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Assessment of Hydro-Chemical Changes in Nalgonda District: A Pre- and Post-Monsoon Comparison

Dr. Eluri Yadaiah[1], Dr. Viplav Duth Shukla[2], Busi Anil Kumar[3]

[1]Associate Professor, Department of Chemistry, Government City College (A), Hyderabad.

[2]Associate Professor, Department of Chemistry, Government City College (A), Hyderabad.

[3]Assistant Professor, Department of Chemistry, Government City College (A), Hyderabad.

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Water sample, Water Pollution, and Physico-Chemical Parameters.

ABSTRACT:
Environmental fluids are crucial for the survival of all living organisms and are found in abundance throughout the Earth. Nowadays this environmental water is heavily polluted and is causing many health problems to the people, cattles, and plants using this water. Consequently, there are ongoing efforts to analyze the composition of environmental waters. However, the use of river water in various industries has resulted in water pollution, which poses a serious threat to life on Earth. As a response to this pollution, many have turned to groundwater as an alternative source. It is crucial to understand that surface water and groundwater are linked; pollution in surface water can affect groundwater quality, which in turn impacts the global water cycle. To address this issue, a comprehensive study was conducted in and around Nalgonda District, spanning both pre-monsoon (01-03-2023 to 31-05-2023) and post-monsoon (01-10-2023 to 31-12-2023) seasons in 2023. The study involved the collection of water samples from various bore-holes located at five different sites along the district. Fourteen key parameters, including pH, electrical conductivity, total dissolved solids, various ions, and specific ion interactions, were analyzed to assess the water quality in the region.

INTRODUCTION

Water is the most crucial substance for the survival of humans and all living organisms. Its importance in supporting life cannot be exaggerated. 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 amount makes up roughly two-thirds of the human body's composition [1]. However, globalization and industrialization have led to a concerning escalation in the pollution of both surface water and groundwater. This widespread pollution impacts almost all water sources, including crucial groundwater reserves. 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 decline has extensive impacts, particularly on groundwater resources. Nalgonda district faces substantial water demands due to its extensive activities. Groundwater recharge has historically been interconnected with surface water sources in this region [2]. The root causes of this wastewater production are attributed to factors such as urbanization, and the 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 agricultural and horticultural purposes via small reservoirs. 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,

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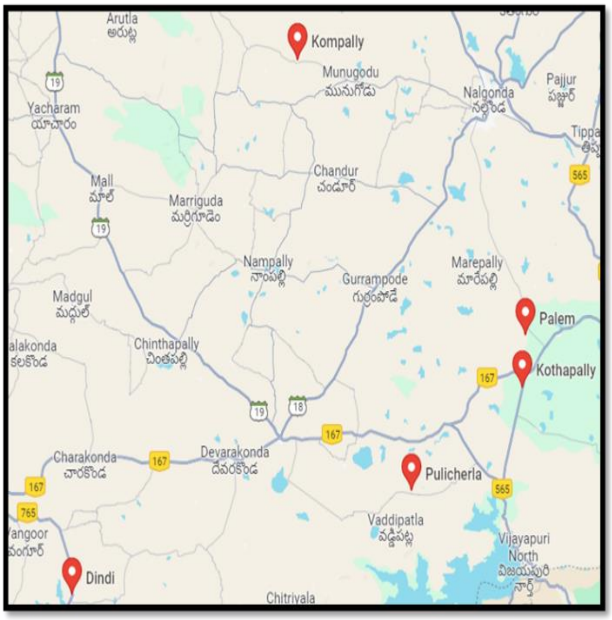
plasticizers, phenols, heavy metals, pesticides, and suspended solids, all of which pose environmental and health hazards [11-13]. Numerous studies have been conducted in India to evaluate the physicochemical characteristics of groundwater and detect contamination During both the pre-monsoon and post-monsoon seasons in 2023, we gathered water samples from five distinct sites in the Nalgonda district, each located approximately 50 kilometers apart. These sampling locations were designated as follows: Site-1 in Kompally, Site-2 in Dindi, Site-3 in Kothapally, Site-4 in Palem, and Site-5 in Pulicherla. To collect these samples, we obtained five groundwater samples from various points. These sources consisted of dug wells, bore wells, and hand pumps, all of which were placed in strategic locations. While collecting samples from open wells, a weighted sample bottle or sampler is 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. Each bottle was carefully rinsed to eliminate any possibility of contamination. 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 Nalgonda District [14-20], underscoring the need for a comprehensive understanding of the challenges posed by water pollution and the critical role of groundwater in addressing them.

