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Comparative Analysis of Hydro-Chemical Characteristics in Rangareddy District Before and After the Monsoon

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Abstract

Environmental fluids are an essential resource for all living organisms and are naturally abundant on Earth. Nowadays this environmental water is heavily polluted and is causing many health problems to the living and non-living organisms using this water. Therefore, efforts are being made to find the composition of the environmental waters. Unfortunately, using river water for various industries has led to water pollution, posing a significant threat to life on Earth.As a result of this contamination, many have shifted to relying on groundwater to meet their water needs. However, it's important to note that surface water and groundwater are interconnected. Pollution in surface water alternatively lead to groundwater contamination, which, in turn, has far-reaching consequences for the global water cycle.

To address this issue, a comprehensive study was conducted in and around Rangareddy District, focusing on the Musi River and spanning both pre-monsoon (March-May) and post-monsoon (October – December) seasons in 2022. The study involved the collection of water samples from various boreholeslocated at five different sites in Ranga Reddy district near Musi River. Fourteen key physico-chemical parameters which include factors like pH, electrical conductivity, total dissolved solids (TDS), and some specific anions and cations, were analyzed to assess the water quality in the region. In the present study it is observed that, in most of the sites,the primary parameter pH shifted towards a higher level from 7.002 (pre-monsoon) to 7.048 (post-monsoon).

INTRODUCTION

Water is the most vital compound essential for the survival of humans and all forms of life. Its significance in sustaining life cannot be overstated. Water is an invaluable natural resource that not only provides a habitat for diverse aquatic life in various ecosystems like rivers, lakes, and oceans but also constitutes a significant portion of the human body, accounting for about two-thirds of its composition [1].However, globalization and industrialization have led to a concerning escalation in the pollution of both surface water and groundwater. This pervasive pollution affects nearly all water bodies, including vital groundwater sources. The contamination of water sources poses a severe threat as polluted water mingles with pristine sources, eroding the natural quality of water.Groundwater, in particular, plays a crucial role in meeting the drinking water needs of both urban and rural areas, facilitating various water supply systems like hand pumps and piped water supplies. Yet, the improper disposal of industrial effluents and domestic sewage waste into rivers has led to a detrimental decline in water quality. This deterioration has far-reaching consequences, especially in terms of groundwater.Rangareddy district, home to 15.05% of Telangana's population, faces substantial water demands due to its extensive activities. Groundwater recharge has historically been interconnected with surface water sources in this region [2], situated on the Deccan plateau along the banks of the Musi River. The Musi River, a tributary of the Krishna River, originates in the Ananthagiri Hills, flowing through the Deccan Plateau in Telangana. Historically, dams like Himayat Sagar and Osman Sagar served as essential water sources for the district.Unfortunately, as the river traverses through Hyderabad, it undergoes a distressing transformation into what resembles a colossal sewer, contaminated by the city's industrial waste and garbage. The root causes of this wastewater production are attributed to factors such as urbanization, and the

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expansion of domestic, industrial, and commercial sectors [3-7].The burgeoning global population continually increases demands for food production, industrial activities, and domestic use, leading to more substantial withdrawals from our finite and renewable freshwater resources [8-10].Despite its historical use for drinking, agricultural, and horticultural purposes via small reservoirs, the Musi-River experienced a catastrophic flood in 1908, leading to significant damage, with tens of thousands of houses and numerous lives lost. In response, the construction of Osman Sagar Dam, initiated by engineer Nawab Ali Nawaz Jung Bhadur, was followed by the establishment of Himayat Sagar Dam. These dams provided drinking water and supported extensive agricultural cultivation downstream of the Musi River, primarily rice crops in rural areas. However, the river now receives substantial amounts of untreated sewage, including industrial and domestic waste, with occasional additions of medical waste. These pollutants are primarily the result of rapid and uncontrolled urbanization. The escalating demand for water in the Greater Hyderabad region has led to the redirection of drinking water sources from Krishna, Manjeera, and Godavari through water pipelines to Hyderabad. In the process, wastewater from the city is discharged into the Musi River. This has led to the deterioration of water quality, marked by unpleasant odors and public aversion to the river water. Consequently, the Musi River has been labeled the first priority river by the first report of the NGT (National Green Tribunal) on Musi River – 2021.The major portion of waste generated is either released into the atmosphere or dispersed into the land, further exacerbating pollution issues as these contaminants are carried away by precipitation, runoff, and filtration processes. The cumulative impact of human activities is the contamination of surface water bodies and groundwater aquifers. Such activities produce a wide range of pollutants, including solvents, oils, grease, plastics, plasticizers, phenols, heavy metals, pesticides, and suspended solids, all of which pose environmental and health hazards [11-13].Numerous studies have been conducted in India to evaluate the physicochemical characteristics of groundwater and detect contamination [14-21], underscoring the need for a comprehensive understanding of the challenges posed by water pollution and the critical role of groundwater in addressing them.

SI. No.	Parameter	Instrument/ Method
1	pH	pH meter
2	Specific Conductivity	Conductivity Meter
3	Total Dissolved Solids (TDS)	Sample Evaporation
4	Carbonate (CO_3^{2-}) Ion	Titration Method
5	Sodium (Na^+) Ion	Flame Photometer
6	Potassium (K^+) Ion	Flame Photometer
7	Calcium (Ca^{+2}) Ion	Titration Method
8	Magnesium (Mg^{+2}) Ion	Titration Method
9	Bicarbonate (HCO_3^-) Ion	Titration Method
10	Chloride (Cl^-) Ion	Titration Method
11	Sulphate (SO_4^{2-}) Ion	Nephelometer
12	Nitrate (NO_3^-) Ion	UV Spectrophotometer
13	Fluoride (F^-) Ion	Ion Meter

METHODOLOGY

During the pre-monsoon (1st March 2022 – 31st May 2022) and post-monsoon (1st October 2022 – 31st December 2022) seasons in 2022,water samples from five distinct sites in the Rangareddy district, each located approximately 30 kilometers apart were gathered. These sampling locations were designated as follows: Site-1 in Amangal, Site-2 in Shadnagar, Site-3 in Kothur, Site-4 in Rajendranagar, and Site-5 in Moinabad.To collect these samples, we obtained five groundwater samples from various points. These sources included dug wells, bore wells, and hand pumps that were strategically positioned along the MusiRiver. While collecting samples from open wells, a weighted

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sample bottle or sampleris used. Additionally, samples from tube wells were obtained after allowing the well to run for approximately 5 minutes.Stringent precautions were taken to minimize the risk of contamination during the bottling process. Specifically, each bottle was meticulously rinsed to ensure the absence of any potential contaminants. All of these water samples were then subjected to a comprehensive analysis of their various parameters, a task that was completed within one week.

