety of elements such as groundwater quality parameters, geological and hydrological conditions, and human activities. Similarly, [7] examined current methods for evaluating groundwater quality and contamination risk in metropolitan areas. The study recognised the shortcomings of existing methodologies and advocated the application of new technologies such as remote sensing and artificial intelligence to improve groundwater quality evaluation.

To summarise, groundwater quality analysis is critical for assessing the condition and health of groundwater resources, as well as ensuring that this precious resource is managed in a sustainable manner. To address the problems posed by human activities and changing environmental circumstances, new and improved methodologies for groundwater quality analysis are required. As a result, additional research is required to create more efficient, cost-effective, and reliable methods for measuring groundwater quality and safeguarding this vital resource.

Groundwater quality analysis usually involves the collection of groundwater samples from wells or other sources, followed by laboratory analysis using various techniques to determine the presence of different chemical and physical parameters. The most commonly analyzed parameters include pH, total dissolved solids (TDS), conductivity, and major cations and anions such as calcium, magnesium, sodium, chloride, sulfate, and nitrate. There is growing concern about the impact of human activities on groundwater quality [8], particularly due to the increased use of fertilizers, pesticides, and other chemicals in agriculture, and the release of contaminants from industrial and sewage disposal practices [9]. To address these issues, regular monitoring of groundwater quality is necessary, and effective management strategies must be developed to minimize the risk of contamination and protect this valuable resource [10]. Groundwater quality analysis is crucial in understanding the status and health of groundwater resources and in ensuring that this valuable resource is managed sustainably.

Water can be found both on the surface and below the surface of the earth, however, only a limited amount of surface water is safe for consumption. In India, a significant portion of the population relies on groundwater for their drinking needs in both rural and urban areas [11]. However, with increasing urbanization and inadequate waste management practices, the groundwater is facing a high risk of contamination. If the source of pollution is not controlled effectively, studies have shown that groundwater may be contaminated which may lead to health hazard if consumed untreated. It is also reported that in many parts of India, groundwater is contaminated with lots of hazardous chemical due to industrial waste as well as the use of pesticides in agricultural field. Water is a crucial factor in our life. It is one of the fundamental needs of human being. For good health it a necessity that water should be fit for drinking.

The current study focuses on the quality of groundwater in Kokrajhar district, located in the Bodoland Territorial Region of India. Groundwater from sources such as tube wells and bore wells is the primary source of water for drinking in the region. As the population continues to grow, there is a corresponding increase in the reliance on groundwater to meet the daily needs of residents. To assess the quality of groundwater in Kokrajhar, a study was conducted by collecting groundwater samples during both pre and post-monsoon periods. The samples were then subjected to laboratory tests for various parameters in order to calculate the groundwater quality index (GWQI).

METHODS AND METHODOLOGY

Study area: The study was conducted in Kokrajhar district, which is located in the Bodoland Territorial Region in Assam, India. It is in the northern part of the Brahmaputra River and covers an area of 3165.44 sq km, bounded by North Latitudes 26^{o}13’30” and 26^{o}53’20” and East Longitudes 89^{o}52’30” and 90^{o}33’10”. According to land use data from 2007-08, the district has a total forest land of 161,195 ha and a total cropped area of 162,821 ha. Kokrajhar experiences an average annual rainfall of 3102.4 mm, with 110 rainy days, with the heaviest rainfall happening from April to August. The Kokrajhar town is located on the bank of the Gaurang river and serves as the headquarters for the district and the Bodoland Territorial Region (BTR). The population of Kokrajhar, as of the 2011 census, is 887,142. The town is divided into 10 wards and the majority of the district is made up of residential areas, public/semi-public spaces, commercial areas, and recreational areas. Fig. 1 shows the map of the study area.

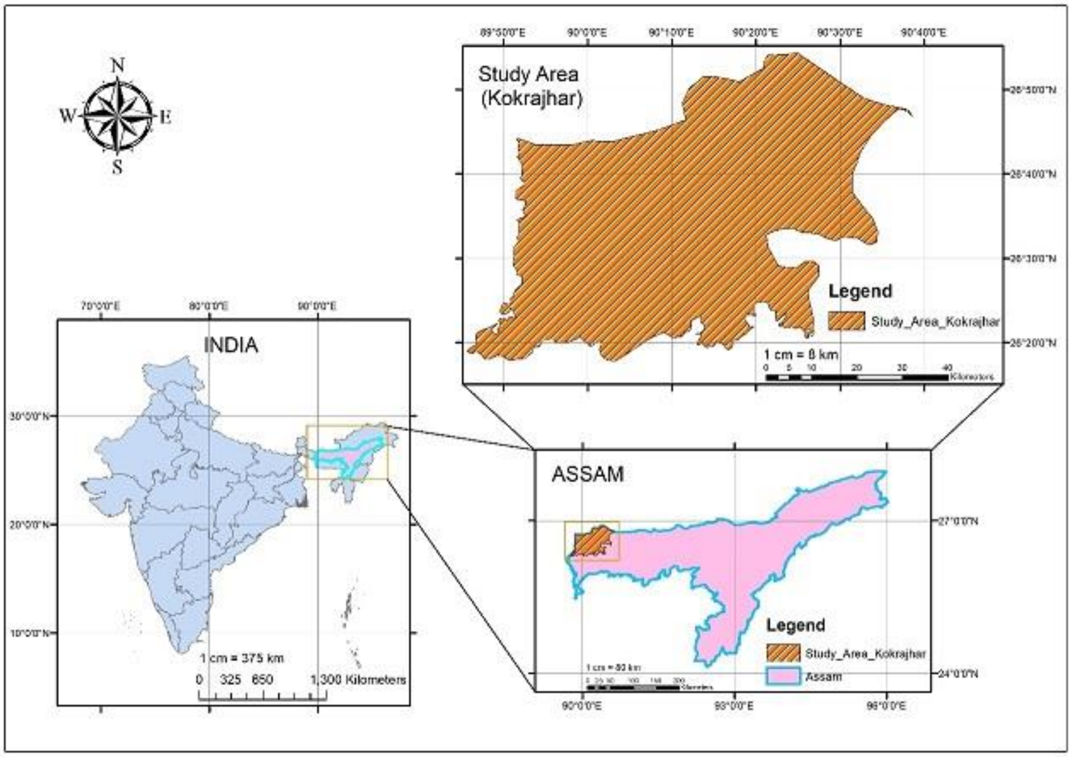

Fig. 1 Map of Study Area (Kokrajhar)

Collection of samples: Collecting groundwater samples for laboratory testing is an important step in determining the quality of the groundwater. The samples should be collected using appropriate techniques to ensure that they are representative of the groundwater and are not contaminated. Groundwater samples were obtained from Kokrajhar town, where efforts were made to gather samples from all 10 wards of the town. A total of 20 samples were collected to cover the entire area. The samples were collected in 500 ml polyethylene bottles, ensuring proper storage to avoid contamination, and each bottle was labeled with a sample number (such as S1, S2, etc.) corresponding to its location. Water samples were collected during both the post-monsoon and pre-monsoon periods.

