Journal homepage: www.scienceletters.researchfloor.org

Contents list available at Journal of e-Science Letters

Journal of e-Science Letters

Original Research Article | ISSN :3041-5454

Seasonal Variations in Groundwater Quality near Quarry Sites of Bagalkot District, Karnataka

Sukumar A. Kokatanur*

JSS IER/PRC Vidygiri, Dharwad-04, India

ABSTRACT

Groundwater serves as an essential resource in semi-arid areas such as Bagalkot District, Karnataka, but it faces increasing threats from intensive limestone quarrying activities. This research examines the seasonal fluctuations in groundwater quality adjacent to quarry sites and assesses the effects of mining operations on critical physico-chemical parameters. A total of twenty groundwater samples were gathered from bore wells at ten different locations during the pre-monsoon (March 2019) and post-monsoon (October 2018) periods. The analysis included parameters such as pH, electrical conductivity (EC), total hardness (TH), total dissolved solids (TDS), calcium, magnesium, chloride, sulphate, phosphate, and alkalinity, all conducted in accordance with established protocols.

To evaluate seasonal variations and statistical methods including Pearson's correlation and paired t-tests were utilized. The findings indicated notable seasonal variations in pH, EC, TH, TDS, magnesium, chloride, and sulphate, with elevated concentrations typically observed in the post-monsoon season as a result of leaching and runoff. Levels of sulphate and phosphate consistently surpassed permissible thresholds, while hardness values exceeded the Bureau of Indian Standards (BIS) recommendations at multiple sites, particularly those in proximity to quarry operations. In contrast, calcium and alkalinity did not exhibit significant seasonal changes. The results emphasize the quarrying-related degradation of groundwater quality and highlight the urgent need for enhanced monitoring, sustainable mining practices, and effective water management strategies to protect public health and ensure the long-term sustainability of groundwater resources in the area.

Keywords: *Groundwater, quarrying, seasons, Impact, Concentration*

1. Introduction

Groundwater serves as an essential resource for domestic, agricultural, and industrial purposes, especially in semi-arid areas like Bagalkot District, Karnataka. Nevertheless, the rapid growth of quarrying activities, particularly in limestone and other mineral extraction has raised significant concerns regarding the sustainability and quality of local groundwater. Quarry operations can disrupt the natural recharge of aquifers, change flow patterns, lower water tables, and promote the infiltration of pollutants, which ultimately degrades water quality. Seasonal changes, influenced by monsoonal rainfall and post-monsoon runoff, further affect the concentration of important physico-chemical parameters such as pH, total dissolved solids, hardness, calcium, and sulphates. Grasping these temporal variations is crucial for evaluating the environmental impacts of quarrying, ensuring a safe water supply, and guiding sustainable groundwater management strategies in the area.

Citation: Sukumar A. Kokatanur (2025). Seasonal Variations in Groundwater Quality near Quarry Sites of Bagalkot District, Karnataka. *Journal of e-Science Letters.*
DOI: https://doi.org/10.51470/eSL.2025.6.3.01

Received: 11 May 2025
Revised: 05 June 2025
Accepted: 14 July 2025
Available: August 02 2025

Corresponding Authors: **Sukumar A. Kokatanur**
Email: **sukky1008@gmail.com**

2. Study area

The study region is in northern Karnataka State, with semi-arid characteristics extending between 15°46' North Latitude and 16°46' North Latitude, and 74°59' East Longitude and 76°20' East Longitude. The district is bordered by Belagavi district to the west, Vijaypur and Gulbarga districts to the north and northeast, Raichur district to the east and Koppal, Gadag, and Dharwad districts to the southeast, south, and southwest. Encompassing an area of 6575 square kilometres, the district had a population of 1,889,752 people as per the 2011 census. It is organized into six taluks and comprises 629 villages. Physiographically, the district is characterized by three divisions: the Deccan trap in the north, the Kaladagi series in the southwest, and the peninsular gneissic topography in the east and southeast. Three major rivers, the Krishna, Ghataprabha, and Malaprabha, drain the district.

3. Objectives

The study is mainly based on the following objectives
a. To know the physic-chemical properties of the ground water
b. To analyse the seasonal impact of limestone quarrying on ground water

4. Data Base and Methodology:

A baseline survey carried out in October 2018 (after the monsoon) and March 2019 (before the monsoon) has been assessed using primary data collected during the field survey.
Pearson's coefficient and correlation techniques were utilized to examine the relationship between distance and the spread of pollutants in the vicinity of the limestone quarry.

William Gosset's T-test method was employed to evaluate the seasonal variation in groundwater quality in the research area.

5. Impact on Groundwater

Limestone quarrying can have a profound effect on groundwater by changing aquifer recharge patterns, increasing runoff, and reducing water tables due to mine dewatering. When quarries intersect phreatic aquifers, the flow of groundwater is disrupted, which often results in the drying up or diminished flow in nearby wells, springs, and streams. Many researches has been evaluated and proved that, the quarry operation has negative impact on ground water quality.