METHODOLOGY

to assess water quality. A range of analytical methods and instruments were employed, including an Electrical Conductivity Meter, pH Meter, Ion Meter, UV Spectrophotometer, Nephelo Meter, and Flame Photometer, to evaluate different water quality parameters.

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

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 calcium and magnesium ions. SAR is calculated using the following formula:

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

with all concentrations being expressed in milli-equivalents per liter.

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RESULTS AND DISCUSSION

A comparative analysis of various parameters, including pH, EC, Total Dissolved Solids (TDS), Carbonate, Bicarbonate, Chloride, Fluoride, Nitrate, Sulphate, Sodium, Potassium, Calcium, and Magnesium during both the pre-monsoon and post-monsoon seasons was done. It is important to note that several of these parameters were found to be within permissible limits at specific sites. Specific Electric Conductance (EC), which serves as an indicator of water quality, was employed to determine the total dissolved solids in water. This measurement is conducted at a temperature of 25°C. Elevated TDS levels can make water unfit for different applications, and they can be directly determined 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. This increase in fluoride levels (the upper limit of F^- is 1.5 mg/L) can be attributed to the discharge of industrial and domestic waste. 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 various health issues, including high blood pressure. Additionally, excessive sodium is not suitable for agricultural purposes. 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's important to note that while 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 Nalgonda District

SI. No.	Parameters	Site 1	Site 2	Site 3	Site 4	Site 5
		Kompally	**Dindi**	**Kothapally**	**Palem**	**Pulicherla**
1	pH at 25^0 C	7.04	7.75	7.7	7.53	7.39
2	Sp. Cond. at 25^0 C	1609	1673	1159	2390	469
3	TDS (mg/l)	1030	1071	742	1530	300
4	Na^+ (mg/l)	219	94	63	288	38
5	K^+ (mg/l)	8	3	27	3	3
6	Ca^{+2} (mg/l)	120	120	80	128	40
7	Mg^{+2} (mg/l)	10	92	49	53	30
8	$CaCO_3$ (mg/l)	0	0	0	0	0
9	HCO_3^- (mg/l)	280	200	180	300	110
10	Cl^- (mg/l)	250	340	180	560	50
11	SO_4^{-2} (mg/l)	25	33	21	39	14

12	NO_3^- (mg/l)	177	153	136	18	34
13	F^- (mg/l)	0.58	1.32	1.2	0.95	0.34
14	SAR	5.16	1.56	1.37	5.39	1.4

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

SI. No.	Parameters	Site 1	Site 2	Site 3	Site 4	Site 5
		Kompally	**Dindi**	**Kothapally**	**Palem**	**Pulicherla**
1	pH at 25^0 C	6.89	7.97	7.98	7.03	7.56
2	Sp. Cond. at 25^0 C	870	834	1050	852	2330
3	TDS mg/l	557	534	672	545	1491
4	Na^+ mg/l	47	91	132	59	268
5	K^+ mg/l	3	9	3	2	5
6	Ca^{+2} mg/l	40	24	64	24	80
7	Mg^{+2} mg/l	58	39	15	58	88
8	$CaCO_3$ mg/l	0	0	0	0	0
9	HCO_3^- mg/l	110	150	170	210	90
10	Cl^- mg/l	180	110	100	60	420
11	SO_4^{2-} mg/l	75	93	91	115	438
12	NO_3^- mg/l	3	25	110	15	45
13	F- mg/l	0.2	0.96	3.12	0.32	1.29
14	SAR	1.11	2.67	3.87	1.48	4.92

Table 3: BIS 10500 (1991) 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	Sp. Cond. (µS/cm)	0.25-1	-------
3	Total Hardness as $CaCO_3$ max mg/l	300	600
4	Bicarbonate	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