MATERIALS AND METHODS

In the pre & post-monsoon period, samples from various designated sites were collected in the Rangareddy District to assess water quality. A range of analytical methods and instruments were employed, to evaluate different water quality parameters as follows:

Sodium Adsorption Ratio (SAR)

The Sodium Adsorption Ratio (SAR) is a numerical value that indicates the proportion of sodium ions in water relative to the combined concentration of calciumand magnesium ions. SAR is calculated using the following formula:

$$\textbf{SAR} = \frac{[Na^{+}]}{\{\frac{([Ca^{2+}]+[Mg^{+2}])}{2}\}^{\frac{1}{2}}}$$

With all concentrations being expressed in milliequivalents per liter.

RESULTS AND DISCUSSION

A comparative analysis of various parameters, including pH, EC, Total Dissolved Solids (TDS), levels of Carbonate, Bicarbonate, Chloride, Fluoride, Nitrate, Sulphate, Sodium, Potassium, Calcium, and Magnesium during both the pre-monsoon and post-monsoon seasonswas done (Table 1 and 2). Several of these parameters were found to be within permissible limits at specific sites (Table 3).Specific Electric Conductance (EC), which serves as an indicator of water quality, was employed to determine the total dissolved solids in water. This measure is taken at a temperature of 25ºC. High TDS levels can render water unsuitable for various purposes, and it can be directly derived from the EC readings. TDS represents the concentration of both organic and inorganic substances that are dissolved in water or present in suspended form. The elevated TDS levels observed in our study are attributed to the discharge of domestic waste into the river.Alkalinity in the water is influenced by the presence of bicarbonates in the form of calcium carbonate. It was noted that the river exhibited lower alkalinity levels during the rainy season. Chloride concentration in water varies, and it is predominantly available as calcium, magnesium, and sodium chlorides.Nitrate concentration in water increased due to the discharge of industrial and domestic waste. Sulfate is a common anion in natural water and plays a role in water hardness. Sodium ions in water are generally considered beneficial for health; however, high sodium content can lead to health issues like high blood pressure, renal failure, hormonal disturbances etc., Additionally, excessive sodium is not suitable for agriculturalpurposes and industrial use.Potassium in water, when within an acceptable range, is beneficial for health. Calcium, which combines with carbonate, bicarbonate, sulfate, and chloride, is a crucial parameter for measuring water hardness. It has the effect of inhibiting lather formation when using soap. Magnesium also contributes to water hardness and is found in various forms in water, including $MgCO_3$, $MgSO_4$, and $MgCl_2$. The concentrations of calcium and magnesium influence the total hardness of water. It may be suitable for domestic, agricultural, and industrial use. It's important to note that hard water is not a direct cause of water pollution, it may not be suitable for domestic and agricultural use.

Table 1: Groundwater Quality Pre-Monsoon in the Rangareddy District

SI. No.	Parameters	Site 1	Site 2	Site 3	Site 4	Site 5
		Amangal	Shadnagar	Kothur	Rajendranagar	Moinabad
1	pH at 25^0 C	7.85	6.92	6.97	6.95	7.32
2	Sp.Cond. at 25^0 C	1780	1508	1616	3163	808
3	TDS (mg/L)	1139	965	1034	2024	517
4	Na^+(mg/ L)	113	46	160	105	58
5	K^+(mg/ L)	2	1	2	2	2

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6	Ca^{+2}(mg/ L)	152	144	96	384	64
7	Mg^{+2}(mg/ L)	68	78	49	83	34
8	$CaCO_3$ (mg/ L)	0	0	0	0	0
9	HCO_3^-(mg/ L)	440	390	310	270	330
10	Cl^-(mg/ L)	240	240	230	760	40
11	SO_4^{-2}(mg/L)	24	15	32	136	14
12	NO_3^-(mg/L)	140	61	140	32	27
13	F^- (mg/L)	0.57	0.49	0.51	0.99	0.54
14	SAR	1.91	0.77	3.32	1.26	1.46

Table 2: Groundwater Quality Post-Monsoon in the Rangareddy District

SI. No.	Parameters	Site 1	Site 2	Site 3	Site 4	Site 5
		Amangal	**Shadnagar**	**Kothur**	**Rajendranagar**	**Moinabad**
1	pH at 25^0 C	7.62	7.1	7.14	7.1	7.28
2	Sp.Cond. at 25^0 C	264	837	120	582	1312
3	TDS (mg/L)	169	536	77	372	840
4	Na^+(mg/L)	7	44	13	12	168
5	K^+(mg/L)	3	1	1	1	4
6	Ca^{+2}(mg/L)	32	56	8	88	56
7	Mg^{+2}(mg/L)	15	44	5	15	39
8	$CaCO_3$ (mg/L)	0	0	0	0	0
9	HCO_3^-(mg/L)	140	300	30	280	160
10	Cl^-(mg/L)	10	40	20	10	200
11	SO_4^{2-}(mg/L)	8	15	8	14	235
12	NO_3^-(mg/L)	13	52	1	3	2
13	F^-(mg/L)	0.18	0.98	0.14	0.36	0.4
14	SAR	0.26	1.06	0.89	0.31	4.22

Table 3: BIS 10500 (2012) Standard Value of Ground Quality Drinking Water.