Zones (1961) studied and evaluated the impact of mining activities on groundwater quality by analyzing seasonal variations in physico-chemical parameters from multiple sampling sites. Parameters measured included pH, EC, TDS, hardness, major ions (Ca^{2+}, Mg^{2+}, Cl^{-}, SO_4^{2-}), nutrients (phosphate, nitrate), and alkalinity, compared against BIS and WHO standards. The results indicated elevated hardness, sulphate, and phosphate in several sites, with post-monsoon increases in most parameters due to runoff and leaching. While pH, TDS, magnesium, and chloride largely remained within permissible limits, persistent exceedances in hardness and sulphate pointed to both geogenic and mining-related contamination, highlighting the need for better groundwater management in mining regions. To understanding of mining impacts, Lamare and Singh (2014) examined the effects of limestone mining and cement plant activities on water quality in East Jaintia Hills, Meghalaya. Using pre- and post-monsoon 2013 data from five impacted sites and one control, they observed elevated pH, EC, TDS, hardness, calcium, and sulphate, with several parameters exceeding BIS limits, particularly near cement plants. Seasonal variation was evident, with most parameters increasing post-monsoon except sulphate. Although the study's spatial coverage was limited, it clearly linked mining activities to water quality deterioration and underscored the need for stricter effluent control.

Around the same time, Garba et al. (2014) assessed groundwater quality impacts from early coal mining in Maiganga, Nigeria, through physical, chemical, and biological analyses of boreholes, wells, and streams. Several contaminants, including nitrate, cyanide, and heavy metals, exceeded WHO limits, and microbial contamination (e.g., E. coli) was widespread. Borehole water, though safer than surface water, still showed significant pollution. Their multi-parameter approach and repeated sampling strengthened the findings, but the study lacked detailed hydrogeological transport analysis and policy-oriented remediation strategies, highlighting the need for improved water treatment, alternative water sources, and stricter mining waste management. Furthermore, Bagga (2017) further investigated the environmental impacts of coal mining in the Sohagpur Coalfield, focusing on the Sharda Open Cast Mine in Madhya Pradesh. Employing field sampling, laboratory analysis, and secondary data, the study revealed significant deterioration in groundwater near mining areas, with elevated electrical conductivity, turbidity, TDS, alkalinity, hardness, and fluoride levels often exceeding BIS standards. Air quality measurements also showed SOx, NOx, and suspended particulate matter above permissible limits in both mining and nearby residential areas. The study concluded that coal mining had substantial adverse effects on environmental quality and public health, emphasizing the adoption of sustainable technologies and stricter regulations.

Most recently, Radhapyari et al. (2022) provided an extensive assessment of mining's impact on groundwater quality in India using pollution indexing techniques. Their review included indices such as the Heavy Metal Pollution Index, Heavy Metal Evaluation Index, Water Quality Index, and Contamination Index, alongside multivariate statistical tools like principal component analysis to identify pollution sources. Health risk assessments for oral and dermal exposure to mine waste metals were also discussed. The work highlighted the value of indexing methods for evaluating pollution status, managing risks, and formulating mitigation measures, offering a methodological framework useful for environmental monitoring and policy planning in mining regions.

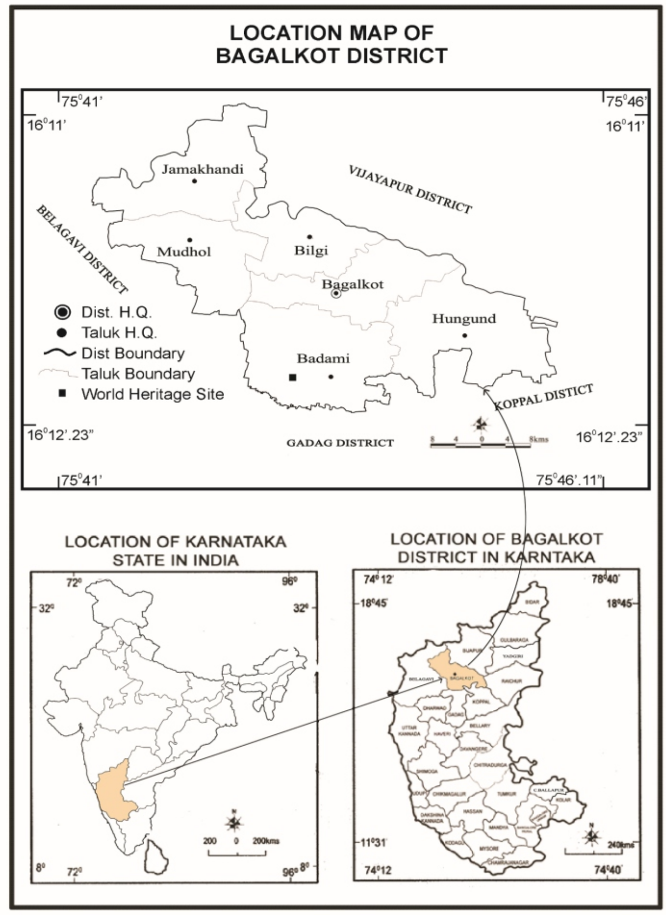

Fig. 1

6. Water Samples Locations and Preparations

Groundwater quality near limestone mining sites in Bagalkot district was assessed through 20 samples from 10 locations within the mining areas (Table 1, Fig. 1). Among 20 samples, 10 samples are collected in the month of October 2018 (post-monsoon) and remaining 10 samples were collected in the month of March 2019 (pre-monsoon). The samples were collected in 1 Ltr polyethylene cans for laboratory analysis. Physico-chemical parameters measured included pH, electrical conductivity, total hardness, total dissolved solids, calcium, chloride, total alkalinity, magnesium, sulfate, and phosphorus. Trace elements were analyzed using standard protocols (APHA-AWWA-WPCF, 1980; Trivedy & Goel, 1984) with an Australian Model GBC-902 atomic absorption spectrometer