Laboratory tests of groundwater samples: The laboratory tests of groundwater samples were conducted for 10 different parameters which includes pH, TDS, Alkalinity, Hardness, Iron content, Calcium, Magnesium, Electrical conductivity, Nitrate, Arsenic. Groundwater laboratory testing is a crucial process to evaluate the quality of water resources. The pH test measures the acidity or basicity of water, which affects the water's ability to neutralize pollutants (Shrestha & Shrestha, 2018). TDS measures the amount of inorganic and organic substances dissolved in water (Wolski et al., 2018). Alkalinity test determines the water's capacity to neutralize acid (Shrestha & Shrestha, 2018), while Hardness test measures the concentration of calcium and magnesium ions (Wolski et al., 2018). Turbidity test measures the cloudiness of water caused by suspended particles (Shrestha & Shrestha, 2018). Nitrate test measures the amount of nitrates in the water, which can indicate contamination from fertilizer or animal waste (Wolski et al., 2018). Calcium and Magnesium tests determine the concentration of these essential minerals in groundwater, which can impact water hardness and taste (Shrestha & Shrestha, 2018). These tests provide valuable information about groundwater quality and help ensure that it is safe for drinking, irrigation, and other uses (Wolski et al., 2018).

Analysis for Groundwater Quality Index (GWQI): The analysis for groundwater quality index was done to study the quality of water both during post and pre monsoon seasons. The effect of monsoon on the groundwater quality were studied. The GWQI was calculated using both Weighted Arithmetic Index Method developed by Brown et al., (1972) and the Canadian Council of Ministers of the Environment (CCME) Water Quality Index (2001) (Damo and Icka, 2013).

Weighted Arithmetic Index (WAI) Method: The Weighted Arithmetic Index (WAI) Method, developed by [12] is a commonly used tool for groundwater quality analysis. This method is based on the concept of assigning weights to different water quality parameters based on their relative importance and then using these weights to calculate an overall index value for each sample. The weights are based on a variety of factors, including the concentration of the parameter in the water sample, the toxicity of the parameter, and the presence of relevant water quality guidelines or standards. The weighted values of each parameter are then summed to produce the overall WAI score for each sample. The WAI has been widely used in groundwater quality analysis for a variety of purposes, including the assessment of water suitability for different uses such as irrigation, drinking and industrial purposes, the identification of potential contamination sources, and the monitoring of water quality trends over time.

Canadian Council of Ministers of the Environment (CCME) Water Quality Index: In 1997 the Canadian Council of Ministers of the Environment (CCME) modified the British Colombia Water Quality Index (WQI) for creating a CCME WQI, which could be applied by many water agencies in various countries with slight modification [13]. The CCME WQI was developed as a tool to assess and report water quality information to both management institutions and the public. The WQI provides a comprehensive and integrated assessment of water quality based on multiple parameters. The WQI ranges from 0 to 100, with higher scores indicating higher water quality and lower scores indicating lower water quality. The WQI is designed to be simple, transparent, and easily understood by a wide range of stakeholders, including government agencies, industry, and the general public. The CCME-WQI is used to support water management and decision-making by providing a consistent and comprehensive assessment of water quality across different regions and jurisdictions in Canada. The WQI is also used as an indicator of progress towards achieving water quality objectives, and as a tool for communication and reporting on water quality status and trends.

RESULTS AND DISCUSSION

Laboratory test results of Pre and Post-monsoon groundwater samples: The results of the laboratory tests for all the 8 parameters are presented in Table 1. All of the samples were found to be within the limits set by the BIS standard, making the groundwater in Kokrajhar suitable for consumption. Upon examining the impact of the

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monsoon on the groundwater's different test parameters, no significant differences were observed. The pH showed a decrease of 4% in S8 and an increase of 3% in S1.

Table 1. Water quality index as per Weighted Arithmetic Index method.

Sample No.	Monsoon	WQI Value	Water Quality Status	Sample No.	Monsoon	WQI Value	Water Quality Status
S1	Post	7.39	Excellent	S11	Post	23.25	Excellent
	Pre	10.86	Excellent		Pre	20.65	Excellent
S2	Post	21.19	Excellent	S12	Post	18.98	Excellent
	Pre	20.77	Excellent		Pre	19.92	Excellent
S3	Post	20.66	Excellent	S13	Post	19.05	Excellent
	Pre	20.48	Excellent		Pre	19.72	Excellent
S4	Post	17.60	Excellent	S14	Post	21.62	Excellent
	Pre	15.79	Excellent		Pre	20.56	Excellent
S5	Post	24.46	Excellent	S15	Post	32.82	Excellent
	Pre	22.29	Excellent		Pre	18.13	Excellent
S6	Post	9.54	Excellent	S16	Post	10.40	Excellent
	Pre	9.42	Excellent		Pre	25.91	Good
S7	Post	22.96	Excellent	S17	Post	26.5	Good
	Pre	20.43	Excellent		Pre	4.96	Excellent
S8	Post	21.64	Excellent	S18	Post	21.99	Excellent
	Pre	15.95	Excellent		Pre	22.64	Excellent
S9	Post	20.66	Excellent	S19	Post	15.17	Excellent
	Pre	19.22	Excellent		Pre	13.97	Excellent
S10	Post	21.01	Excellent	S20	Post	26.02	Good
	Pre	19.36	Excellent		Pre	27.01	Good

The TDS levels decreased during the post-monsoon period for all samples, with the lowest decrease of 91% in S12. The alkalinity of the water samples also decreased during the post-monsoon, with the lowest decrease of 51% in S10. The changes in hardness varied among the samples, with the highest increase of 42% in S5 and the lowest decrease of 33% in S20. The changes in the NO_3-, Ca, and Mg content also varied in different samples.

The contour maps displaying the variations of all the test parameters were created using the Inverse Distance Weighted (IDW) method by using the ArcGIS software. Figures 2 to 9 depict the contour maps generated for different test parameters, providing a clear understanding of the changes in the parameters during both pre- and post-monsoon periods.