SI. No	Substance Characteristic	Requirement (desirable)	Permissible limit
1	pH value	6.5 to 8.5	No Relaxation
2	Specific Conductivity (µS/cm)	0.25-1	-------
3	Total Hardness as $CaCO_3$, mg/L Max	300	600
4	Bicarbonate mg/L, Max	200	600
5	Chlorides (as Cl^-) mg/L, Max	250	1000
6	Fluoride (as F^-) mg/L, Max	1	1.5
7	Nitrate (as NO_3^-) mg/L	Max 45	No Relaxation
8	Sulfate (as SO_4^{2-}) mg/L	Max 200	400
9	Calcium (as Ca^{+2}) mg/L	Max 75	200
10	Magnesium (as Mg^{2+}) mg/L	Max 30	100

At all proposed sites maximum number of parameters exceeds the standardlimits given by the BIS 10500 (2012) standard of drinking water [21], given above in Table III. Nitrate, Chloride, and Total Hardnesswere also too high at the proposed sites; excess Fluoride is presentwhich affects health. Total dissolved solids, Chloride,Fluoride, Nitrate, and Total Hardness are compared with the BIS10500 (2012) standard of

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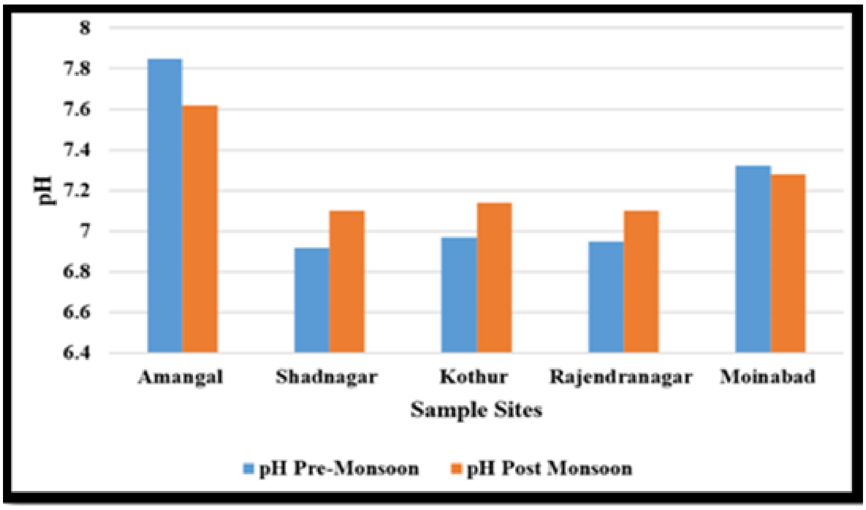
drinking water value in pre-monsoonand post-monsoon represented by graphical method at the proposed siteswhich is shown in graphs 1 to 14. These parameters directly or indirectly affect human health. In the months of Pre-monsoon, groundwater levels decrease due to summer or less rain, groundwater levels decrease due to variation of concentrations water may be polluted.The study ofthe given parameters of selected sites reveals that they were affected by higher contamination, the comparison is given below by graphical method and discusses affect and health-impacted parameters such as Total DissolvedSolids (TDS), presence of ions like Chloride, Fluoride, Nitrate, and Total Hardness ofwater proposed five sites at both seasons these values are comparedwith standard values given by the BIS (Bureau of Indian Standards) (Table 3). In graph representation, the seasons were taken on X- axis, and site groundwater quality parameterswereon Y- axis.

Analysis of pH Parameter

The mean pH value slightly increased from 7.202 before the monsoon to 7.248 after the monsoon. Before the monsoon, the site with the highest pH was "Amangal" (pH 7.85), while the lowest was "Shadnagar" (pH 6.92). After the monsoon, the site with the highest pH remained "Amangal" (pH 7.62), while the lowest was "Shadnagar" (pH 7.1). The pH values at all sites increased slightly after the monsoon, indicating a trendtoward higher pH levels. Seasonal changes, such as increased rainfall and water table fluctuations during the monsoon, can influence pH levels. The increase in pH after the monsoon might be attributed to the dilution effect caused by higher water recharge during the rainy season. These pH variations, though relatively small, can have implications for water quality and the aquatic ecosystem. Understanding seasonal pH trends is essential for managing water resources and assessing the environmental impact on aquatic life.

Table 4: Amount of pH in Pre - & Post – Monsoon Season

Sites	pH	
	Pre-Monsoon	Post Monsoon
Amangal	7.85	7.62
Shadnagar	6.92	7.1
Kothur	6.97	7.14
Rajendranagar	6.95	7.1
Moinabad	7.32	7.28
Mean Value	7.202	7.248



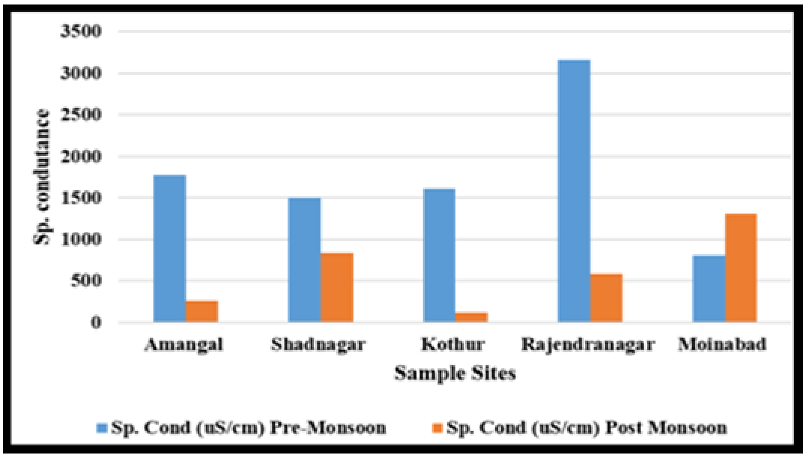
Graph 1: Comparison of pH in Pre - & Post – Monsoon Season

Analysis of Specific Conductivity Parameter

The mean specific conductivity (Sp. Cond) decreased significantly from 1775.0 µS/cm before the monsoon to 623.0 µS/cm after the monsoon.Before the monsoon, the site with the highest Sp. Cond was "Rajendranagar" (3163 µS/cm), while the lowest was "Moinabad" (808). After the monsoon, the site with the highest Sp. Cond remained "Rajendranagar" (582 µS/cm), and the lowest was "Kothur" (120 µS/cm). Specific conductivity values decreased at all sites after the monsoon, indicating a substantial drop in ion concentrations in the groundwater.The significant decrease in specific conductivity after the monsoon suggests dilution of ions due to increased recharge and reduced evaporation during the rainy season. A decrease in specific conductivity can indicate improved water quality in terms of reduced dissolved solids and ions. This change can be beneficial for various uses of groundwater, including drinking water supply and irrigation.Site-specific factors, such as geological formations and local anthropogenic activities, can influence Sp. Cond variations. Understanding these local factors is important for a comprehensive analysis.

