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DECIPHERING HYDROGEOCHEMICAL SIGNATURES OF GROUNDWATER UNDER COAL MINING STRESS: A TWO-YEAR SPATIO-TEMPORAL INVESTIGATION FROM CHHINDWARA (CENTRAL INDIA)

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ABSTRACT
The quality of the water is the main factor affecting the existence of all living beings on Earth. The condition of the groundwater in the mining zones is the people' top worry. Groundwater samples from the coal mining areas of the Chhindwara district were collected in different sessions for the current study. These samples were analyzed for pH, TDS (Total Dissolved Solid), Electrical Conductivity (EC), Chlorides, Sulfate, Nitrate, Iron, Hardness, Magnesium, and Sodium, among other aspects of water quality. After analysis, the findings were contrasted with other water quality criteria, such as IS and WHO. The findings indicate that the quality of the groundwater was somewhat impacted by the mining activities.

KEYWORDS: Mining activities, Groundwater, Physico-chemical properties, Environmental impacts.

INTRODUCTION
Groundwater is utilized in homes, businesses, and agriculture all around the world. The need for fresh water has grown dramatically over the past few decades as a result of both the quickening pace of industrialization and population growth. According to the WHO, about 80% of all human diseases are caused by water-related ailments (Kavitha and Elangovan, 2010).

Groundwater is an invaluable natural resource that provides for all living things' basic needs. Hydrological processes, electronics, or any other way cannot produce or add to it (Brindha and Elango, 2011; Sathiyamurthy, 2012). People all throughout the world struggle without access to clean water, even though 75% of the planet is covered in water. Ground water is an essential resource for domestic, agricultural, and industrial uses (Jameel and Sirajudeen, 2006; Rengaraj et al., 1996).

Since groundwater quality is a major indicator of whether or not it is acceptable for human use, agriculture, and/or industry, understanding it is essential. Globally, worries over the quality of water have increased recently. Numerous studies were conducted to assess groundwater quality (Khan et al. 2020; Babiker et al. 2007). Groundwater is, in fact, the primary source of water supply and is today the most significant natural resource for a range of human pursuits (Prasad & Narayana, 2004). Over one-third of the world's population depends on groundwater for both direct consumption and food production, according to Morris et al. (2003). Additionally, many emerging and impoverished nations have looked to groundwater as a source of safe drinking water, especially for rural populations (Gordana et al. 2014).

The primary elements affecting groundwater quality are the degree and kind of human involvement as well as subterranean geochemical, physical, and biological processes (Zaporozec, 1981). As a result, it becomes essential to regularly assess the water's quality and come up with solutions (Yisa and Jimoh, 2010). It is impossible to improve the quality of contaminated groundwater by eliminating the contaminants at the source (Ramakrishnaiah et al. 2009). Because groundwater has a substantial potential to supply future water demand, it is imperative that human activities on the surface do not negatively impact the precious resource (Sarukkalige, 2009). Public health, hygiene, and the availability of clean water are all severely impacted by poor environmental management (Okoro et al. 2009). Tay and Kortatsi (2008) highlight the significance of groundwater as a source of drinking water for people worldwide. There is little doubt that changes in quality and the ensuing pollution can affect people's health.

India uses the most groundwater worldwide, with an estimated 230 km of groundwater being used each year. Furthermore, more than 60% of India's groundwater is utilized for agriculture, and 85% is used for drinking water. As a result, groundwater levels have dropped by more than 4 meters in various parts of the country (CGWB 2014). Groundwater is currently disappearing from the planet at a rate of 800 km^3 annually. Groundwater depletion is significantly influenced by irrigated agricultural regions (Burek et al. 2016, Dimple et al. 2022).