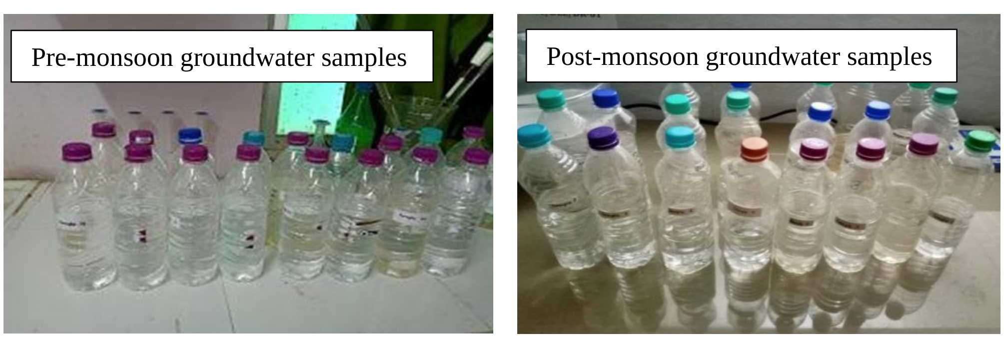

Fig. 2 Ground water samples collected during pre and post monsoon periods.

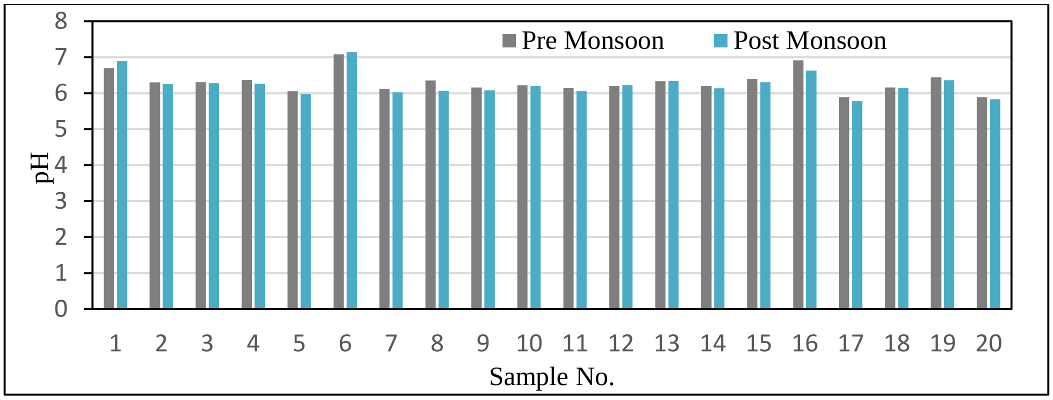

Fig. 3 pH value of ground water during pre and post monsoon periods.

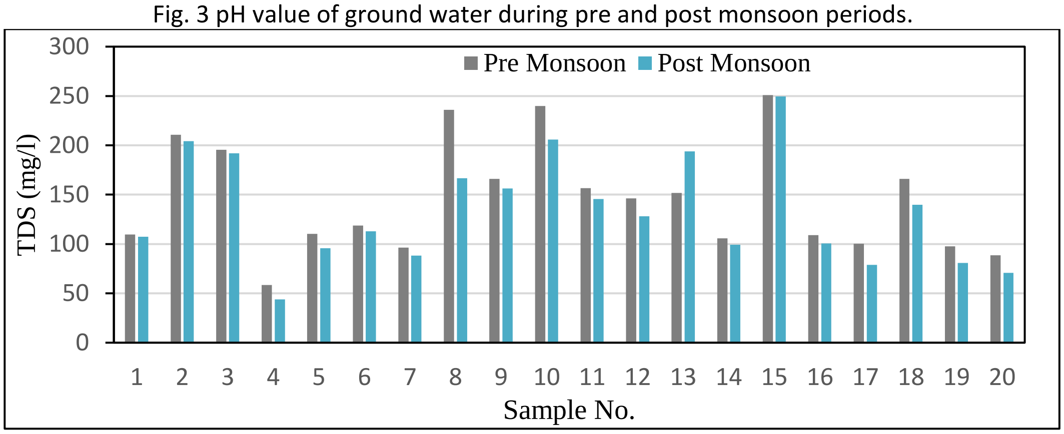

Fig. 4 TDS value of ground water during pre and post monsoon periods.

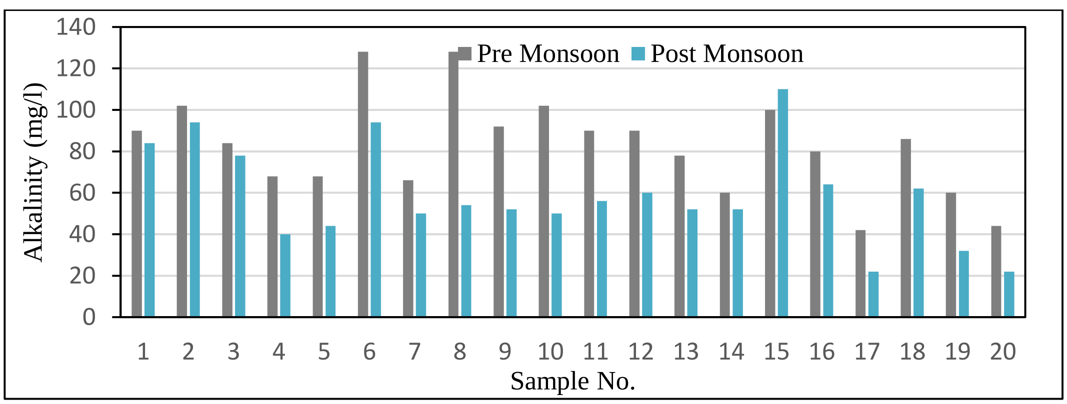

Fig. 5 Alkalinity of ground water during pre and post monsoon periods.

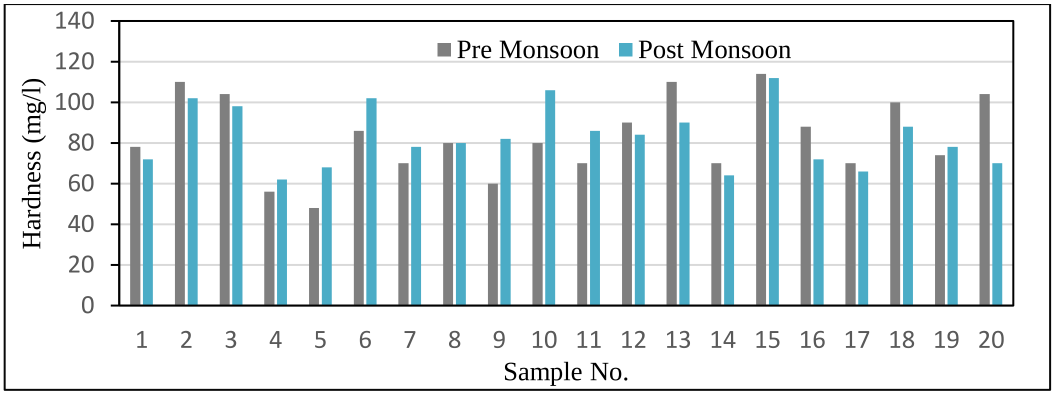

Fig. 6 Hardness of ground water during pre and post monsoon periods.