Table 5: Amount of Specific Cond. in Pre-Monsoon & Post –Monsoon Season

Sites	Sp. Cond (µS/cm)	
	Pre-Monsoon	Post Monsoon
Amangal	1780	264
Shadnagar	1508	837
Kothur	1616	120
Rajendranagar	3163	582
Moinabad	808	1312



Graph 2: Comparison of Specific Cond. in Pre – Monsoon & Post – Monsoon Season

Analysis of Total Dissolved Solids (TDS):

The mean Total Dissolved Solids (TDS) decreased significantly from 1155.8 mg/L before the monsoon to 398.8 mg/L after the monsoon. Before the monsoon, the site with the highest TDS was "Rajendranagar" (2024 mg/L), while the lowest was "Moinabad" (517 mg/L). After the monsoon, the site with the highest TDS remained "Moinabad" (840 mg/L), and the lowest was "Kothur" (77 mg/L). TDS values decreased at all sites after the monsoon, indicating a significant reduction in dissolved solids in the groundwater.

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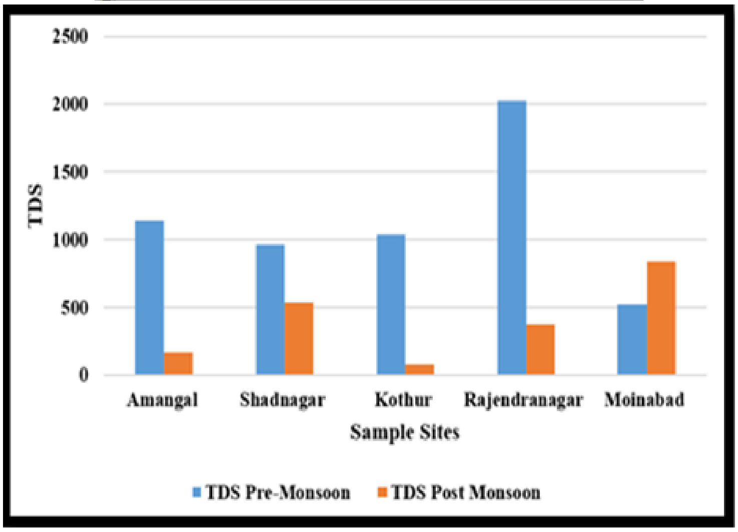
Table 6: Amount of TDS in Pre – Monsoon & Post – Monsoon Season

Sites	TDS	
	Pre-Monsoon	Post Monsoon
Amangal	1139	169
Shadnagar	965	536
Kothur	1034	77
Rajendranagar	2024	372
Moinabad	517	840



Graph 3: Comparison of TDS in Pre - Monsoon & Post – Monsoon Season

The substantial decrease in TDS after the monsoon suggests dilution of dissolved solids, which is typical during the rainy season when groundwater recharge occurs. The observed decrease in TDS after the monsoon season is indicative of improved groundwater quality with lower dissolved solids concentrations, which is typically associated with increased recharge and dilution during the rainy season.

Analysis of Sodium Ion (Na^+) Concentration

The mean sodium ion (Na^+) concentration decreased from 96.4 mg/L before the monsoon to 48.8 mg/L after the monsoon.Before the monsoon, the site with the highest Na^+ concentration was "Kothur" (160 mg/L), while the lowest was "Shadnagar" (46 mg/L).After the monsoon, the site with the highest Na^+ concentration was "Moinabad" (168 mg/L), and the lowest was "Amangal" (7 mg/L).

Table 7: Amount of Na^+ in Pre – Monsoon & Post – Monsoon Season

Sites	Na+ (mg/L)	
	Pre-Monsoon	Post Monsoon
Amangal	113	7
Shadnagar	46	44
Kothur	160	13
Rajendranagar	105	12
Moinabad	58	168

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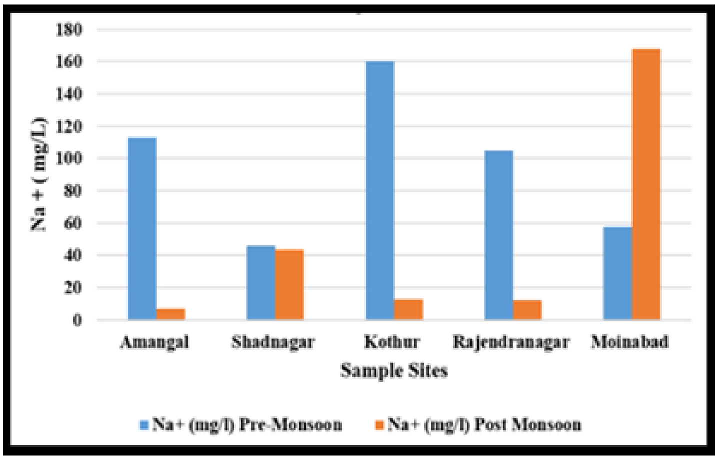

Graph 4: Comparison of Na^+ in Pre – Monsoon & Post – Monsoon Season

Na^+ concentrations decreased at most sites after the monsoon, indicating a reduction in sodium ions in the groundwater. The decrease in Na+ concentrations can be attributed to the dilution effect of increased recharge during the monsoon season, which leads to reduced ion concentrations.The decrease in sodium ion concentrations after the monsoon season is consistent with the dilution effect typical of the rainy season, resulting in improved groundwater quality. This reduction has positive implications for various water uses, especially in agriculture and drinking water supply.

Analysis of Potassium Ion (K^+) Concentration

The mean potassium ion (K^+) concentration increased slightly from 1.8 mg/L before the monsoon to 2.0 mg/L after the monsoon.Before the monsoon, all sites had similar K+ concentrations, with values mostly around 2 mg/L.After the monsoon, there was somevariability among sites, with the highest K^+ concentration observed at "Moinabad" (4 mg/L) and the lowest at "Shadnagar" (1 mg/L).