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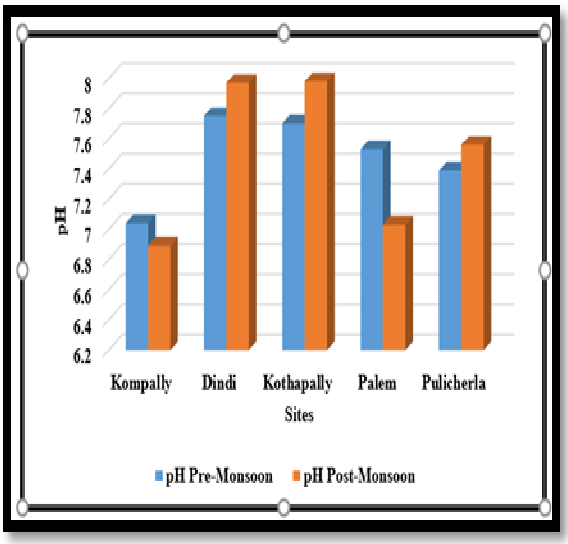
8	Sulfate (as SO_4^{2-}) mg/L	Max 200	400
9	Calcium (as Ca^{+2}) mg/L	Max 75	200
10	Magnesium (as Mg^{2+}) mg/L	Max 30	100

At all proposed sites maximum number of parameters exceeds the standard limits given by the BIS 10500 (1991) standard of drinking water given above in Table III. Nitrate, Chloride, and Total Hardness are too high at the proposed sites; excess Fluoride is present which affects health. Total dissolved solids, Chloride, Fluoride, Nitrate, and Total Hardness are compared with the BIS 10500 (1991) standard of drinking water value in pre- and post-monsoon represented by graphical method at the proposed sites which is shown in graphs 1 to 14 because these parameters directly effect on human health. In the months of Pre-monsoon, ground water levels are decreased due to summer or less rain, as groundwater levels decreases water becomes more polluted. The study of the given parameters of selected sites reveals that they were affected by higher contamination, the comparison is given below by graphical method and discussed about highly affected and health-impacted parameters such as Total Dissolved Solids (TDS), Chloride, Fluoride, Nitrate, and Total Hardness of proposed sites at both seasons these values are compared with standard values given by the World Health Organization. In the represented graphs the seasons were taken on X- axis and site groundwater quality parameters were taken on Y- axis.

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

Sites	pH	
	Pre-Monsoon	Post-Monsoon
Kompally	7.04	6.89
Dindi	7.75	7.97
Kothapally	7.7	7.98
Palem	7.53	7.03
Pulicherla	7.39	7.56



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

The mean pH value slightly increased from 7.482 before the monsoon to 7.486 after the monsoon. Before the monsoon, the site with the highest pH was "Dindi" (pH 7.75), while the lowest was "Kompally" (pH 7.04). After the monsoon, the site with the highest pH remained "Kothapally" (pH 7.98), while the lowest was "Kompally" (pH 6.89). The pH values at most of the sites increased slightly after the monsoon, indicating a trend toward 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.

The mean specific conductivity (Sp. Cond) decreased significantly from 1460.0 µS/cm before the monsoon to 1187.0 µS/cm after the monsoon.

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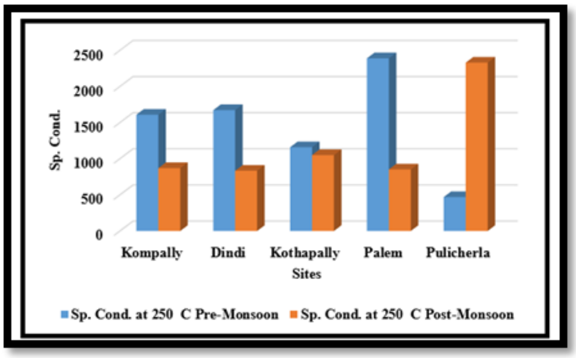
Table 5: Amount of Sp. Cond. (µS/cm) in Pre - & Post – Monsoon Season