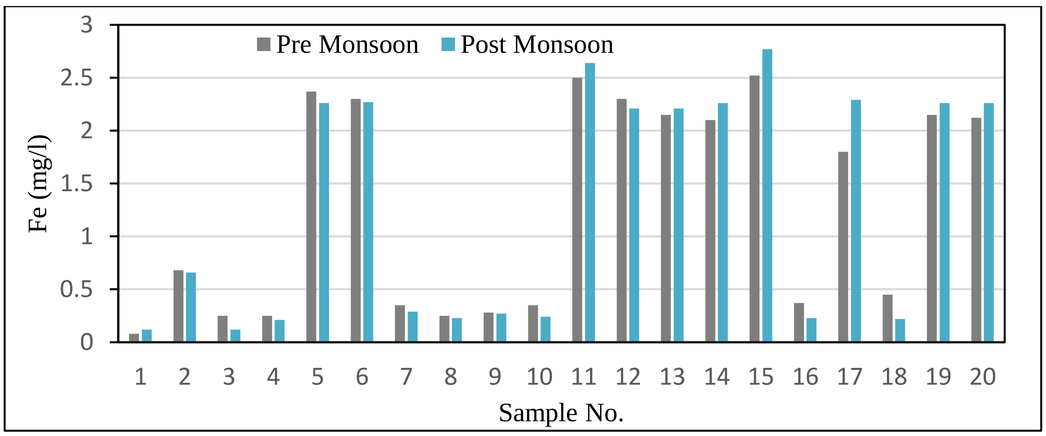

Fig. 7 Iron content of ground water during pre and post monsoon periods.

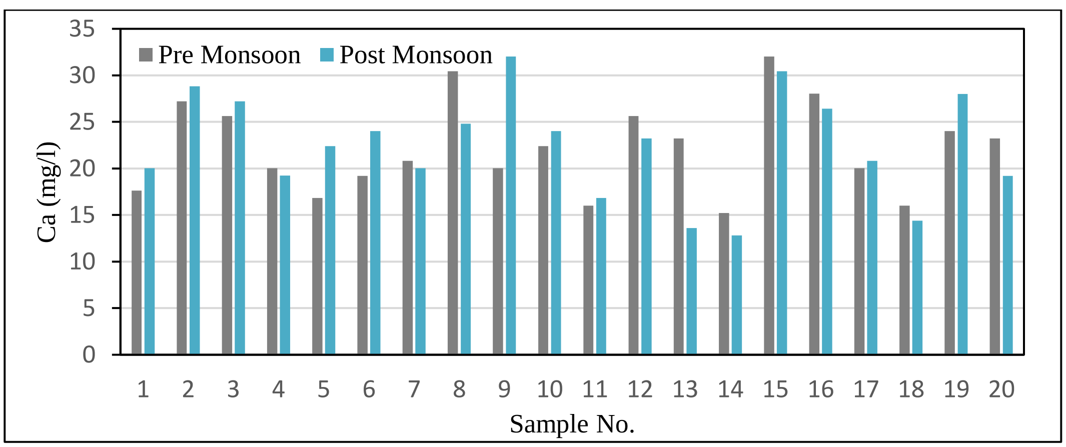

Fig. 8 Calcium content of ground water during pre and post monsoon periods.

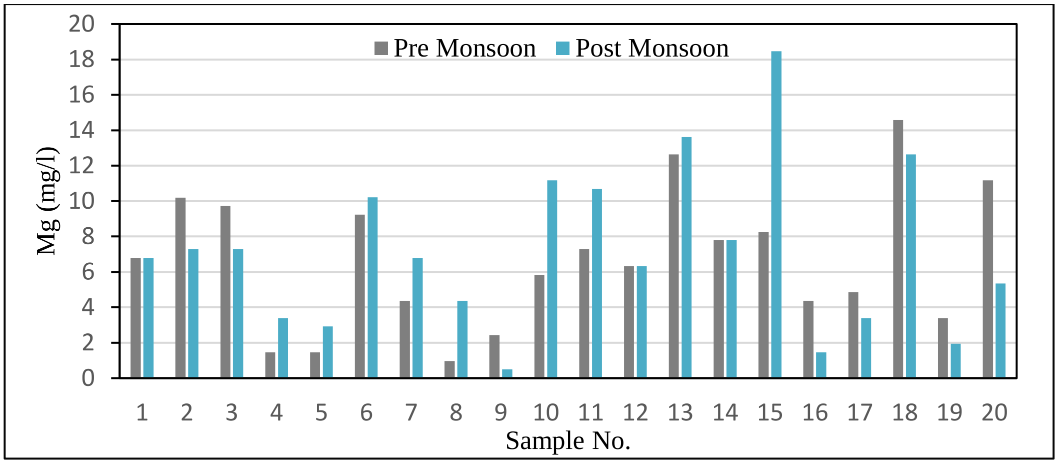

Fig. 9 Magnesium content of ground water during pre and post monsoon periods.

Groundwater quality index (GWQI): As shown in Table 2, out of 20 samples the groundwater quality status showed excellent in 16 samples and good in 4 samples when determined using Arithmetic Water Quality Index. When CCME WQI was used all the samples showed excellent in water quality status. Therefore, it would be safe to conclude that the ground water in this area of study is fit for consumption.

Table 2. Water quality index as per CCME-WQI method.

Sample No.	CCME WQI Value	Water Quality Status	Sample No.	CCME WQI Value	Water Quality Status
S1	96.13	Excellent	S11	96.13	Excellent
S2	96.13	Excellent	S12	96.13	Excellent
S3	96.13	Excellent	S13	96.13	Excellent
S4	96.13	Excellent	S14	96.13	Excellent
S5	96.13	Excellent	S15	96.13	Excellent
S6	96.13	Excellent	S16	96.13	Excellent
S7	96.13	Excellent	S17	96.13	Excellent
S8	96.13	Excellent	S18	96.13	Excellent
S9	96.13	Excellent	S19	96.13	Excellent
S10	96.13	Excellent	S20	96.13	Excellent

Groundwater quality index analysis is a crucial aspect of water resource management and protection. The assessment of groundwater quality provides essential information about the suitability of water for various uses, such as drinking, irrigation, and industrial purposes, and helps to identify potential sources of contamination. The development of groundwater quality indices, such as the Canadian Council of Ministers of the Environment (CCME) Water Quality Index and the Weighted Arithmetic Index Method, has been instrumental in the analysis of groundwater quality. These indices provide a simple and easily interpretable summary of water quality based on multiple parameters, making them valuable tools for water resource management and decision-making (Figs. 10-22).