Table 8: Amount of K^+ in Pre – Monsoon & Post – Monsoon Season

Sites	K+ (mg/l)	
	Pre-Monsoon	Post Monsoon
Amangal	2	3
Shadnagar	1	1
Kothur	2	1
Rajendranagar	2	1
Moinabad	2	4

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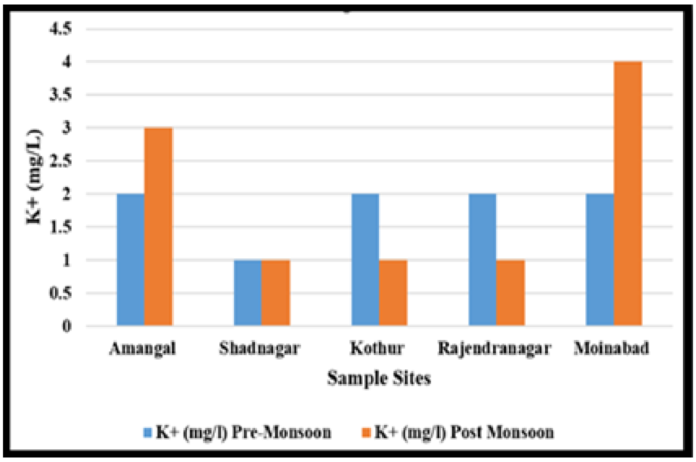


Graph 5: Comparison of K^+ in Pre – Monsoon & Post – Monsoon Season

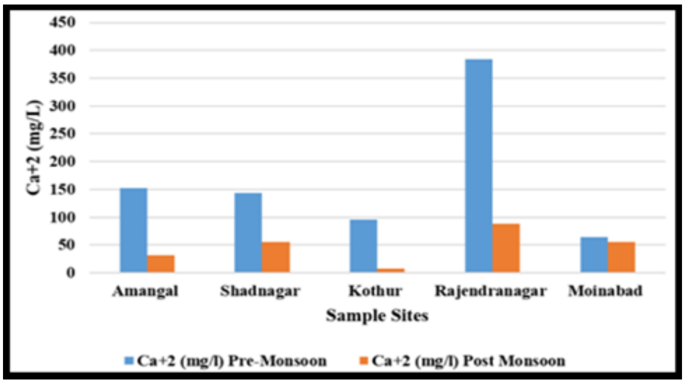
While the overall increase in K+ concentration is small, there is some variation between sites. K^+ levels increased at some sites and remained relatively stable at others. The small increase in potassium ion concentrations after the monsoon season suggests some variations in ion sources or local geological factors. While the change is relatively minor, it highlights the importance of continuous monitoring and considering local conditions in groundwater quality assessments.

Analysis of Calcium Ion (Ca^{2+}) Concentration

The mean calcium ion (Ca^{2+}) concentration decreased significantly from 168 mg/L before the monsoon to 48 mg/L after the monsoon.Before the monsoon, the site with the highest calcium ion concentration was "Rajendranagar" (384 mg/L), while the lowest was "Moinabad" (64 mg/L).

Table 9: Amount of Ca^{+2} in Pre – Monsoon & Post – Monsoon Season

Sites	Ca+2 (mg/l)	
	Pre-Monsoon	Post Monsoon
Amangal	152	32
Shadnagar	144	56
Kothur	96	8
Rajendranagar	384	88
Moinabad	64	56



Graph 6: Comparison of Ca^{+2} in Pre – Monsoon & Post – Monsoon Season

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After the monsoon, the site with the highest Ca^{2+} concentration remained "Rajendranagar" (88 mg/L), and the lowest was "Kothur" (8 mg/L).Ca^{2+} concentrations decreased at all sites after the monsoon, indicating a significant reduction in calcium ions in the groundwater. The decrease in Ca^{2+} concentrations can be attributed to the dilution effect of increased recharge during the monsoon season, which leads to reduced ion concentrations.The observed decrease in calcium ion concentrations after the monsoon season is indicative of improved groundwater quality with reduced water hardness. This change has implications for water quality in terms of household use and industrial processes, and it aligns with the dilution effect typically associated with increased groundwater recharge during the rainy season.

Analysis of Magnesium Ion (Mg^{2+}) Concentration

The mean magnesium ion (Mg^{2+}) concentration decreased from 62.4 mg/L before the monsoon to 23.6 mg/L after the monsoon. Before the monsoon, the site with the highest Mg^{2+} concentration was "Rajendranagar" (83 mg/L), while the lowest was "Moinabad" (34 mg/L).After the monsoon, the site with the highest Mg^{2+} concentration was again "Shadnagar" (44 mg/L), and the lowest was "Kothur" (5 mg/L). Mg^{2+} concentrations decreased at all sites after the monsoon, indicating a significant reduction in magnesium ions in the groundwater. The decrease in Mg^{2+} concentrations can be attributed to the dilution effect of increased recharge during the monsoon season, which leads to reduced ion concentrations. The observed decrease in magnesium ion concentrations after the monsoon season is indicative of improved groundwater quality with reduced water hardness. This change has implications for water quality interms of household use and industrial processes and aligns with the dilution effect typically associated with increased groundwater recharge during the rainy season. In this case, the absence of detectable calcium carbonate suggests that the groundwater in these areas is relatively soft and does not contribute to water hardness, which can be advantageous for specific uses.

Table 10: Amount of Mg^{+2} in Pre – Monsoon & Post – Monsoon Season

Sites	Mg+2 (mg/l)	
	Pre-Monsoon	Post Monsoon
Amangal	68	15
Shadnagar	78	44
Kothur	49	5
Rajendranagar	83	15
Moinabad	34	39

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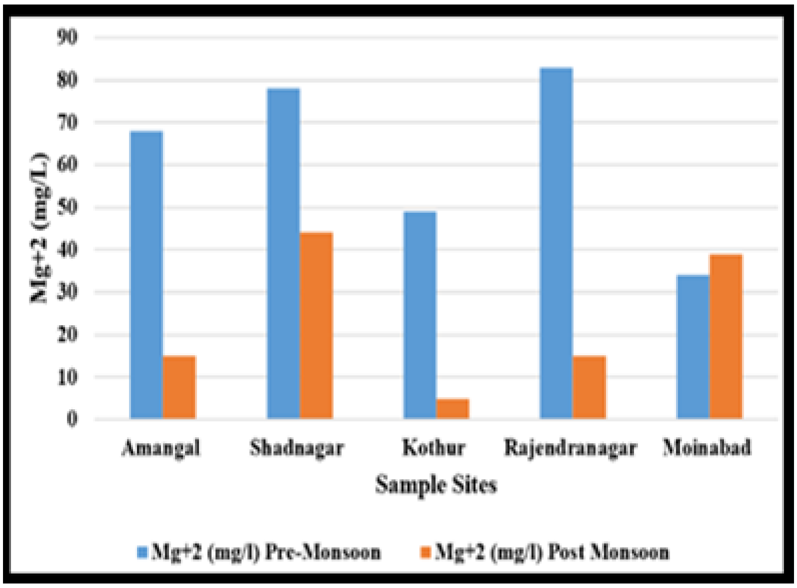