Sites	Sp. Cond. at 250 C	
	Pre-Monsoon	Post-Monsoon
Kompally	1609	870
Dindi	1673	834
Kothapally	1159	1050
Palem	2390	852
Pulicherla	469	2330



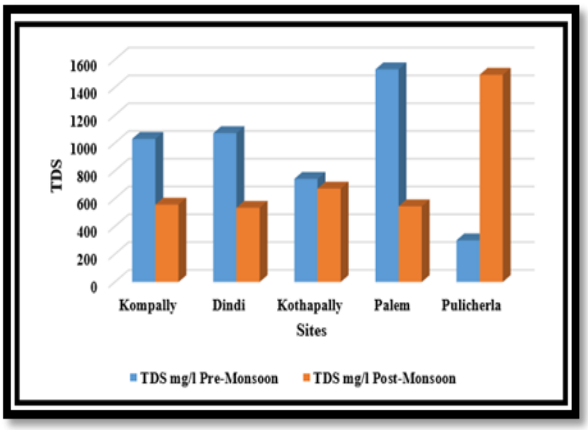
Graph 2: Comparison of Sp. Cond. (µS/cm) in Pre - & Post – Monsoon Season

Before the monsoon, the site with the highest Sp. Cond was "Palem" (2390 µS/cm), while the lowest was "Pulicherla" (469 µS/cm). After the monsoon, the site with the highest Sp. Cond remained "Pulicherla" (2330 µS/cm), and the lowest was "Palem" (852 µS/cm). Specific conductivity values decreased at most of the 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.

The mean Total Dissolved Solids (TDS) decreased significantly from 934.6 mg/L before the monsoon to 759.8 mg/L after the monsoon. Before the monsoon, the site with the highest TDS was "Palem" (1530 mg/L), while the lowest was "Pulicherla" (300 mg/L). After the monsoon, the site with the highest TDS remained "Pulicherla" (1491 mg/L), and the lowest was "Dindi" (534 mg/L). TDS values decreased at most of the sites after the monsoon, indicating a significant reduction in dissolved solids in the groundwater.

Table 6: Amount of TDS (mg/L)in Pre - & Post – Monsoon Season

Sites	TDS mg/l	
	Pre-Monsoon	Post-Monsoon
Kompally	1030	557
Dindi	1071	534
Kothapally	742	672
Palem	1530	545
Pulicherla	300	1491



Graph 3: Comparison of TDS (mg/L)in Pre - & 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

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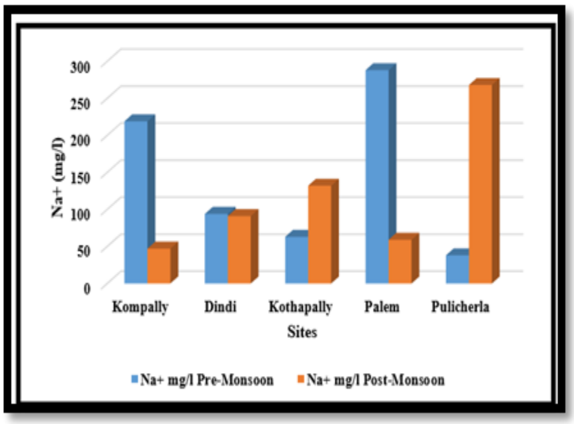
typically associated with increased recharge and dilution during the rainy season.

Table 7: Amount of Na^+ (mg/L) in Pre - & Post – Monsoon Season

Sites	Na+ mg/l	
	Pre-Monsoon	Post-Monsoon
Kompally	219	47
Dindi	94	91
Kothapally	63	132
Palem	288	59
Pulicherla	38	268