In this study, the results of the 8 test parameters showed no significant changes during pre- and post-monsoon periods, with only minor variations. The groundwater was found to be within the limits set by the BIS standard, making it suitable for consumption. The Groundwater Quality Index (GWQI) results obtained using both the CCME-WQI and WAI methods showed that most of the groundwater quality status were excellent and good. The high quality of groundwater in this region is likely due to the low levels of pollution from industries and a lack of significant pollution sources. The results may also vary depending on the depth of the groundwater source in some locations. The presence of rice fields near some water sources has been shown to have a little to moderate impact on groundwater quality during the post-monsoon period.

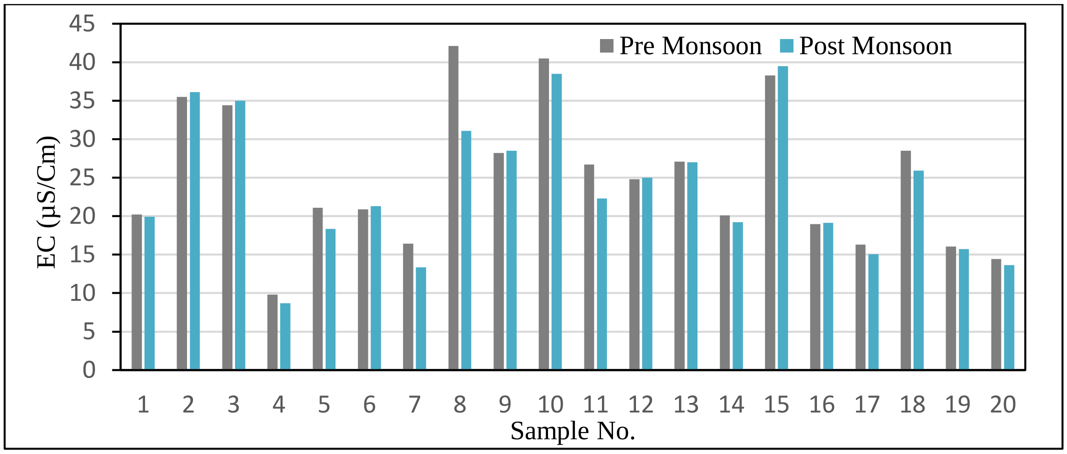

Fig. 10 Electrical conductivity of ground water during pre and post monsoon periods.