Table 1: Location of ground water samples around limestone quarry, Bagalkot District, Karnataka

Sl. No.	Sample No.	Distance from quarry site (in km)	Name of the place	Water Samples type
1.	GW S1	0.8	Chikka Shellikeri	Bore well
2.	GW S2	1.2	Chikka Shellikeri	Bore well
3.	GW S3	0.4	Kaladagi	Bore well
4.	GW S4	1	Kaladagi	Bore well
5.	GW S5	0.7	Muddapur	Bore well
6.	GW S6	1.3	H. Ningapur	Bore well
7.	GW S7	1	Muddapur	Bore well
8.	GW S8	1.2	Timmapura	Bore well
9.	GW S9	0.6	Hebbal	Bore well
10.	GW S10	0.9	Muddapur	Bore well

Source: *Collected from the field survey-Oct.2018-March 2019*

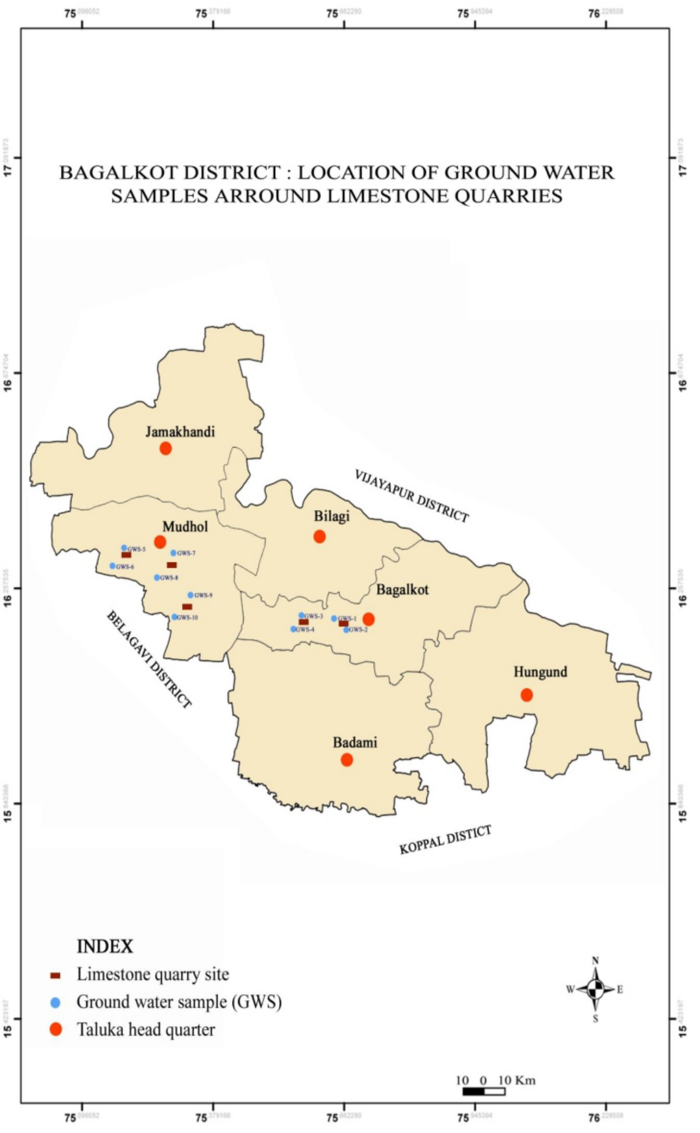

Fig. 2

Tables 2 and 3 reveals the average concentration of various elements at varying distances from the limestone quarries, whereas Table 4 demonstrates the results of the Paired t-test, highlighting significant differences between pre-monsoon and post-monsoon water samples collected from different locations.

Table 2: Physico-Chemical Properties of Ground Water Samples Around Limestone Quarries from Pre-monsoon Season

Water Properties / Water Samples	Distance from quarry site (in km)	pH	EC	TH Mg/L	TDS Mg/L	Calcium Mg/L	Magnesium Mg/L	Chloride Mg/L	Sulphate Mg/L	Phosphate Mg/L	Alkalinity Mg/L
GW S1	0.8	7.1	129	91.33	80.01	48.31	4.82	12.11	63.21	3.23	38.12
GW S2	1.2	6.0	196	126.54	76.11	38.81	5.71	14.22	81.21	2.0	74.33
GW S3	0.4	7.9	197	115.25	82.21	42.21	4.01	10.81	102.33	1.86	48.49
GW S4	1	7.1	201	180.52	72.18	37.62	6.31	9.61	87.63	2.14	70.78
GW S5	0.7	7.0	160	80.58	78.11	36.12	4.63	8.71	98.21	2.0	48.23
GW S6	1.3	7.9	386	300.29	388.10	96.72	9.36	8.13	978.21	2.88	179.23
GW S7	1	7.6	490	265.25	365.16	110.21	10.41	9.87	945.23	2.03	182.36
GW S8	1.2	6.5	421	288.23	378.28	108.42	8.88	10.18	870.42	2.97	171.61
GW S9	0.6	7.2	443	264.66	310.31	114.63	9.81	10.88	880.22	1.97	213.32
GW S10	0.9	6.2	502	299.53	390.28	112.11	10.21	11.67	990.61	2.04	118.49