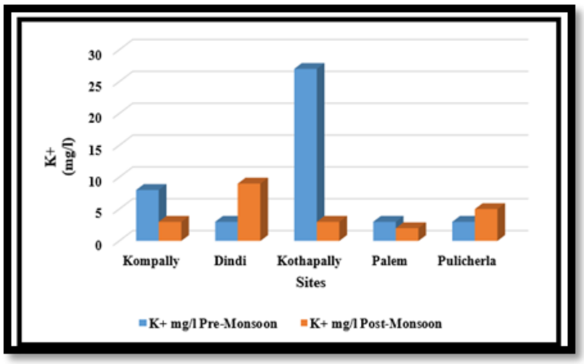


Graph 4: Comparison of Na^+ (mg/L) in Pre - & Post – Monsoon Season

The mean sodium ion (Na^+) concentration decreased from 140.4 mg/L before the monsoon to 119.4 mg/L after the monsoon. Before the monsoon, the site with the highest Na+ concentration was "Palem" (288 mg/L), while the lowest was "Pulicherla" (38 mg/L). After the monsoon, the site with the highest Na+ concentration was "Pulicherla" (268 mg/L), and the lowest was "Kompally" (47 mg/L). 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.

Table 8: Amount of K^+ (mg/L) in Pre - & Post – Monsoon Season

Sites	K+ mg/l	
	Pre-Monsoon	Post-Monsoon
Kompally	8	3
Dindi	3	9
Kothapally	27	3
Palem	3	2
Pulicherla	3	5



Graph 5: Comparison of K^+ (mg/L) in Pre - & Post – Monsoon Season

The mean potassium ion (K^+) concentration increased slightly from 8.8 mg/L before the monsoon to 4.4 mg/L after the monsoon. Before the monsoon, most of the sites had similar K+ concentrations, with values mostly around 3 mg/L. After the monsoon, there was some variability among sites, with the highest K^+ concentration observed at "Dindi" (9 mg/L) and the lowest at "Palem" (2 mg/L). 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.

The mean calcium ion (Ca^{2+}) concentration decreased significantly from 97.6 mg/L before the monsoon to 46.4 mg/L after the monsoon. Before the monsoon, the site with the highest calcium ion concentration was "Palem"

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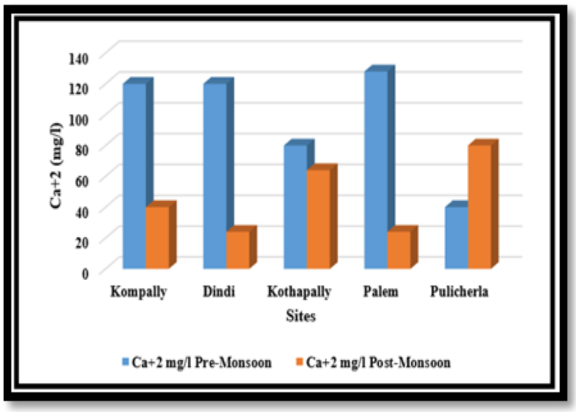
(128 mg/L), while the lowest was "Pulicherla" (40 mg/L).

Table 9: Amount of Ca^{+2} (mg/L) in Pre - & Post – Monsoon Season

Sites	Ca+2 mg/l	
	Pre-Monsoon	Post-Monsoon
Kompally	120	40
Dindi	120	24
Kothapally	80	64
Palem	128	24
Pulicherla	40	80



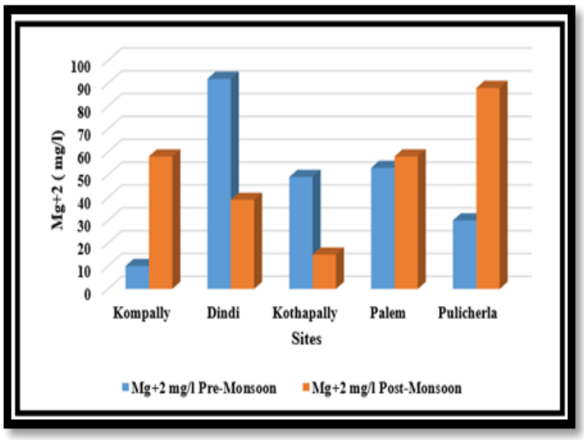
Graph 6: Comparison of Ca^{+2} (mg/L) in Pre - & Post – Monsoon Season

After the monsoon, the site with the highest Ca^{2+} concentration "Pulicherla" (80 mg/L), and the lowest was "Dindi & Palem" (24 mg/L). Ca^{2+} concentrations decreased at most of the 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.