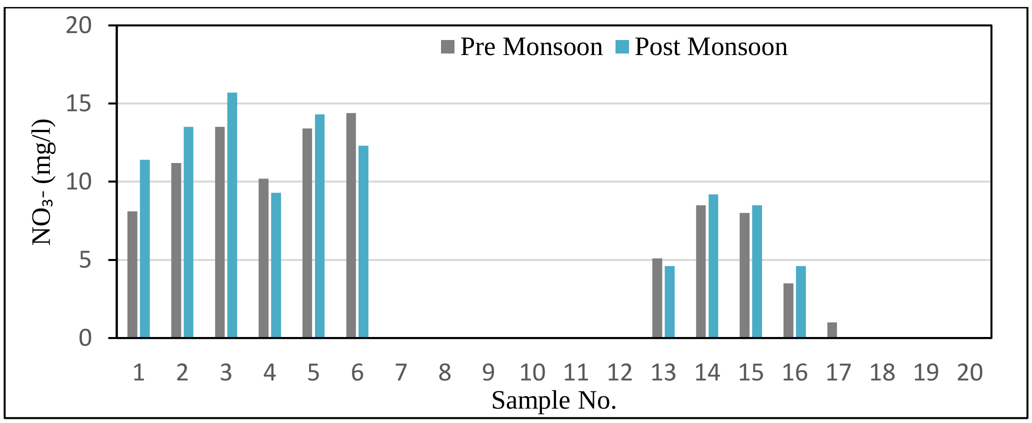

Fig. 11 Nitrate content of ground water during pre and post monsoon periods

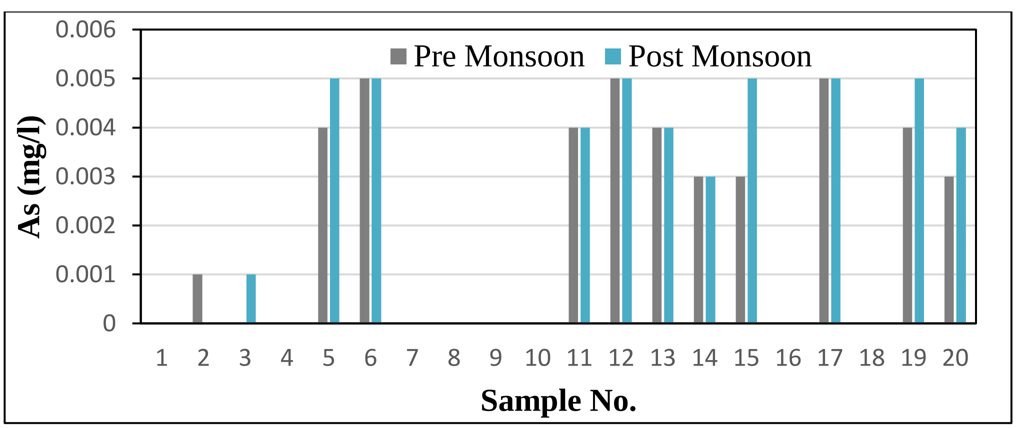

Fig. 12 Arsenic content of ground water during pre and post monsoon periods

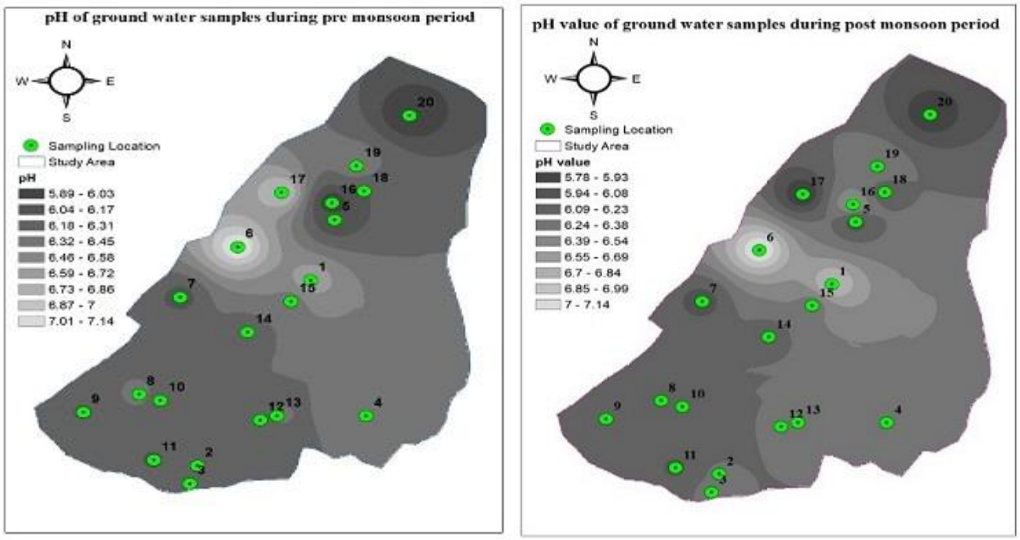

Fig. 13 Variation of pH in ground water during Pre and Post-Monsoon periods

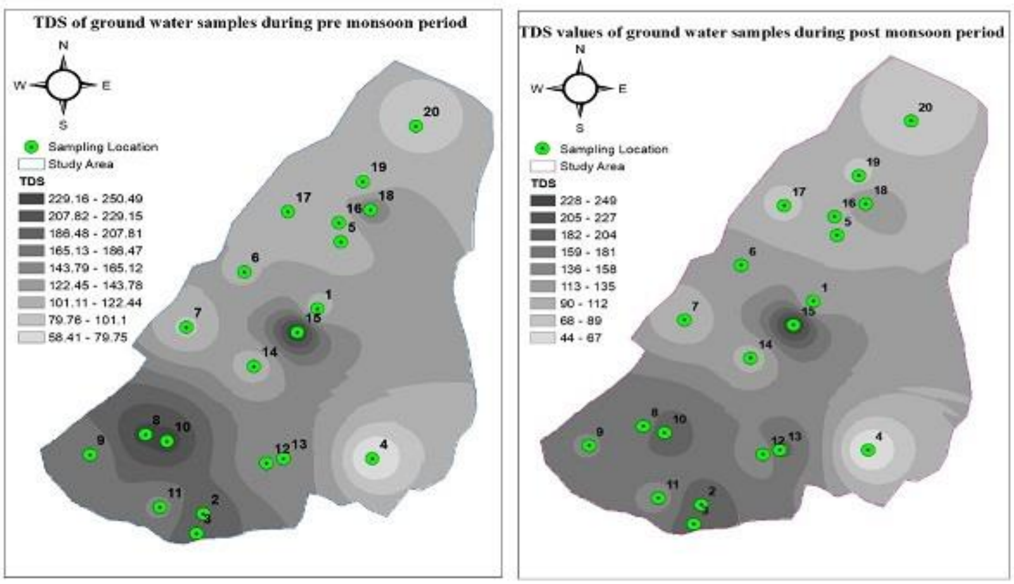

Fig. 14 Variation of TDS in ground water during Pre and Post-Monsoon periods

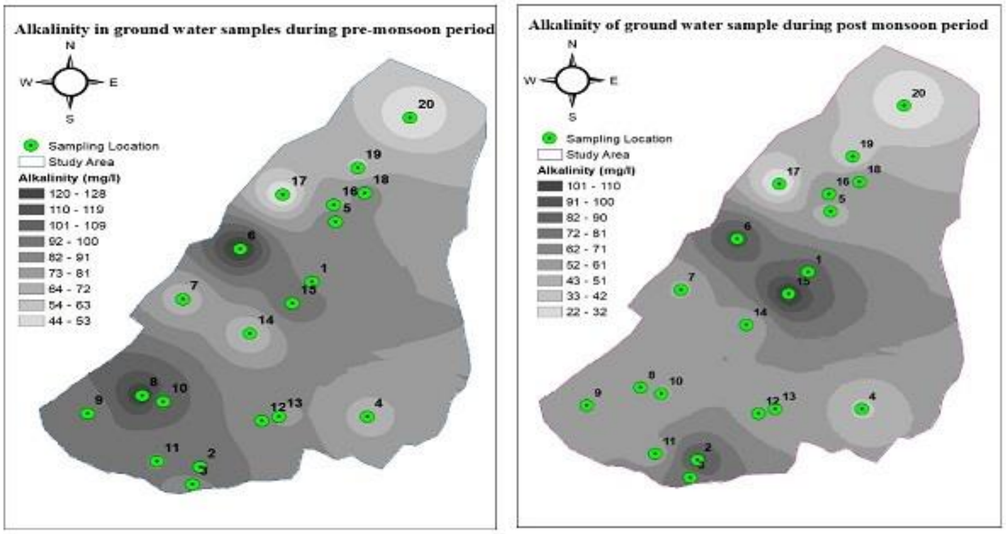

Fig. 15 Variation of Alkalinity in ground water during pre and post monsoon periods.

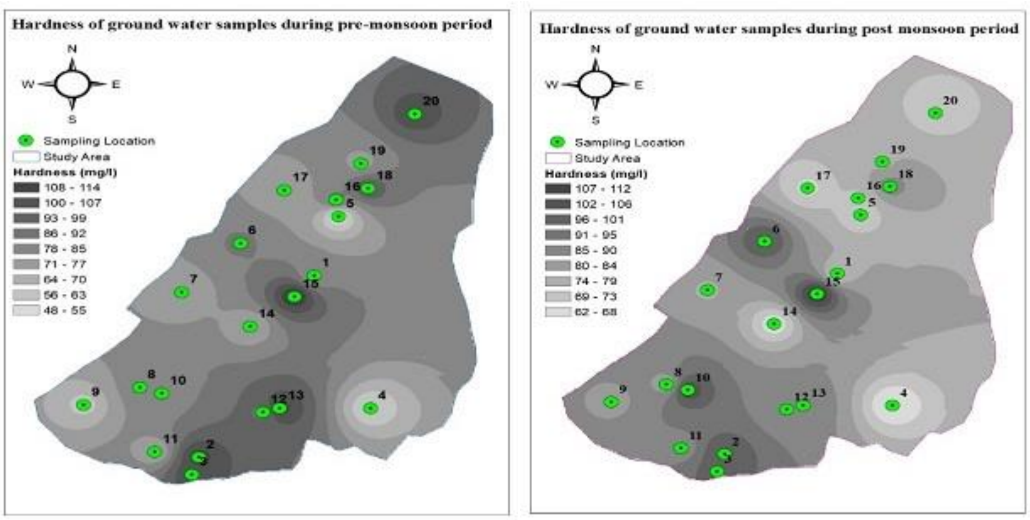

Fig. 16 Variation in Hardness in ground water during Pre and post monsoon periods.