Graph 7: Comparison of Mg^{+2} in Pre – Monsoon & Post – Monsoon Season

Analysis of Bicarbonate Ion (HCO_3^-)

The mean bicarbonate ion (HCO_3^-) concentration decreased from 348 mg/L before the monsoon to 182 mg/L after the monsoon.Before the monsoon, the site with the highest HCO_3^- concentration was "Amangal" (440 mg/L), while the lowest was "Rajendranagar" (270 mg/L). After the monsoon, the site with the highest HCO_3^- concentration remained "Shadnagar" (300 mg/L), and the lowest was "Kothur" (30 mg/L).HCO_3^- concentrations decreased at all sites after the monsoon, indicating a significant reduction in bicarbonate ions in the groundwater. The decrease in HCO_3^- concentrations can be attributed to various factors, including changes in ion sources, groundwater recharge, and local geology. Increased recharge during the monsoon can lead to the dilution of ions. The observed decrease in bicarbonate ion concentrations after the monsoon season is indicative of improved groundwater quality with reduced alkalinity and water hardness. This change has implications for water quality, making it potentially more suitable for drinking water and industrial processes, but continued monitoring is necessary to track changes over time.

Table 11: Amount of HCO_3^{-1} in Pre – Monsoon & Post – Monsoon Season

Sites	HCO_3^{-1} (mg/l)	
	Pre-Monsoon	Post Monsoon
Amangal	440	140
Shadnagar	390	300
Kothur	310	30
Rajendranagar	270	280
Moinabad	330	160

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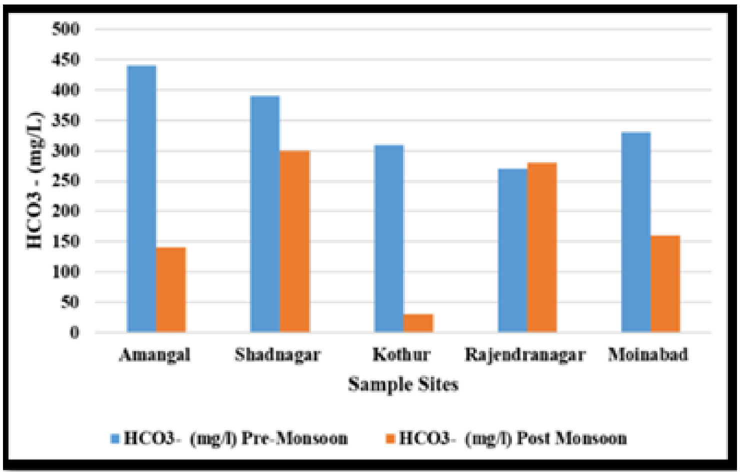


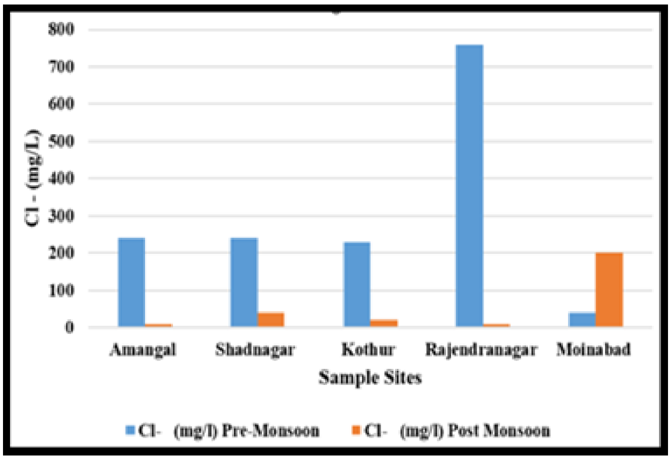
Graph 8: Comparison of HCO_3^{-1} in Pre – Monsoon & Post – Monsoon Season

Analysis of Chloride Ion (Cl^-)

The mean chloride ion (Cl^-) concentration decreased significantly from302 mg/L before the monsoon to 56 mg/L after the monsoon.Before the monsoon, the site with the highest Cl^- concentration was "Rajendranagar" (760 mg/L), while the lowest was "Moinabad" (40 mg/L). After the monsoon, the site with the highest Cl^- concentration was "Moinabad" (200 mg/L), and the lowest was "Rajendranagar & Amangal" (10 mg/L).Cl^- concentrations decreased at most sites after the monsoon, indicating a substantial reduction in chloride ions in the groundwater.

Table 12: Amount of Cl^- in Pre - Monsoon& Post – Monsoon Season

Sites	Cl- (mg/l)	
	Pre-Monsoon	Post Monsoon
Amangal	240	10
Shadnagar	240	40
Kothur	230	20
Rajendranagar	760	10
Moinabad	40	200



Graph 9: Comparison of Cl^- in Pre – Monsoon & Post – Monsoon Season

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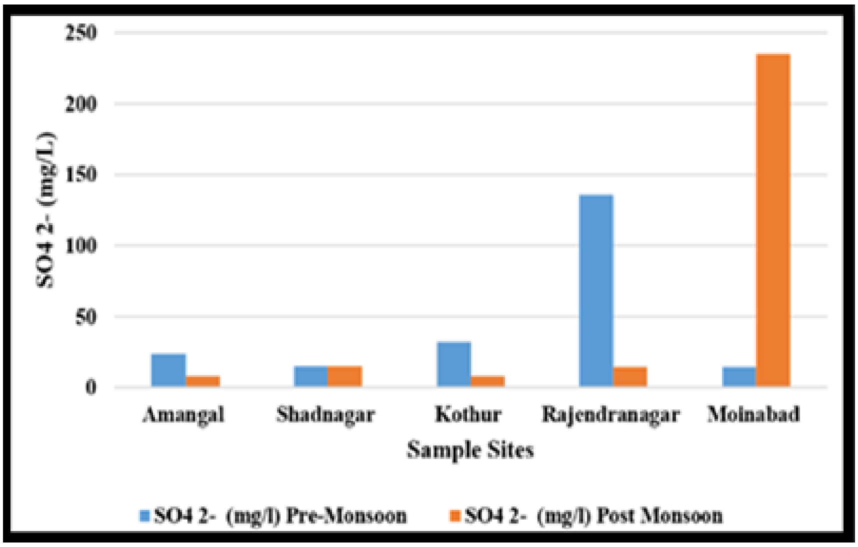
The decrease in Cl^- concentrations can be attributed to the dilution effect of increased recharge during the monsoon season, which leads to reduced ion concentrations. The observed decrease in chloride ion concentrations after the monsoon season is indicative of improved groundwater quality with reduced salinity. This change has positive implications for various water uses, particularly drinking water supply, as it makes the water more palatable and suitable for consumption. However, continued monitoring is necessary to ensure that these improvements persist over time.