Source: Complied with a tested results- 2018-19

Table 3: Physico-Chemical Properties of Ground Water Samples Around Limestone Quarries from Post-monsoon Season

Water Properties / Water Samples	Distance from quarry site (in km)	pH	EC	TH Mg/L	TDS Mg/L	Calcium Mg/L	Magnesium Mg/L	Chloride Mg/L	Sulphate Mg/L	Phosphate Mg/L	Alkalinity Mg/L
GW S1	0.8	8.2	140	170.12	180	52.13	5.39	14.11	32.11	3.81	52.13
GW S2	1.2	8.0	211	240.12	161	42.11	6.31	16.28	48.92	2.82	82.91
GW S3	0.4	8.8	220	120.1	181	45.35	8.41	12.31	54.69	2.12	89.23
GW S4	1	7.8	245	180.11	146	44.37	7.24	11.33	42.17	3.0	56.27
GW S5	0.7	8.1	196	310.18	440	102.21	9.12	12.33	48.29	1.92	216.16
GW S6	1.3	8.4	421	410.10	481	114.31	19.21	12.81	441.17	2.11	196.19
GW S7	1	7.8	531	379.08	398	115.12	17.43	13.17	701.12	2.22	202.30
GW S8	1.2	7.2	481	386.12	431	118.31	15.12	12.91	640.31	3.01	198.31
GW S9	0.6	9.0	492	371.02	396	116.18	18.21	14.17	660.38	1.42	220.44
GW S10	0.9	8.0	554	356.21	442	116.71	20.41	13.01	702.12	2.81	126.41

Source: Complied with a tested results- 2018-19

Table 4: Paired t-test for Significant Difference between Pre-monsoon and Post Monsoon

Sl.No.	Elements	Diff b/w means	t-stat	P-value
1	pH	-1.08	-5.63	0.000323142
2	EC	-36.6	-7.2	5.06E-05
3	TH	-91.098	-4.43	0.001636645
4	TDS	-103.525	-3.5	0.006716237
5	Calcium	-12.164	-1.97	0.0800721
6	Magnesium	-5.27	-4.5	0.001479071
7	Chloride	-2.624	-7.66	3.13E-05
8	Sulphate	172.6	3.319	0.008958944
9	Phosphate	-0.212	-1.18	0.2677821
10	Alkalinity	-29.539	-1.84	0.09848424

Source: *Personal computation*

7. RESULTS and Discussion of Ground Water Samples

7.1 Potential Hydrogen (pH)

pH indicates the acidity or alkalinity of water, which is defined as the negative logarithm of the concentration of hydrogen ions. The pH scale ranges from 0 to 14, where 7 is considered neutral, values above 7 are basic, and those below 7 are acidic. Rainwater usually has a slightly acidic pH of 5.6 attributable to atmospheric carbon dioxide presence. For safe drinking water and the health of aquatic life, a pH range of 6.5 to 8.5 is necessary.

In pre-monsoon conditions, soil pH varies from 6.0 (S2) to 7.9 (S6). In contrast, post-monsoon pH values range from 7.02 (S8) to 9.0 (S9), generally showing higher pH levels than those observed pre-monsoon. Most samples reflect alkaline conditions, although some post-monsoon readings surpass the BIS limit of 8.5 (BIS 10500:2012). Paired testing has confirmed that the average pH is significantly higher in post-monsoon samples compared to pre-monsoon ones.

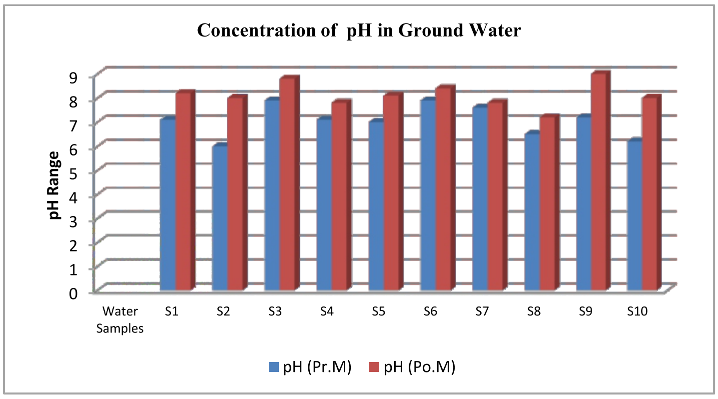

Fig. 3

7.2 Electrical Conductivity

Electrical Conductivity (EC) quantifies a solution's capacity to transmit electrical current, which is indicative of its ion concentration. This measurement serves as a crucial parameter for salinity or total dissolved solids, important for evaluating water usage in irrigation, firefighting, and various other applications.