Study Area: Pench Kanhan Valley Coal Mining Area

The present study was conducted on the Chhindwara district which is located in the southern part of Madhya Pradesh. The study was conducted on the Western Coalfield regions of the Chhindwara district which was approximately located between latitude 21˚52' N to 22˚17' N and longitude 78˚45' E to 79˚20'E. it is part of the Pench Kanhan Valley Coalfield area, is located 30 kilometers (19 miles) northwest of Chhindwara. While the Pench Valley has five seams in a column of 50-80 m thickness, the Kanhan Valley coal belt runs for around 25 km (16 mi). The total coal reserves (proven, indicated, and inferred) in the Pench Kanhan Coalfield are 2,411.28 million tons, according to the Geological Survey of India. Newton, Chikli, Borkuhi, Ramanwara, Eklahera, Bamori, North Chandameta, East Dongar Chikli, Ambara Sukri, Datla, and Shivpuri are important collieries in the Pench valley.

MATERIALS AND METHODS

Eleven sample sites were used in this study. Samples of ground water were collected from tube wells and hand pumps. In 2021 and 2022, water samples were gathered from many sampling locations during the pre-monsoon, monsoon, and post-monsoon seasons (Table 1, Figure 1). pH, dissolved oxygen, and conductivity were among the 13 parameters of the samples that were examined on-site; the other parameters were examined in a lab. Standard procedures were followed in order to collect the samples in the sterile plastic sampling vial. Bottles were properly labeled and sealed on the spot following sample collection. The samples were brought to the laboratory of the Indira Priyadarshini College in Chhindwara while being kept cool. There, they were examined using the APHA's standard protocols (1986). Following analysis, the findings were contrasted with IS, BIS, and WHO criteria.

Table – 1: Showing the geographical positions of sampling locations

Station Name	Station Code	Type of Water	Latitude	Longitude
Urdhan	Site-1 (S1)	Hand Pump	22.280704	78.948102
	Site-2 (S2)	Hand Pump	22.281551	78.955840
Nehariya	Site-3 (S3)	Hand Pump	22.278661	78.964388
	Site-4 (S4)	Hand Pump	22.280520	78.977331
Zurra Mathni	Site-5 (S5)	Hand Pump	22.239437	78.932032
	Site-6 (S6)	Hand Pump	22.244252	78.943292
Vishnupuri	Site-7 (S7)	Hand Pump	22.201533	78.858497
	Site-8 (S8)	Hand Pump	22.195165	78.858158
New Sethia	Site-9 (S9)	Hand Pump	22.215822	78.843600
	Site-10 (S10)	Hand Pump	22.216018	78.844242
Mahendrapuri	Site-11 (S11)	Hand Pump	22.180273	78.77250

Figure – 1: Google earth map showing sample collection sites in study area

Data analysis

Standard procedures were followed in order to collect the samples in the sterile plastic sampling vial. Bottles were properly labeled and sealed on the spot following sample collection. The samples were brought to the laboratory of the Indira Priyadarshini College in Chhindwara while being kept cool. There, they were analyzed using the APHA's standard methods (1986). Following analysis, the findings were contrasted with IS, BIS, and WHO criteria. All water samples were gathered in plastic bottles (two trash) using a random sampling approach. Google Earth Pro software was used to determine groundwater sample locations. After these locations were selected, site visits were conducted to get locals' approval. During the sampling procedure, the positions of the research area were recorded using the Global Positioning System (GPS).

Physico-chemical analysis

The physical examination of water samples was conducted at the sampling site utilizing portable instruments, and this analysis was then performed in the laboratory of the Indira Priyadarshini College, Chhindwara; the results were used in the final results of that study.

WHO and IS 10500:2012 Drinking Standards

The present study was carried out Pench coal mine area in Chhindwara district. All the water quality parameters compared with WHO and IS 10500:2012 standard. Water quality regulations are critical to making sure the safety of drinking water. The World Health Organization (WHO) and the Bureau of Indian Standards (10500:2012) have established recommendations for acceptable water quality. This study compares the drinking water quality parameters set by the World Health Organization and the Indian Standard 10500:2012.