Analysis of Sulfate Ion (SO_4^{2-})

The mean sulfate ion (SO_4^{2-}) concentration increased slightly from 44.2 mg/L before the monsoon to 56 mg/L after the monsoon. Before the monsoon, the site with the highest SO_4^{2-} concentration was "Rajendranagar" (136 mg/L), while the lowest was "Shadnagar" (15 mg/L).

Table 13: Amount of SO_4^{2-} in Pre – Monsoon & Post – Monsoon Season

Sites	SO_4^{2-} (mg/l)	
	Pre-Monsoon	Post Monsoon
Amangal	24	8
Shadnagar	15	15
Kothur	32	8
Rajendranagar	136	14
Moinabad	14	235



Graph 10: Comparison of SO_4^{2-} in Pre – Monsoon & Post – Monsoon Season

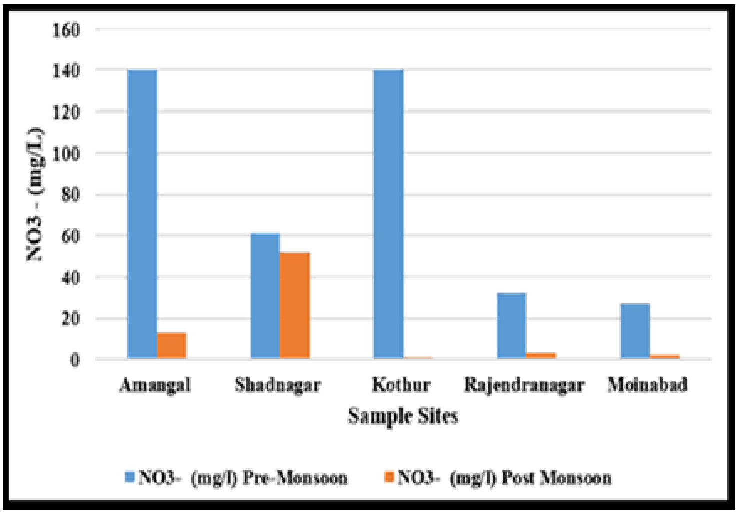
After the monsoon, the site with the highest SO_4^{2-} concentration was "Moinabad" (235 mg/L), and the lowest was "Amangal & Kothur" (8 mg/L). SO_4^{2-} concentrations increased at some sites after the monsoon and decreased at others, resulting in a slight overall increase. The slight increase in sulfate ion concentrations after the monsoon season suggests some variations in ion sources and local geological factors. These variations may have implications for water quality, particularly in terms of taste and potential health concerns. Continual monitoring is important to understand these changes over time.

Analysis of Nitrate ion (NO_3^-)

The mean nitrate ion (NO_3^-) concentration decreased significantly from 80 mg/L before the monsoon to 14.2 mg/L after the monsoon. Before the monsoon, the site with the highest NO_3^- concentration was "Amangal & Kothur" (140 mg/L), while the lowest was "Rajendranagar" (32 mg/L).

Table 14: Amount of NO_3^- in Pre – Monsoon & Post – Monsoon Season

Sites	NO_3^- (mg/L)	
	Pre-Monsoon	Post Monsoon
Amangal	140	13
Shadnagar	61	52
Kothur	140	1
Rajendranagar	32	3
Moinabad	27	2



Graph 11: Comparison of NO_3^- in Pre – Monsoon & Post – Monsoon Season

After the monsoon, the site with the highest NO_3^- concentration was "Shadnagar" (52 mg/L), and the lowest was "Kothur" (1 mg/L).NO_3^- concentrations decreased at all sites after the monsoon, indicating a substantial reduction in nitrate ions in the groundwater. The decrease in NO_3^- concentrations can be attributed to the dilution effect and potential changes in ion sources, groundwater recharge, and local factors. The significant decrease in nitrate ion concentrations after the monsoon season is a positive development, as it reduces the potential health risks associated with high nitrate levels in drinking water. It is essential to continue monitoring to ensure the maintenance of safe water quality over time.

Analysis of Fluoride Ion (F^-)

The mean fluoride ion (F^-) concentration decreased from 0.62 mg/L before the monsoon to 0.412 mg/L after the monsoon.Before the monsoon, the site with the highest F^-concentration was "Rajendranagar" (0.99 mg/L), while the lowest was "Shadnagar" (0.49 mg/L). After the monsoon, the site with the highest F^- concentration was "Shadnagar" (0.98 mg/L), and the lowest was "Kothur" (0.14 mg/L).F^- concentrations decreased at some sites after the monsoon and increased

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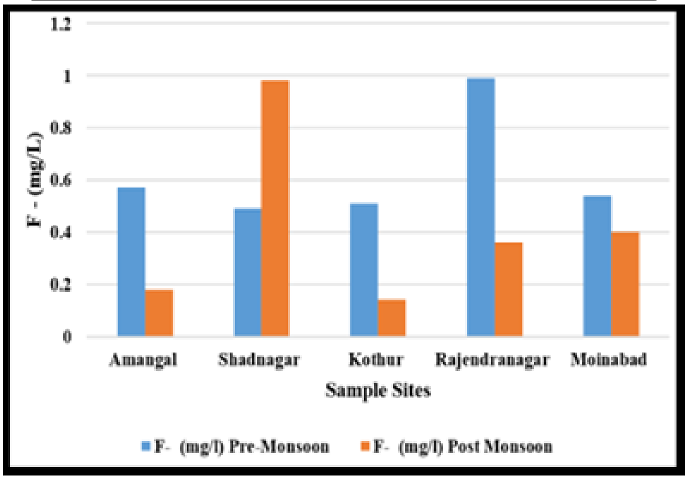
at others, resulting in an overall reduction.The variation in F^- concentrations may be influenced by factors such as changes in ion sources, groundwater recharge, and local geology. Seasonal variations in groundwater quality are common.The observed changes in fluoride ion concentrations after the monsoon season suggest variations in groundwater quality. Proper monitoring and management are essential to maintain safe fluoride levels for drinking water to avoid potential dental health issues, such as dental fluorosis.