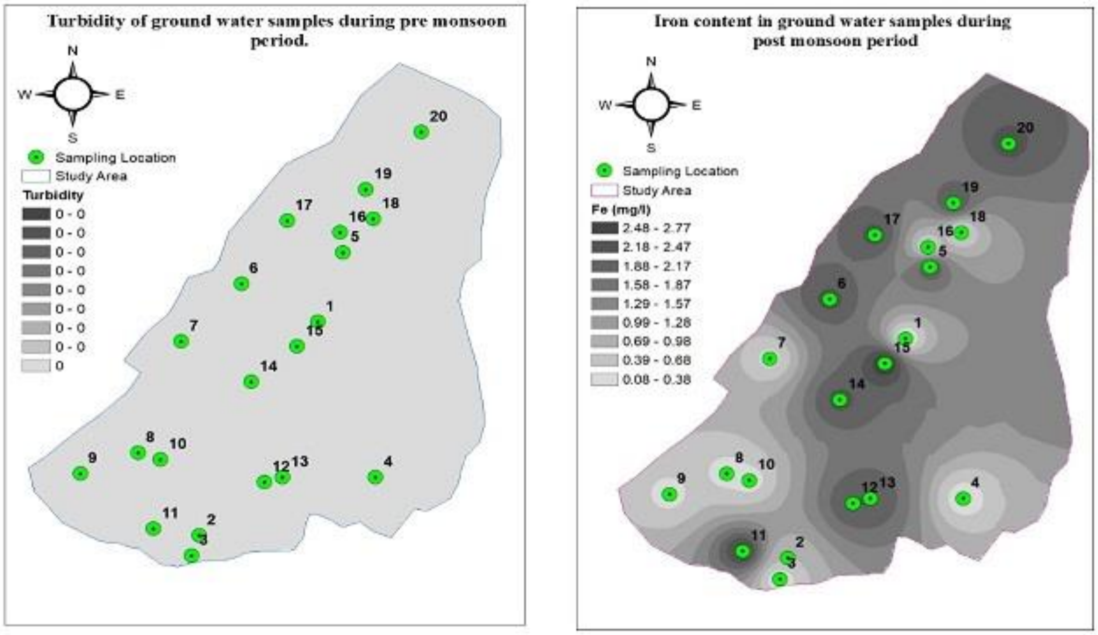

Fig. 17 Variation in turbidity of ground water during pre and post monsoon periods.

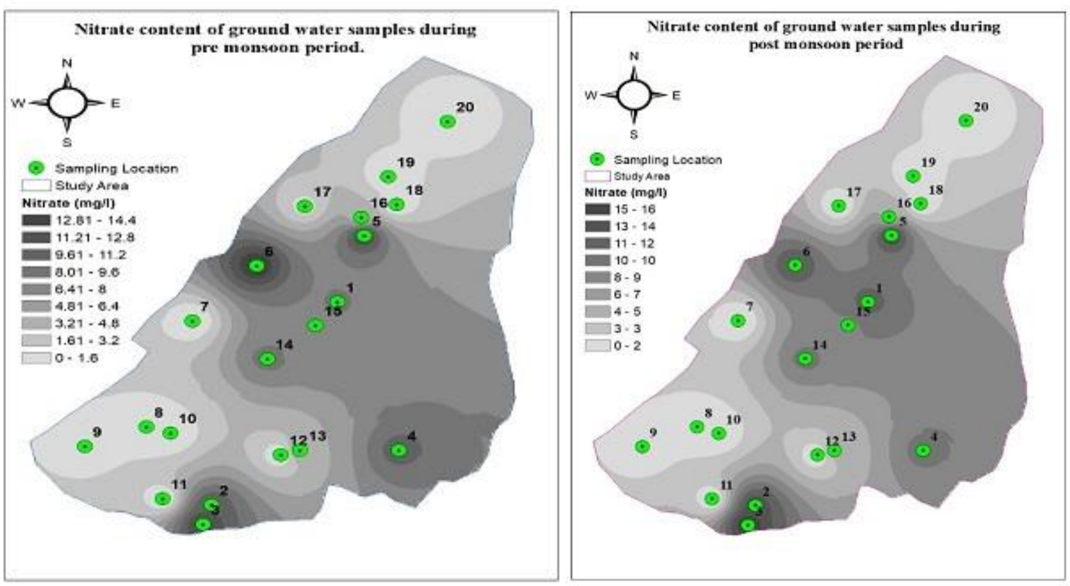

Fig. 18 Variation in Nitrate content in ground water during pre and post monsoon periods.

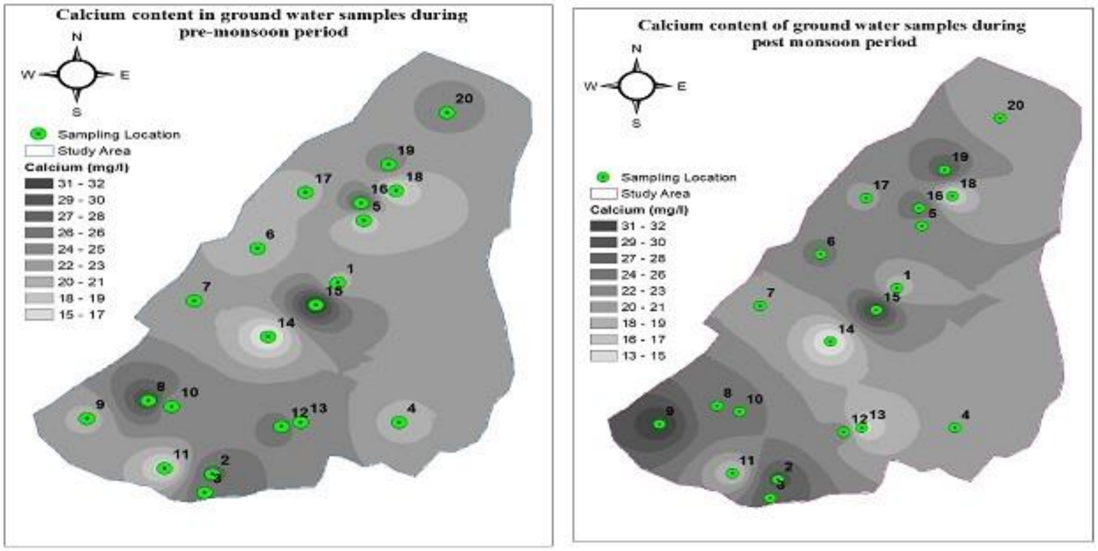

Fig. 19 Variation in Calcium content in ground water during pre and post monsoon periods.