RESULT AND DISCUSSIONS

Effect of various parameters

Potential of Hydrogen (pH)

Ground water samples had an average pH of 7.69 for the pre-monsoon, monsoon, and post-monsoon seasons of 2021, ranging from 6.48 to 8.15. S7 had the highest value during the post-monsoon season, followed by S2, S10, S11, and S6, while S1 and S10 had the lowest values prior to the monsoon season. Ground water samples in 2022 had a mean pH of 7.73 and ranged from 7.20 to 8.20 during the pre-monsoon, monsoon, and post-monsoon seasons. S5, S9, S3, and S11 showed high values following the monsoon season, while S7 and S6 showed low values before to the monsoon season. The WHO states that the pH limit is between 6.5 and 8.5. Nevertheless, during the pre-monsoon, post-monsoon, and monsoon seasons, some of the samples that were examined dropped below the allowable limit. According to IS 10500:2012, drinking water should have a pH between 6.5 and 8.5. Similar findings were reported by Narayana and Suresh (1989).

Electrical Conductivity (EC)

In 2021 and 2022, ground water samples' electrical conductivity (EC) ranged from 241.79 to 489.55 µ.mho.cm^{-1}, with an average of 350.06 µ.mho.cm^{-1}. The EC values of the samples analyzed were found to be within the allowed limit defined by the WHO drinking water standard in the pre-monsoon, monsoon seasons and post-monsoon. EC has a WHO limit of 1000 µ.mho.cm^{-1}. The pre-monsoon (2021) season had the highest value at S11, while the post-monsoon (2021) season had the lowest value at S7. In a similar vein, the monsoon season (2022) saw the highest value at S6, while the pre-monsoon season (2022) saw the lowest value at S4. Similar findings were reported by Paliwal (1975), who noted that in the semi-arid and desert areas of Rajasthan, groundwater that was mostly accessible at depths of 200 to 300 feet showed electrical conductivity of well-water ranging from 5,000 µ.mho.cm^{-1} to 6,000 µ.mho.cm^{-1}. According to Tiwari (2001b) and Lakshmi et al. (2016), water's conductivity ranges from 529 to 3070 at 25°C, whereas electrical conductivity ranges from 375 to 925 µ.mho.cm^{-1} (Yogitha and Ramchandra, 2018).

Total Dissolved Solids (TDS)

Total dissolved solids (TDS) in ground water samples ranged from 158.00 to 328.00 mg/l throughout the post-monsoon, pre-monsoon, and monsoon seasons of 2021, with an average of 236.91 mg/l. The pre-monsoon season at S11 had the highest TDS value, whereas the post-monsoon season at S9 had the lowest value. Total dissolved solids (TDS) in ground water samples ranged from 172.00 to 303.00 mg/l in 2022, with an average of 231.38 mg/l. The pre-monsoon season at S4 had a low value, whereas the monsoon season at S6 had a high value. In the post-monsoon, pre-monsoon, and monsoon seasons, all sample TDS readings were determined to be within the WHO and IS 10500:2012 acceptable limits. Total dissolved solids levels fluctuate during the post-monsoon season due to the dissolving of soil particles (Ramababu and Bandyopadhyay, 1996). The disintegration of soil particles is responsible for the increase in TDS concentrations in groundwater seen in this study, according to Joseph (2001) and Rao et al. (1986).

Acidity

Ground water samples from the 2021 post-monsoon, pre-monsoon, and monsoon seasons had mean acidity levels of 14.18 mg/l, with a range of 6 to 30 mg/l. S11 and S8 had the highest values during the monsoon season, while S9 had the lowest values following the monsoon season. In a similar vein, samples obtained in 2022 had mean acidity values ranging from 6 to 20 mg/l. The acidity was lowest at S6 prior to the monsoon and highest at S9 following the monsoon. Similar results were found in the groundwater of Alappuzha district, Kerala, according to Aswini et al. (2016).