Pre-monsoon soil EC values varied from 129 µS (S1) to 502 µS (S10). In contrast, post-monsoon measurements ranged from 140 µS (S1) to 554 µS (S10), typically exceeding pre-monsoon figures. The observed spatial variation indicates elevated EC levels following the monsoon. Results from paired tests validated a notable rise in average EC during the post-monsoon period when compared to pre-monsoon

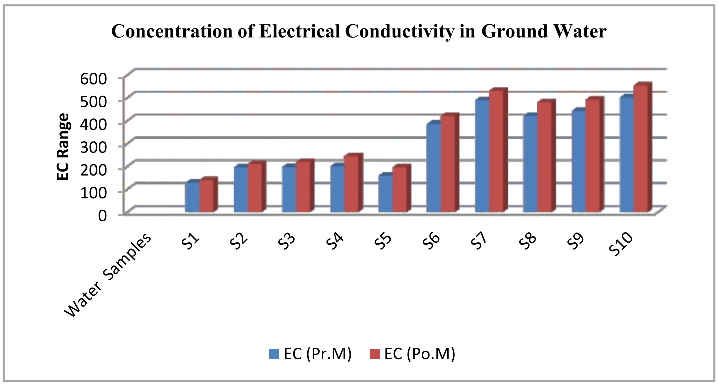

Fig. 4

7.3 Total hardness (TH)

Hardness indicates the mineral content of water, primarily derived from calcium and magnesium ions found in soil, rock, and particularly limestone. These ions can be present as chlorides, nitrates, bicarbonates, or sulfates. Hard water, defined as having more than 300 mg/L, can lead to scaling and diminish soap lathering, while concentrations up to 500 mg/L are typically safe, although excessive levels may induce a laxative effect. The Bureau of Indian Standards (BIS) specifies that the acceptable limit for groundwater hardness is 200 mg/L.

During the pre-monsoon period, Total Hardness (TH) varied from 80.58 mg/L (S5) to 300.29 mg/L (S6). In the post-monsoon period, values ranged from 120.1 mg/L (S3) to 410.10 mg/L (S6), indicating generally elevated concentrations. The sites S1–S5 were within permissible limits during the pre-monsoon, while S1, S3, and S4 remained acceptable in the post-monsoon. However, higher-than-permissible levels were observed at S6–S10 during the pre-monsoon and at S2, S5–S10 in the post-monsoon. Results from paired tests indicated a significant rise in average hardness after the monsoon compared to before.

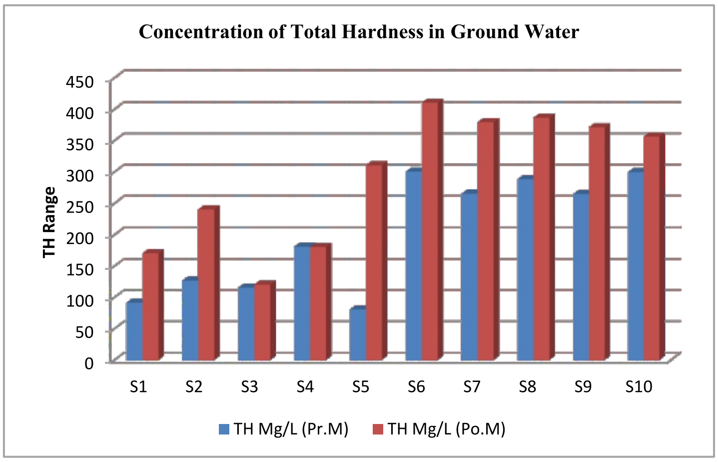

Fig. 5

7.4 Total Dissolved Solids (TDS)

Total Dissolved Solids (TDS) indicate the total concentration of dissolved materials in water, primarily consisting of inorganic salts like calcium, magnesium, potassium, sodium, and related anions such as carbonates, bicarbonates, chlorides, nitrates, and sulfates. Water sourced from mineral springs typically exhibits high TDS levels due to its interaction with saline rocks. Increased TDS can lead to scaling, discoloration, diminished soap lather, a metallic taste, and accelerated wear of water filters. Elevated levels may also signal the presence of harmful pollutants from runoff or wastewater discharge. The Bureau of Indian Standards (BIS) (10500:2012) sets the acceptable limits for TDS in drinking water.

During the pre-monsoon period, TDS values varied from 72.18 mg/L (S4) to 390.28 mg/L (S10), whereas post-monsoon measurements ranged from 146 mg/L (S4) to 481 mg/L (S6). All samples were within the BIS guidelines during both seasons. In general, TDS levels were higher after the monsoon, with paired test results indicating a notable seasonal increase.

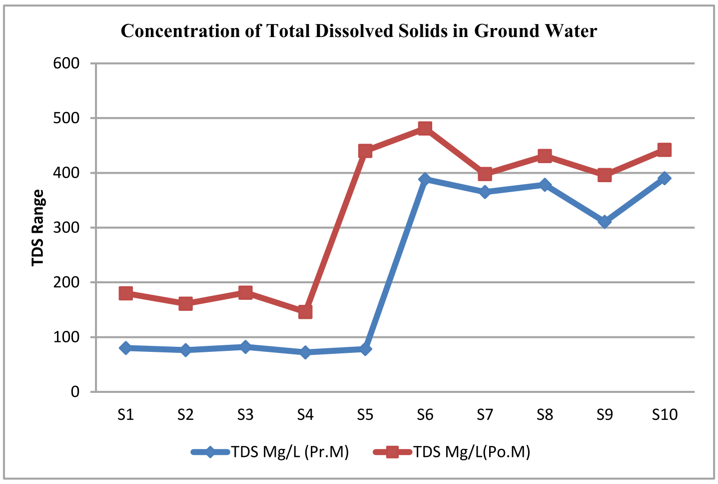

Fig. 6

7.5 Calcium (Ca)

Calcium, recognized as the fifth most prevalent natural element, is found in all natural waters, primarily due to the weathering of rocks like limestone, dolomite, and minerals such as calcite. In the area under study, calcite plays a major role in contributing to water hardness. Although high levels of calcium do not pose a health risk, they can lead to household issues; however, calcium is beneficial for bone density, may aid in the prevention of certain cancers, and can help decrease the absorption of heavy metals in the body.