Table 10: Amount of Mg^{+2} (mg/L) in Pre - & Post – Monsoon Season

Sites	Mg+2 mg/l	
	Pre-Monsoon	Post-Monsoon
Kompally	10	58
Dindi	92	39
Kothapally	49	15
Palem	53	58
Pulicherla	30	88

The mean magnesium ion (Mg^{2+}) concentration increased from 46.8 mg/L before the monsoon to 51.6 mg/L after the monsoon.



Graph 7: Comparison of Ca^{+2} (mg/L) in Pre - & Post – Monsoon Season

Before the monsoon, the site with the highest Mg^{2+} concentration was "Dindi" (92 mg/L), while the lowest was "Kompally" (10 mg/L). After the monsoon, the site with the highest Mg^{2+} concentration was again "Pulicherla" (88 mg/L), and the lowest was "Kothapally" (15 mg/L). Mg^{2+} concentrations increased at most of the sites after the monsoon, indicating a significant increase in magnesium ions in the groundwater. The increase in Mg^{2+} concentrations can be attributed to the dilution effect of decreased recharge during the monsoon season, which leads to increased ion concentrations. The observed increase in magnesium ion concentrations after the monsoon season is indicative of deteriorated groundwater quality with increased water hardness. This

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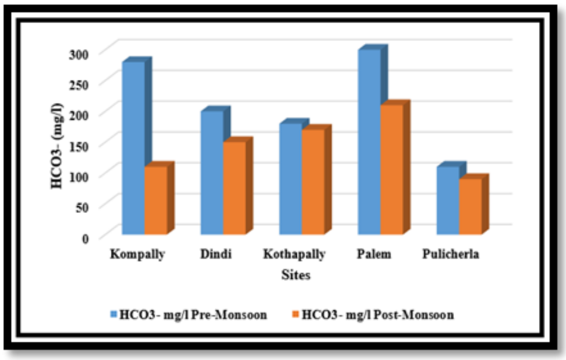
change has implications for water quality in terms of household use and industrial processes and aligns with the dilution effect typically associated with decreased groundwater recharge during the rainy season. In this case, the absence of detectable calcium carbonate suggests that the groundwater in these areas is relatively soft and does not contribute to water hardness, which can be advantageous for specific uses.

Table 11: Amount of HCO_3^- (mg/L) in Pre - & Post – Monsoon Season

Sites	HCO3- mg/l	
	Pre-Monsoon	Post-Monsoon
Kompally	280	110
Dindi	200	150
Kothapally	180	170
Palem	300	210
Pulicherla	110	90

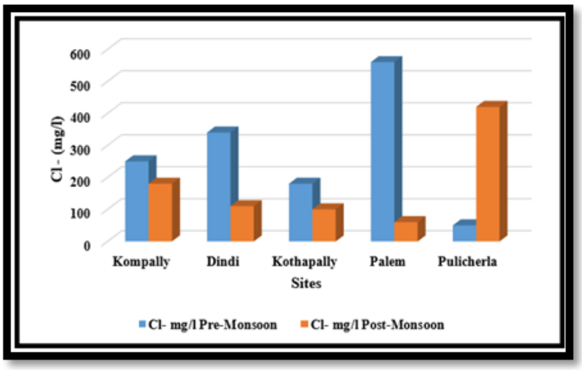


Graph 8: Comparison of HCO_3^- (mg/L) in Pre - & Post – Monsoon Season

The mean bicarbonate ion (HCO_3^-) concentration decreased from 214 mg/L before the monsoon to 146 mg/L after the monsoon. Before the monsoon, the site with the highest HCO_3^- concentration was "Palem" (300 mg/L), while the lowest was "Pulicherla" (110 mg/L). After the monsoon, the site with the highest HCO_3^- concentration remained "Palem" (210 mg/L), and the lowest was "Pulicherla" (90 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 12: Amount of Cl^- (mg/L) in Pre - & Post – Monsoon Season

Sites	Cl- mg/l	
	Pre-Monsoon	Post-Monsoon
Kompally	250	180
Dindi	340	110
Kothapally	180	100
Palem	560	60
Pulicherla	50	420