Total Alkalinity

The mean alkalinity values in ground water samples varied from 142 to 280 mg/l during the 2021 post-monsoon, pre-monsoon, and monsoon seasons, with an average of 188.91 mg/l. The pre-monsoon season had the highest value at S13, and the monsoon season had the lowest value at S7. In contrast, ground water samples in 2022 had an average alkalinity of 162.61 mg/l, ranging from 132 to 192 mg/l. The pre-monsoon season had the highest value at S7, while the monsoon season had the lowest value at S9. Similar results were found in the groundwater of Ludhiana, Punjab, according to Bhatnagar et al. (1981). The groundwater quality in the desert district of Rajasthan has been documented by Gopal and Bhargava (1982). Tiwari (2001b) reported similar results to the present findings. In the post-monsoon, pre-monsoon, and monsoon seasons, the alkalinity of every sample examined was found to be within the WHO-permitted range. The WHO states that an alkalinity level of 200 mg/l is appropriate.

Dissolved Oxygen (DO)

The average dissolved oxygen levels in ground water samples for the 2021 monsoon, pre-monsoon, and post-monsoon seasons were 7.61 mg/l, with a range of 6.6 to 8.8 mg/l. S1, S5, S6, and S11 had the highest value during the monsoon season, while S10 and S11 had the lowest value during the pre-monsoon season. The average dissolved oxygen levels in groundwater samples for the 2022 post-monsoon, pre-monsoon, and monsoon seasons were 8.38 mg/l, with a range of 7.4 to 9.2 mg/l. During the pre-monsoon season, S8 had a high value and S7 had a low value. Every location falls within an acceptable range and is suitable for drinking, according to the data collected. This could manifest as a drop in the groundwater table during the pre-monsoon season, which could result in an increase in DO levels. The DO levels dropped as a result of surface water runoff and precipitation raising the water table through percolation. These components support the conclusions of Adhikari (1998), Abdulla et al. (2000), Patel (1994), and Sohani et al. (2001). The WHO states that a dissolved oxygen level of 5 mg/l is appropriate. DO levels below 5 mg/l are undesirable, whereas those above 5 mg/l are considerable. In the post-monsoon, pre-monsoon, and monsoon seasons, DO readings in every sample under examination were found to be below the WHO recommended limit.

Biological Oxygen Demand (BOD)

The average BOD values in ground water samples varied from 0.8 to 2.40 mg/l during the 2021 post-monsoon, pre-monsoon, and monsoon seasons, with an average of 1.77 mg/l. S7 and S11 had high values during the pre-monsoon season, while S6 had low values. The mean BOD levels in ground water samples varied from 1.2 to 5.2 mg/l over the 2022 post-monsoon, pre-monsoon, and monsoon seasons, with an average of 2.48 mg/l. S3 had a high value during the monsoon season, whereas S1 and S11 had low values before to the monsoon. Bhatia and Dave's (1980) findings is in line with the current BOD values. They discovered that the biochemical oxygen demand values in rural Rourkela ranged from 0.25 to 21.0 mg/L, while Patel and Tiwari (1988) showed that BOD levels in the groundwater of Munirka villages in Delhi ranged from 2.43 to 14.31 mg/L.

Chemical Oxygen Demand (COD)

The average COD values in ground water samples for the 2021 monsoon, pre-monsoon, and post-monsoon seasons were 4.63 mg/l, with a range of 2.4 to 8.2 mg/l. Prior to the monsoon season, S11 had the highest value, and following the monsoon, S7 had the lowest value. The average COD values in ground water samples for the 2022 post-monsoon, pre-monsoon, and monsoon seasons were 5.70 mg/l, with a range of 3.0 to 10.50 mg/l. S3 had the highest value following the monsoon season, whereas S5 and S6 had the lowest value before to the monsoon. COD levels in the groundwater study in Arunachal Pradesh ranged from 2.5 mg/L to 20.5 mg/L, according to similar findings by Das (1991) and Viraraghavan and Warnock (1975). Singh et al. (2001) from Bikaner thought that COD was an important metric for assessing the carbonaceous fraction of organic matter. Over 70% of the samples fall within permissible ranges according to Kolekar's (2017) Standards method and the APHA's COD and BOD values. In the post-monsoon, pre-monsoon, and monsoon seasons, COD levels were found to be below the WHO-permitted limit in every sample that was analyzed. The WHO states that a COD level of 15 mg/l is acceptable.