During the pre-monsoon period, calcium levels varied from 36.12 mg/L (S5) to 114.63 mg/L (S9). In the post-monsoon period, values ranged from 42.11 mg/L (S2) to 118.31 mg/L (S8), with generally elevated concentrations observed in the post-monsoon season. The Bureau of Indian Standards (BIS) specifies that the permissible level of calcium in groundwater is 75 mg/L. Samples S1–S4 in both seasons and S5 in the pre-monsoon period were within acceptable limits, while S6–S10 in both seasons and S5 in the post-monsoon period exceeded this limit. Results from paired tests indicated no significant difference between the average calcium levels of the pre-monsoon and post-monsoon periods.

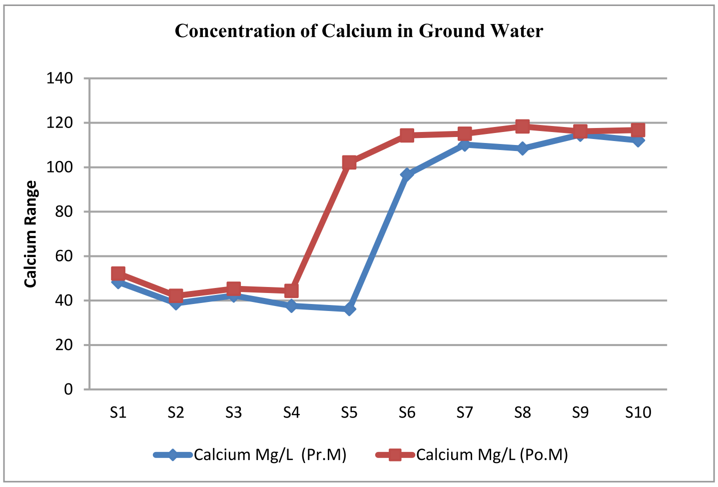

Fig. 7

7.6 Magnesium (Mg)

Magnesium (Mg), recognized as the eighth most prevalent natural element, typically infiltrates groundwater through the weathering of minerals such as magnesite and sedimentary rocks like limestone and dolomite. Magnesite significantly contributes to the hardness of water. Although hard water does not pose health hazards, elevated magnesium concentrations especially those exceeding 700 mg/L as magnesium sulfate—can induce a laxative effect, although the body usually acclimatizes. The Bureau of Indian Standards (BIS) (10500:2012) outlines the acceptable limits for magnesium in potable water.

During the pre-monsoon period, magnesium levels varied from 4.01 mg/L (S3) to 10.41 mg/L (S7), whereas post-monsoon measurements ranged from 5.39 mg/L (S1) to 20.41 mg/L (S10). The concentrations observed after the monsoon were consistently higher, yet all samples remained compliant with BIS standards across both seasons. Results from paired tests indicated a notable seasonal rise in average magnesium levels.

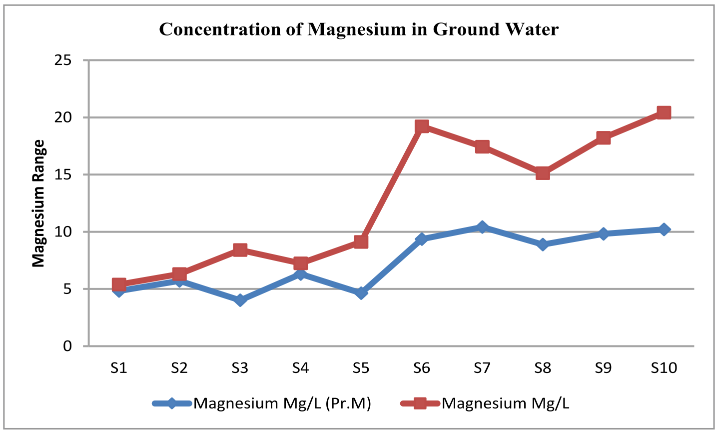

Fig. 8

7.7 Chloride (Cl)

Chloride (Cl) is found naturally in lakes, streams, and groundwater, with concentrations exceeding 250 mg/L in freshwater often suggesting potential wastewater contamination.

Sources of chloride include wastewater discharge, agricultural runoff, and rocks that contain chloride. Although it is typically non-toxic, elevated chloride levels can give water a salty flavor, and excessive sodium intake from table salt is associated with kidney and heart problems. Additionally, chloride plays a crucial role in the normal cellular functions of both plants and animals. The Bureau of Indian Standards (BIS) has established the permissible limit for chloride in drinking water at 250 mg/L.

Pre-monsoon chloride levels varied from 8.13 mg/L (S6) to 14.22 mg/L (S2), whereas post-monsoon levels ranged from 11.33 mg/L (S4) to 16.28 mg/L (S2). All samples collected during both seasons were well within the BIS guidelines, with post-monsoon concentrations generally being higher. Results from paired tests indicated a significant increase in average chloride concentration between the two seasons.