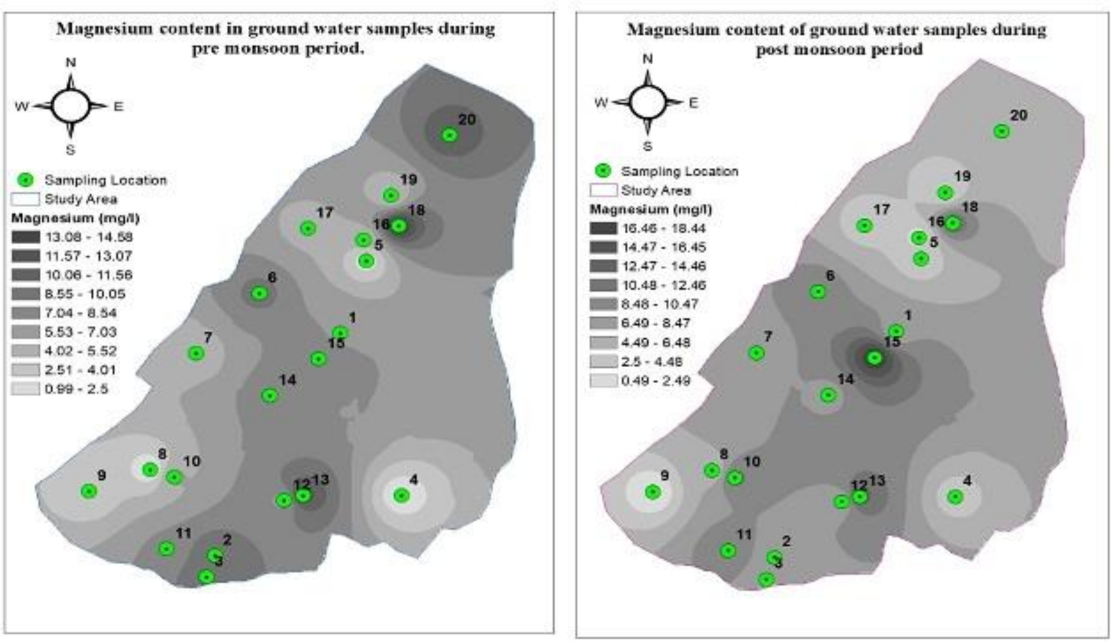

Fig. 20 Variation in magnesium content in ground water during pre and post monsoon periods.

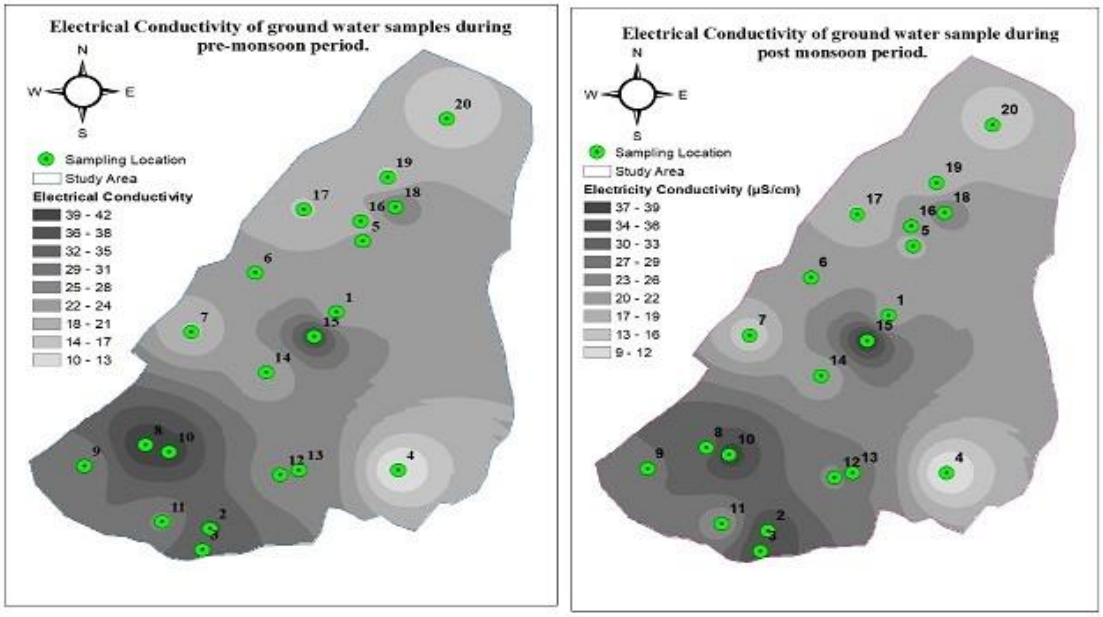

Fig. 21 Electrical conductivity of ground water during pre and post monsoon periods.

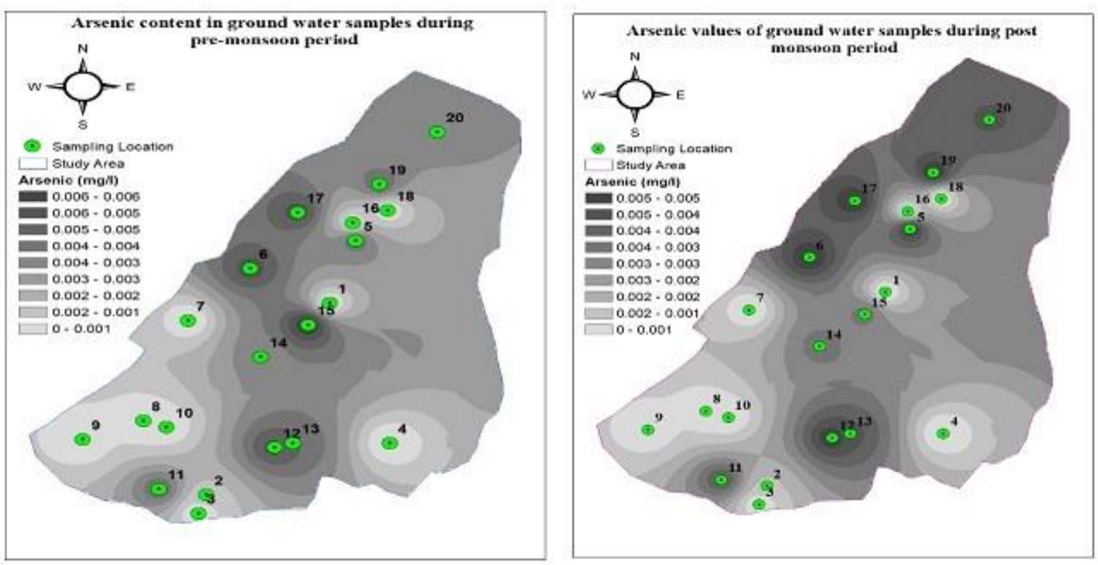

Fig. 22 Arsenic content of ground water during pre and post monsoon periods.

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