Chloride

The average chloride levels in ground water samples varied from 38 to 172 mg/l during the 2021 post-monsoon, pre-monsoon, and monsoon seasons, with an average of 90.85 mg/l. The monsoon season saw the highest amount of chloride at S7, followed by S6, while the post-monsoon season saw the lowest value at S5. The average chloride levels in ground water samples varied from 36 to 118 mg/l over the 2022 post-monsoon, pre-monsoon, and monsoon seasons, with an average of 78.67 mg/l. S5 had a low value before to the monsoon, whereas S7 had a high value throughout the monsoon season. Chloride is safe for human health at lower concentrations. Large amounts can give water a salty taste without having a laxative effect, even though their concentrations are normally limited to 250 mg/L in supplies intended for public consumption (Ramprakash and Rao, 1989). During the post-monsoon, pre-monsoon, and monsoon seasons, all samples were found to have chloride levels within the WHO acceptable range. The WHO states that a maximum of 250 mg/l of chloride is permitted.

Free Carbon dioxide (Free CO_2)

The average free CO_2 levels in ground water samples obtained throughout the 2021 post-monsoon, pre-monsoon, and monsoon seasons ranged from 2 to 8 mg/l, while the average chloride value was 4.52 mg/l. While the lowest value was recorded during the pre-monsoon season at S2, followed by S6, the greatest value was found during the monsoon season at S6, followed by S10. In a similar vein, ground water samples in 2022 had an average chloride level of 7.67 mg/l and mean free CO_2 levels ranging from 4 to 12 mg/l. Before the monsoon season, S2 had the highest value, followed by S7, and after the monsoon season, S10 had the lowest value. Similarly, The values of free CO_2 ranges from 19.8 mg/L to 92.4 mg/L. (Shraddha, et al., 2025)

Bi-Carbonate and Carbonate

The mean Bi-Carbonate concentrations in ground water samples collected throughout the 2021 post-monsoon, pre-monsoon, and monsoon seasons ranged from 46 to 214 mg/l, with an average of 122.91 mg/l. S5 had the highest value during the pre-monsoon season and the lowest during the post-monsoon season. Prior to the post-monsoon season, S3 had the highest Bi-Carbonate value, followed by S7, and S8 had the lowest value. Similarly, in 2022, the mean Bi-Carbonate concentrations in ground water samples ranged from 58 to 104 mg/l, with an average of 80.91 mg/l. During the post-monsoon, pre-monsoon, and monsoon seasons of 2021, carbonate levels in groundwater samples varied from 0 to 18 mg/l, with an average of 5.27 mg/l. The S5 pre-monsoon season had the highest value, and the S8 pre-monsoon season had the lowest. During the post-monsoon, pre-monsoon, and monsoon seasons of 2022, carbonate levels in groundwater samples varied from 0 to 16 mg/l, with an average of 4.18 mg/l. The lowest value was recorded at S1, followed by S4 and S7 prior to the monsoon, and the highest value was recorded at S3 after the monsoon season.

Total Hardness (Ca and Mg Hardness)

The mean total hardness (TH) readings in ground water samples during the 2021 monsoon, pre-monsoon, and post-monsoon seasons varied from 92 to 244 mg/l, with an average of 146.73 mg/l. Ground water samples had an average Ca hardness of 97.82 mg/l, with a range of 60 to 162 mg/l. Ground water samples had an average magnesium hardness of 48.85 mg/l, ranging from 22 to 92 mg/l. Prior to the monsoon season, S10 had the highest total hardness, while during the monsoon season, S10 had the lowest. Ca hardness peaked at S11 prior to the monsoon season and decreased at S2 following it. The mean total hardness (TH) readings in ground water samples during the 2021 monsoon, pre-monsoon, and post-monsoon seasons varied from 92 to 244 mg/l, with an average of 146.73 mg/l. Ground water samples had an average Ca hardness of 97.82 mg/l, with a range of 60 to 162 mg/l. Ground water samples had an average magnesium hardness of 48.85 mg/l, ranging from 22 to 92 mg/l. Prior to the monsoon season, S10 had the highest total hardness, while during the monsoon season, S10 had the lowest. Ca hardness peaked at S11 prior to the monsoon season and decreased at S2 following it. Magnesium hardness peaked at S4 in the post-monsoon season and at S10 in the monsoon season. In the post-monsoon, pre-monsoon, and monsoon seasons, the TH (Ca and Mg) values of the examined samples were determined to be within the allowable limit. The WHO states that 200 mg/l of TH is the acceptable maximum.