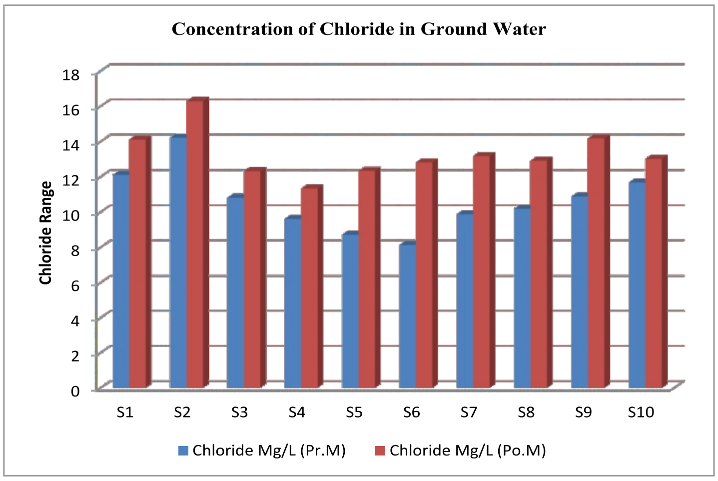

Fig. 9

7.8 Sulfate (SO_4)

Sulfate, a highly soluble compound present in air, soil, and water, is frequently found in aquifers and groundwater. The primary sources include the combustion of fossil fuels, which emits sulfur that oxidizes into sulfate and is subsequently deposited through precipitation or dry deposition. In groundwater, elevated sulfate concentrations typically arise from interactions with sulfate-rich rocks like gypsum and anhydrite, facilitated by processes such as reduction, precipitation, and dissolution. The World Health Organization (WHO) and the Bureau of Indian Standards (BIS) (10500:2012) set a maximum permissible limit of 250 mg/L.

Pre-monsoon sulfate levels varied from 63.21 mg/L (S1) to 990.61 mg/L (S10), while post-monsoon levels ranged from 32.11 mg/L (S1) to 702.12 mg/L (S10). Higher concentrations were predominantly observed during the pre-monsoon season. Samples from S1 to S5 in both seasons remained within the permissible limits, whereas S6 to S10 surpassed the limit in both periods. Results from paired tests indicated a significant seasonal variation, with average sulfate levels being higher in the pre-monsoon season compared to the post-monsoon.

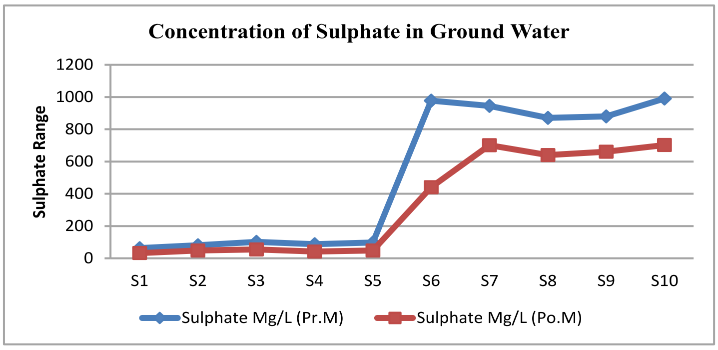

Fig. 10

7.9 Phosphates (P)

Phosphorus is a vital nutrient for the growth of plants, naturally found in rocks, soil, and vegetation, and is extensively utilized in agriculture as fertilizer. It is also present in detergents, sludges, and both animal and human waste. Although it is primarily immobile in soil, specific conditions such as low levels of iron, aluminum, and manganese or the direct transport of waste can enable phosphorus to infiltrate groundwater. Even in minimal concentrations, it has the potential to stimulate algal blooms, which can deteriorate water quality. The BSI (10500:2012) establishes an acceptable limit of 0.1 mg/L and a permissible limit of 1.0 mg/L for phosphate in groundwater.

Pre-monsoon phosphate concentrations varied from 1.86 mg/L (S3) to 3.23 mg/L (S1), while post-monsoon levels ranged from 1.42 mg/L (S9) to 3.81 mg/L (S1). All samples surpassed the permissible limits set by BIS during both seasons. Results from paired tests showed no significant seasonal variation in phosphate levels.

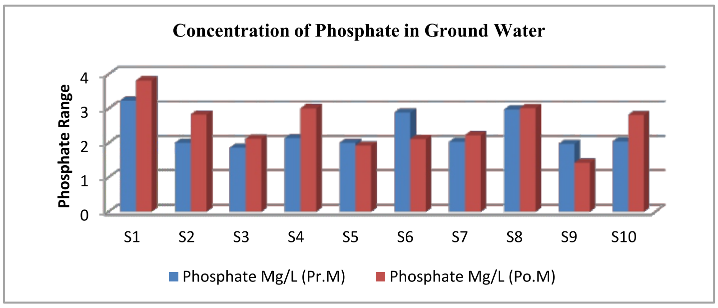

Fig. 11

7.10 The Alkalinity

Alkalinity refers to the ability of water to maintain its acidity levels, primarily influenced by the presence of dissolved bicarbonate and carbonate ions, along with minor contributions from hydroxide, silicate, and borate. It is measured in mg/L as calcium carbonate and naturally occurs due to the dissolution of atmospheric and soils CO_2 in water, as well as the breakdown of carbonate minerals. Additionally, human activities, such as waste disposal, can lead to increased alkalinity. High alkalinity levels may result in an unpleasant taste or the formation of scale in pipes. According to BIS (10500:2012), a desirable alkalinity limit is set at 200 mg/L, with a maximum permissible limit of 600 mg/L.