Graph 9: Comparison of Cl^- (mg/L) in Pre - & Post – Monsoon Season

The mean chloride ion (Cl^-) concentration decreased significantly from 276 mg/L before the monsoon to 174 mg/L after the monsoon. Before the monsoon, the site with the highest Cl^- concentration was "Palem" (560 mg/L), while the lowest was "Pulicherla" (50 mg/L). After the monsoon, the site with the highest Cl^- concentration was "Pulicherla" (420 mg/L), and the lowest was "Palem" (60 mg/L). Cl^- concentrations decreased at most sites after the monsoon, indicating a substantial reduction in chloride ions in the groundwater. 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

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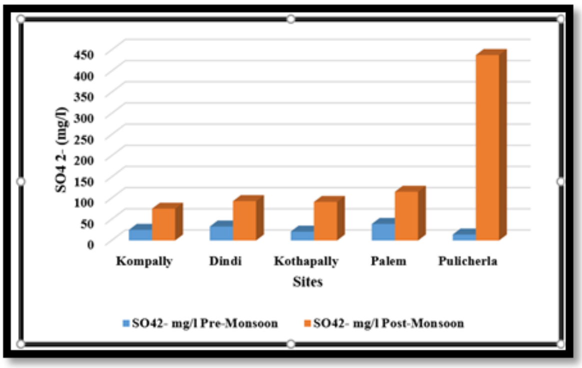
improved groundwater quality with reduced salinity. This change has positive implications for various water uses, particularly drinking water supply, as it makes the water more palatable and suitable for consumption. However, continued monitoring is necessary to ensure that these improvements persist over time.

The mean sulfate ion (SO_4^{2-}) concentration increased slightly from 26.4 mg/L before the monsoon to 162.2 mg/L after the monsoon. Before the monsoon, the site with the highest SO_4^{2-} concentration was "Palem" (39 mg/L), while the lowest was "Pulicherla" (14 mg/L). After

Table 13: Amount of SO_4^{2-} (mg/L) in Pre - & Post – Monsoon Season

Sites	SO42- mg/l	
	Pre-Monsoon	Post-Monsoon
Kompally	25	75
Dindi	33	93
Kothapally	21	91
Palem	39	115
Pulicherla	14	438

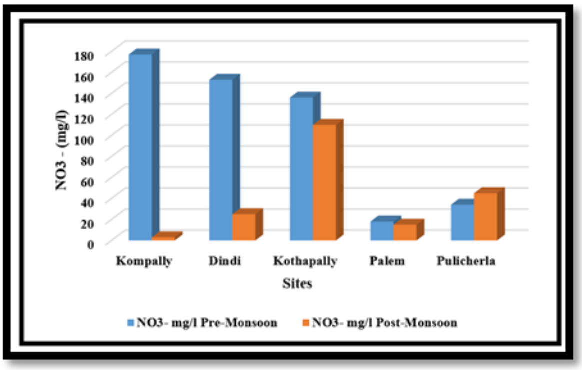


Graph 10: Comparison of SO_4^{2-} (mg/L) in Pre - & Post – Monsoon Season

the monsoon, the site with the highest SO_4^{2-} concentration was "Pulicherla" (438 mg/L), and the lowest was "Kompally" (75 mg/L). SO_4^{2-} concentrations increased at all sites after the monsoon, resulting in an overall increase. The 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.

Table 14: Amount of NO_3^- (mg/L) in Pre - & Post – Monsoon Season

Sites	NO3- mg/l	
	Pre-Monsoon	Post-Monsoon
Kompally	177	3
Dindi	153	25
Kothapally	136	110
Palem	18	15
Pulicherla	34	45



Graph 11: Comparison of NO_3^- (mg/L) in Pre - & Post – Monsoon Season

The mean nitrate ion (NO_3^-) concentration decreased significantly from 103.6 mg/L before the monsoon to 39.6 mg/L after the monsoon. Before the monsoon, the site with the highest NO_3^- concentration was "Kompally" (177 mg/L), while the lowest was "Palem" (18 mg/L). After the monsoon, the site with the highest NO_3^- concentration was "Kothapally" (110 mg/L), and the lowest was "Kompally" (3 mg/L). NO_3^- concentrations decreased at most of the 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.