Fluoride

The average fluoride levels in ground water samples for the 2021 post-monsoon, pre-monsoon, and monsoon seasons were 0.16 mg/l, with a range of 0.01 to 0.58 mg/l. Low values were noted in the monsoon season at S1, followed by S5, S9, and S10, while high values were recorded in the pre-monsoon season at S11 and S4. The average fluoride levels in ground water samples for the 2022 monsoon, pre-monsoon, and post-monsoon seasons were 0.24 mg/l, with a range of 0.04 to 1.2 mg/l. S8 had the highest value following the monsoon season, whereas S1 had the lowest values during that time. A high fluoride content in water can cause skeletal fluorosis, tooth mottling, knee joint deformation, spinal column bending, and other bone issues, such as paralysis, according to Sudarshan and Rajeshwara (1991). High fluoride levels can cause decreased spermatozoa motility in humans (Choudhury et al., 1970), which can result in low fertility and fewer births (Freni Jefferson, 1994), in addition to having a negative impact on economically significant plants and animals. During the post-monsoon, pre-monsoon, and monsoon seasons in both years, fluoride levels in every sample tested were found to be below the WHO-permitted limit. The WHO states that 1.5 mg/l of fluoride is appropriate.

Sodium

The average salt concentration in ground water samples for the 2021 monsoon, pre-monsoon, and post-monsoon seasons was 79.27 mg/L, with a range of 42 to 128 mg/l. The pre-monsoon season at S11 had the highest value, and the monsoon season at S8 had the lowest value. In contrast, the average sodium and potassium values in ground water samples varied from 52 to 112 mg/l over the 2022 post-monsoon, pre-monsoon, and monsoon seasons, with an average sodium value of 77.94 mg/L. S5 reported the highest value following the monsoon season, whereas S8 recorded the lowest value prior to the monsoon season. Similar findings were reported by Kalshetty et al. (2011) and Lakshmi et al. (2016). Ca>Na>Mg>K and Cl>So4>HCO3 are the most common ion abundance sequences in Chidambaram's drinkable water (Rajkumar et al., 2016). In the post-monsoon, pre-monsoon, and monsoon seasons, every sample examined was found to be within the WHO's allowable level. The WHO states that 200 mg/l of sodium is the acceptable maximum.

Potassium

The average potassium levels in ground water samples varied from 1.2 to 4.8 mg/l over the 2021 post-monsoon, pre-monsoon, and monsoon seasons, with an average of 2.57 mg/l. Low levels were seen at S1 during the monsoon, whereas high values were noted at S5 before the monsoon season. The average potassium levels in ground water samples for the monsoon, pre-monsoon, and post-monsoon seasons of 2022 were 3.25 mg/l, with a range of 1.8 to 6.2 mg/l. Before the monsoon season, S1 had the highest value, while after the monsoon season, S8 had the lowest value. Potassium deficiency in groundwater is caused by two factors, one of which is the reluctance of potassium minerals to breakdown. Potassium fixing in clay minerals is the other (Goldich, 1938).

The biological features of freshwater settings depend on potassium as a macronutrient. Similar findings were also reported by Pandey et al. (1996), Lakshmanan et al. (1986), Chowdhary et al. (1994), Garg et al. (2000), Gupta and Singh (2000). During the post-monsoon, pre-monsoon, and monsoon seasons, potassium levels in all assessed samples were found to be within the WHO-permitted limits. The WHO states that 12 mg/l of potassium is acceptable.