During the pre-monsoon period, alkalinity levels varied from 38.12 mg/L (S1) to 213.32 mg/L (S9), with only S9 surpassing the desirable limit. In the post-monsoon period, values ranged from 52.13 mg/L (S1) to 220.44 mg/L (S9). All samples collected in both seasons remained below the maximum permissible limit. Results from paired tests showed no significant seasonal variation in alkalinity.

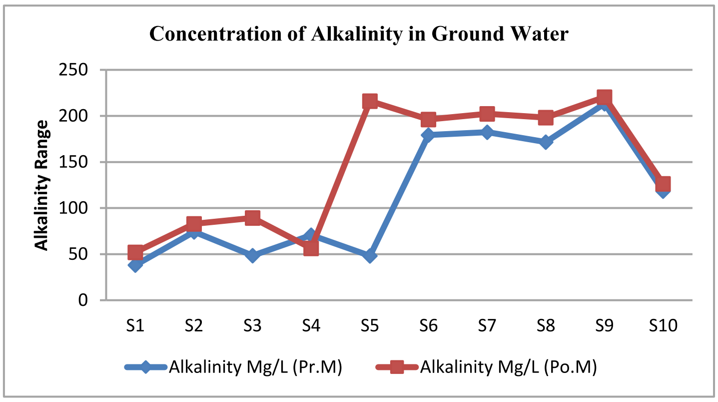

Fig. 12

8. Findings

- The pH values recorded during both seasons were predominantly alkaline, with slightly elevated readings observed in the post-monsoon period; all values remained within the BIS limits, except for a few instances that surpassed the upper threshold in the post-monsoon season.
- Electrical Conductivity (EC) was found to be higher in the post-monsoon season, suggesting an increase in ion concentration following rainfall recharge.
- There was a significant rise in Total Hardness after the monsoon, with several locations (particularly S6–S10) exceeding the BIS permissible limit of 200 mg/L during both seasons.
- Total Dissolved Solids (TDS) were within BIS limits across all samples, although post-monsoon values were consistently elevated.
- Magnesium levels remained within acceptable limits in all samples, but there was a notable increase in levels post-monsoon.
- Chloride concentrations were significantly below BIS limits, with post-monsoon values showing a slight increase across all sites.
- Sulfate concentrations surpassed the permissible limit of 250 mg/L at S6–S10 in both seasons, with higher averages noted in the pre-monsoon period.
- Phosphate concentrations exceeded the permissible limit of 1.0 mg/L in all samples across both seasons, with no notable seasonal differences.

- Alkalinity levels were below the maximum permissible limit of 600 mg/L in all samples; however, only S9 exceeded the desirable limit of 200 mg/L in both seasons, with no significant seasonal variation.

Conclusion

According to paired t- test conducted for the collected water samples from the study area, the average values of potential of Hydrogen (pH), Electric Conductivity (EC), Total Hardness (TH), Total Dissolved Solids (TDS), Magnesium (Mg), Chloride (Cl) and Sulphates (SO_4), there is a significant difference between pre and post monsoon seasons. It reveals the increase in the concentration of the above properties in post- monsoon and maintained low in the pre- monsoon season.

The water sample collected from the study area showed insignificant difference in the values of Calcium (Ca), Phosphorous (P) and Alkalinity between pre monsoon and post monsoon seasons may be due to the amount of rain has effect on these physicochemical properties and these elements may not interact with the water molecules.

References

1. APHA. (2005). *Standard methods for the examination of water and wastewater* (21st ed.). American Public Health Association/American Water Works Association/Water Environment Federation.

2. Bagga, R. (2017). *Environmental impacts of coal mining in the Sohagpur Coalfield: A case study of Sharda Open Cast Mine, Madhya Pradesh, India*.

3. Dhar, B. B., & Ahmad, M. (1993). Impact of mining and processing activities on surrounding environment – A case study. *Journal of Mining Research, 2*(2), 34–41.

4. Environmental Impact Assessment (EIA) Study for Exploratory Drilling of Oil Exploration in the Block PEL of Kangra-Mandi, Himachal Pradesh. (2009). National Environmental Engineering Research Institute.

5. Eugene, R. L., & Singh, O. P. (2014). Degradation in water quality due to limestone mining in East Jaintia Hills, Meghalaya, India. *International Research Journal of Environmental Sciences, 3*(5), 13–20.

6. Garba, M., [Other authors if any]. (2014). Assessment of groundwater quality impacts from early coal mining in Maiganga, Nigeria.

7. Gopalkrushna, M. (2011). Determination of physico-chemical parameters of surface water samples in and around Akot City. *International Journal of Research in Chemistry and Environment, 1*(2), 183–187.

8. Lamare, A., & Singh, R. (2014). Effects of limestone mining and cement plant activities on water quality in East Jaintia Hills, Meghalaya.

9. Radhapyari, R. (2022). Mining impacts on groundwater quality in India: Pollution indexing and risk assessment.

10. Zones, C. P. (1961). Impact of mining activities on groundwater quality: Seasonal variations and physico-chemical analysis.