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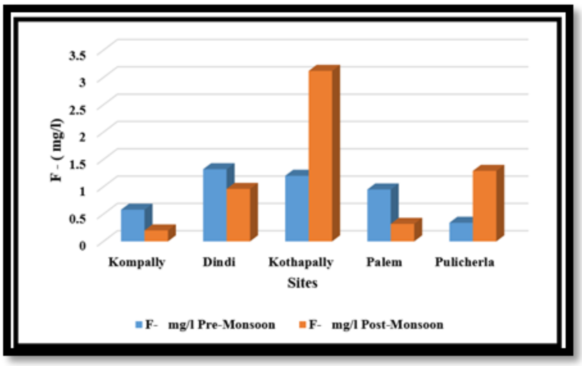
The mean fluoride ion (F^-) concentration decreased from 0.878 mg/L before the monsoon to 1.178 mg/L after the monsoon. Before the monsoon, the site with the highest F^- concentration was "Dindi" (1.32 mg/L), while the lowest was "Pulicherla" (0.34 mg/L). After the monsoon, the site with the highest F^- concentration was "Kothapally" (3.12 mg/L), and the lowest was "Kompally" (0.20 mg/L). F^- concentrations increased at some sites after the monsoon and decreased at others, resulting in an overall increase.

Table 15: Amount of F^- (mg/L) in Pre - & Post – Monsoon Season

Sites	F- mg/l	
	Pre-Monsoon	Post-Monsoon
Kompally	0.58	0.2
Dindi	1.32	0.96
Kothapally	1.2	3.12
Palem	0.95	0.32
Pulicherla	0.34	1.29

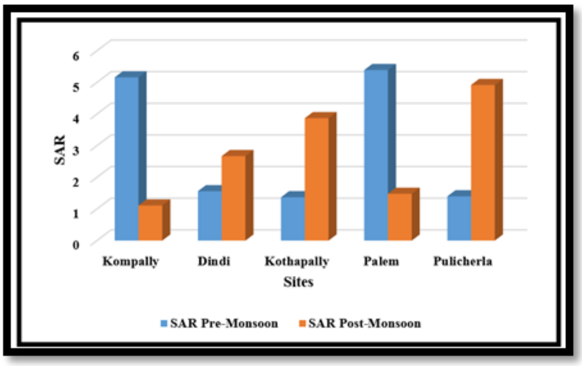


Graph 12: Comparison of F^- (mg/L) in Pre - & Post – Monsoon Season

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

Sites	SAR	
	Pre-Monsoon	Post-Monsoon
Kompally	5.16	1.11
Dindi	1.56	2.67
Kothapally	1.37	3.87
Palem	5.39	1.48
Pulicherla	1.4	4.92



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

The mean SAR decreased from 2.976 before the monsoon to 2.810 after the monsoon. Before the monsoon, the site with the highest SAR was "Palem" (5.39), while the lowest was "Kothapally" (1.37). After the monsoon, the site with the highest SAR was "Pulicherla" (4.92), and the lowest was “Kompally" (1.11). SAR values increased at some sites after the monsoon and decreased at others, resulting in an overall increase. 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.

CONCLUSION

In conclusion, our study examined various key parameters related to groundwater quality before and after the monsoon season in the Nalgonda district. These parameters provide crucial insights into the changes in water quality, which can have significant implications for various uses, including drinking water supply, agriculture, and environmental sustainability. One of the primary parameters we assessed was pH, which showed a slight increase from 7.482 before the monsoon to 7.486 after the monsoon. This trend was consistent across most sites, indicating a shift towards higher pH levels after the 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 1460.0 µS/cm before the monsoon to 1187.0 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, 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 934.6 mg/L before the monsoon to 759.8 mg/L after the monsoon. This significant reduction in dissolved solids is a typical outcome during the rainy season, primarily driven by groundwater recharge and dilution. Lower TDS levels are generally 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 calcium 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 decreases and others increasing. 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, our study provides valuable insights into the dynamics of groundwater quality in the Nalgonda 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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