Nitrate

During the 2021 monsoon, pre-monsoon, and post-monsoon seasons, the average nitrate levels in groundwater samples were 7.4 mg/l, with a range of 4 to 11.20 mg/l. While S1 recorded a low value during the monsoon season, S5 recorded a high value prior to the monsoon. During the 2022 post-monsoon, pre-monsoon, and monsoon seasons, the average nitrate levels in the ground water samples were 7.84 mg/l, with a range of 3.8 to 13 mg/l. Similar to the previous year, S1 had the lowest value during the monsoon season and S5 had the highest value during the pre-monsoon season. A similar finding has been made by Saxena and Saxena (2013). In the post-monsoon, pre-monsoon, and monsoon seasons, nitrate levels in groundwater samples were determined to be within the WHO's allowable range. The WHO states that 45 mg/l of nitrate is the acceptable level.

Sulphate (SO4)

Ground water samples from 2021's post-monsoon, pre-monsoon, and monsoon seasons had sulphate concentrations ranging from 50 to 102 mg/l, with an average of 70.55 mg/l. The monsoon season had the lowest score at S9, while the pre-monsoon season had the highest value at S10. S6 recorded the greatest value during the pre-monsoon season, while S7 recorded the lowest value during the monsoon season. The mean sulfate levels in ground water samples during the post-monsoon, pre-monsoon, and monsoon seasons of 2022 ranged from 50 to 102 mg/l, with an average of 71.06 mg/l. Similar findings were made by Abool et al., (1986), who reported that the sulfate content of well water in Bhopal city varies from 0.2 mg/L to 65.6 mg/L. According to Jacks (1973), sulfate levels varied from 0.3 mg/L to 20.3 mg/L. In the post-monsoon, pre-monsoon, and monsoon seasons, every sulfate sample that was examined was determined to be within the WHO's allowable range. The WHO states that 200 mg/l of sulfate is the acceptable maximum.

Heavy Metals

Iron (Fe) concentrations in groundwater samples during the 2021 monsoon, pre-monsoon, and post-monsoon seasons ranged from 0.01 to 0.8 mg/l, with an average of 0.14 mg/l. In the pre-monsoon season, S6 has a high iron (Fe) value, while S2 has a low iron (Fe) value in the research region. The majority of Cupper (Cu) ground water samples were found to be below the detectable limit (BDL), with the highest concentration of Cupper (Cu) recorded at S5 during the monsoon season. During the pre-Monsson season, the collected ground water samples had a high value of nickel (Ni) at S10 and a low value at S1. Zinc (Zn) levels in groundwater samples were found to be high at S6 during the post-Monsson season and low at S3 during the Monsson season. Iron (Fe) concentrations in ground water samples during the 2022 monsoon, pre-monsoon, and post-monsoon seasons ranged from 0.01 to 0.6 mg/l, with an average of 0.14 mg/l. S6 has a high iron (Fe) value during pre-monsoon seasons, while S5, S7, and S8 have low iron (Fe) values during post-monsoon seasons in the research area. In the pre-monsoon season, the highest concentration of copper (Cu) in groundwater samples was discovered at S6, and 50% of these samples had concentrations below the detectable limit (BDL). Nickel (Ni) levels in groundwater samples were found to be high at S5 during the pre-Monsson season and low at S2 during the Monsson season. In the post-monsoon season, S8 had a high Zinc (Zn) value, but S1 had a low Zinc (Zn) value in the groundwater samples that were obtained during the Monsson season.

CONCLUSION

The present study analyzed ground water samples collected from 11 sites in six villages in and around Pench Kanhan coalfield, Chhindwara District area, for the years 2021 and 2022. According to the study, mining operations have a significant impact on the quality of groundwater in the Chhindwara area of Madhya Pradesh. Pre-monsoon pollutant concentrations are often higher, according to analyses of a number of physicochemical parameters like as pH, TDS, EC, chloride, hardness, nitrate, and heavy metals. The findings show the importance of regular monitoring due to the potential risks associated with mining-induced contamination, even if the majority of values fall within the permitted thresholds established by ISI and WHO guidelines.

ACKNOWLEDGEMENT

The authors thank Amity University Rajasthan, Jaipur, for all of their cooperation in carrying out the research work.

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