Table 15: Amount of F^- in Pre – Monsoon & Post – Monsoon Season

Sites	F^- (mg/l)	
	Pre-Monsoon	Post Monsoon
Amangal	0.57	0.18
Shadnagar	0.49	0.98
Kothur	0.51	0.14
Rajendranagar	0.99	0.36
Moinabad	0.54	0.4



Graph 12: Comparison of F^- in Pre – Monsoon & Post – Monsoon Season

Analysis of SAR

The mean SAR decreased from 1.744 before the monsoon to 1.348 after the monsoon.Before the monsoon, the site with the highest SAR was "Kothur" (3.32), while the lowest was "Shadnagar" (0.77).Afterthe monsoon, the site with the highest SAR was "Moinabad" (4.22), and the lowest was "Amangal" (0.26). SAR values decreased at some sites after the monsoon and increasedat others, resulting in an overall reduction.The observed changes in SAR values before and after the monsoon season suggest variations in groundwater quality, which can have implications for irrigation. Proper monitoring and management are essential to maintain suitable conditions for agriculture, as changes in SAR values can impact soil structure and crop productivity.

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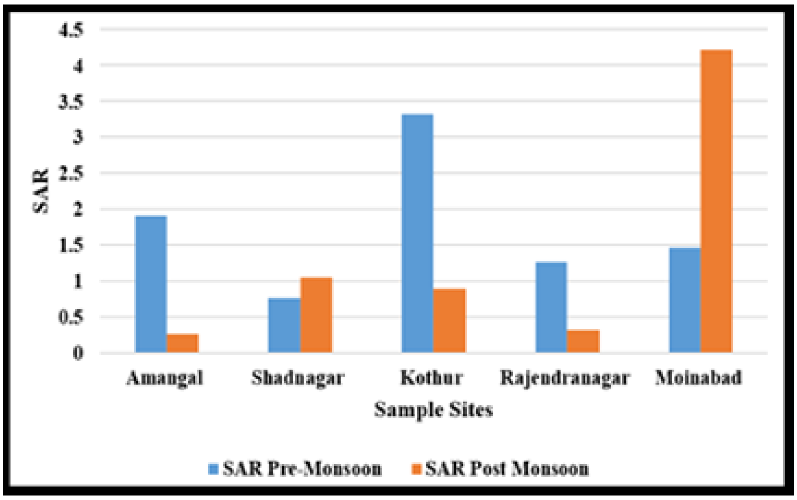
Table 16: Amount of SAR in Pre – Monsoon & Post – Monsoon Season

Sites	SAR	
	Pre-Monsoon	Post Monsoon
Amangal	1.91	0.26
Shadnagar	0.77	1.06
Kothur	3.32	0.89
Rajendranagar	1.26	0.31
Moinabad	1.46	4.22



Graph 13: Comparison of SAR in Pre – Monsoon & Post – Monsoon Season

CONCLUSION

In conclusion, the present study examined various key parameters related to groundwater quality before and after the monsoon season in the Rangareddy district near the Musi River. These parameters provide crucial insights into the changes in water quality, which can have significant implications for various uses, including drinking water supply, agriculture, industry, and environmental sustainability. One of the primary parameters assessed was pH, which showed a slight increase from 7.002 (before the monsoon) to 7.048 (after the monsoon). This trend was consistent across five sites, indicating a shift towards higher pH levels in the post-monsoon. Seasonal changes, such as increased rainfall and fluctuations in the water table, likely contributed to this shift. While the change in pH was relatively small, it holds importance for water quality and aquatic ecosystems, underscoring the need for a comprehensive understanding of seasonal pH trends to manage water resources effectively.Another crucial parameter, specific conductivity (Sp. Cond), exhibited a significant decrease from 1775.0 µS/cm (before the monsoon) to 823.0 µS/cm (after the monsoon). This decrease in specific conductivity is indicative of reduced ion concentrations in groundwater. The monsoon season, characterized by increased recharge and reduced evaporation of water, likely played a significant role in this reduction. A lower specific conductivity suggests improved water quality with lower dissolved solids and ions, which is beneficial for various water uses, including drinking water supply and irrigation. Total Dissolved Solids (TDS) displayed a substantial decrease from 1355.8 mg/L before the monsoon to 398.8 mg/L (after the monsoon). This significant reduction in dissolved solids is a typical outcome during the rainy season, primarily driven by

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groundwater recharge and dilution. Lower TDS levels aregenerally associated with improved groundwater quality and reduced concentrations of dissolved solids. The concentrations of various ions, including sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), and magnesium (Mg^{2+}), exhibited variations in response to the monsoon season. While some ions showed a decrease in concentration, others displayed minor increases. These variations could be attributed to factors such as changes in ion sources and local geological influences. Importantly, the decrease in sodium and magnesium ions is favorable for water quality, as it reduces health and water hardness concerns. Nitrate (NO_3^-) concentrations decreased significantly after the monsoon, which is a positive development for drinking water quality. High nitrate levels can pose health risks, and the reduction observed is attributed to the dilution effect of increased recharge during the monsoon season. Fluoride (F^-) concentrations showed variations, with some sites experiencing disproportionate fluctuations. This underscores the influence of local factors and seasonal variations in groundwater quality. Proper monitoring and management are necessary to maintain safe fluoride levels for drinking water. The sodium adsorption ratio (SAR) values also exhibited variations before and after the monsoon. These changes can have implications for agriculture, as SAR values can impact soil structure and crop productivity. Maintaining suitable conditions for irrigation is essential.In summary, present study provides valuable insights into the dynamics of groundwater quality in the Rangareddy district, particularly in response to the monsoon season. The observed trends indicate improved water quality in terms of reduced ion concentrations and dissolved solids. These changes are favorable for various water uses, including drinking water supply and agriculture. However, it is crucial to continue monitoring and managing groundwater resources to ensure the persistence of these positive trends and to address site-specific factors that influence water quality. This comprehensive understanding of seasonal groundwater quality variations is vital for sustainable water resource management and environmental conservation.

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