

A CASE STUDY OF SEASONAL VARIATION IN PHYSIOCHEMICAL PARAMETERS OF GROUNDWATER ANAKAPALLIABATTOIR

Hemant Khandare

Post Graduate Department of Geology, RTM Nagpur University, Nagpur

Abstract

The home, agricultural, and industrial requirements of the world are all supported by groundwater, which is one of the most important natural resources. Changes in the seasons have a significant impact on the physicochemical properties of the substance, including pH, electrical conductivity, total dissolved solids, hardness, alkalinity, and concentrations of key ions. These changes have a significant impact on the quality of the substance. Through an examination of a number of physicochemical characteristics throughout the pre-monsoon, monsoon, and post-monsoon periods, this study analyzes the seasonal fluctuation in groundwater quality. Standard procedures were utilized for the laboratory examination of the water samples that were obtained from a variety of bore wells and hand pumps located across the research region. In the pre-monsoon season, there were increased concentrations of total dissolved solids, hardness, and chloride owing to evaporation and lower recharge. On the other hand, during the monsoon season, dilution effects improved overall water quality. The results showed that there were substantial seasonal changes in key parameters. Samples taken after the monsoon season revealed moderate levels, which are indicative of partial recharge and leaching from layering of the soil. The findings bring to light the impact that hydrological cycles have on the quality of groundwater and underscore the need of maintaining a continuous monitoring system and implementing management techniques that are environmentally responsible. It is essential to have a solid understanding of these seasonal trends in order to guarantee the protected exploitation of groundwater and to formulate water resource regulations that are appropriate to the region.

Keywords: Seasonal, Physiochemical, Groundwater

Introduction

It is well acknowledged that groundwater is among the most dependable and extensively utilized sources of fresh water all over the world. Particularly in areas where surface water supplies are limited or unreliable, it plays a crucial part in supplying the day-to-day requirements of household, agricultural, and industrial operations. This is especially true in places where surface water resources are sparse. Nearly eighty percent of the rural population and a significant portion of the urban population in developing nations like India are directly dependent on groundwater for drinking and agricultural needs. However, the ever-increasing demand, in conjunction with the unregulated exploitation and contamination, has given rise to significant worries over the quality and sustainability of the resource. In the process of determining the quality of groundwater, a complex interaction between natural processes and anthropogenic impacts makes the determination. Important indicators of groundwater quality include physicochemical characteristics including pH, electrical conductivity (EC), total dissolved solids (TDS), hardness, alkalinity, chloride, sulphate, nitrate, calcium, and

magnesium. These factors are used to determine the quality of groundwater. Not only do these factors determine whether or not water is suitable for drinking and irrigation, but they also represent the geochemical reactions that are taking place under the surface, the properties of the soil, and the levels of pollution. Changes in the seasons add another layer of complexity to this picture. Variations in these physicochemical features are caused by variations in rainfall, recharge patterns, evaporation, and activities that are caused by humans during the different seasons. Groundwater exhibits substantial temporal fluctuation between pre-monsoon, monsoon, and post-monsoon periods in various regions of India and the world. This holds true for groundwater in general. In the pre-monsoon season, for instance, greater concentrations of dissolved solids and hardness are frequently found due to decreased recharging and increased evaporation. On the other hand, the monsoon season brings with it diluting effects from rainfall. In most cases, the quality of water after the monsoon season is a reflection of partial recharging and the leaching of minerals from the underground profile. Not only do these seasonal patterns have an effect on the availability of water, but they also provide difficulties for the implementation of long-term water management measures. It is consequently vital for successful groundwater management to monitor and comprehend seasonal fluctuations in order to properly manage groundwater. In addition to assisting in the identification of key periods of water quality decline, it offers insights for the planning of safe drinking water supply and facilitates the utilization of water in agricultural settings. In addition, these kinds of studies lend help to the creation of sustainable water policies that are uniquely adapted to the hydrogeological characteristics of the local area. The current study looks at the seasonal changes that occur in the physicochemical properties of groundwater in the area that was chosen for the investigation. The project is to examine the amount of seasonal changes, identify plausible reasons, and evaluate the overall quality of groundwater for drinking and irrigation purposes by methodically examining samples taken before the monsoon, during the monsoon, and after the monsoon. It is anticipated that the findings will lead to a better understanding of the dynamics of groundwater quality and will help sustainable resource management on both the local and regional scales.

Global Studies

There have been a number of studies that have established the seasonal variations in the quality of groundwater across a variety of geographical locations. For the most part, the seasonal fluctuation in groundwater characteristics is regulated by anthropogenic activities such as irrigation and urban water usage, as well as by recharge and evaporation, as stated by Todd and Mays (2005). As Karanth (1997) pointed out, the chemistry of groundwater is a reflection of the interaction between water and geological formations, and this interaction varies depending on the time of year when the water is recharged. Al-Khashman and Jaradat (2006) found that pre-monsoon groundwater in arid and semi-arid locations has a tendency to exhibit increased electrical conductivity and total dissolved solids due to concentration effects. On the other hand, the monsoon season results in dilution and better quality of the groundwater.

Indian Studies

Researchers from a number of different institutions have investigated the seasonal behavior of groundwater characteristics in the setting of India. It was discovered by Rao et al. (2012) that there were substantial seasonal fluctuations in the quality of the groundwater in Andhra Pradesh. The researchers found that the pre-monsoon season had greater levels of hardness and chloride than the post-monsoon season for the groundwater. In a similar vein, Singh et al. (2014) conducted research on groundwater in Uttar Pradesh and found that monsoon recharge decreased concentrations of nitrate and sulphate, which resulted in an improvement in the appropriateness of drinking water. Research conducted by Subba Rao (2006) in the coastal region of Andhra Pradesh revealed that the presence of seasonal saltwater intrusion during the monsoon season has a substantial impact on the levels of chloride and salinity in groundwater.

Parameters Affected by Seasonality

pH, electrical conductivity, total dissolved solids, hardness, and significant ions including chloride, nitrate, sulphate, calcium, and magnesium are the characteristics that are most affected by seasonal fluctuation. Other parameters that are affected by seasonal variation include water temperature. According to Hem (1991), total dissolved solids (TDS) and electrical conductivity (EC) rise during dry seasons as a result of evaporation and the concentration of salts. On the other hand, the values of TDS and EC fall during the rainy season owing to dilution. As a result of the leaching of fertilizers, the levels of groundwater nitrates, which are frequently associated with agricultural runoff, have a tendency to rise following the beginning of the monsoon season (Pritchard et al., 2008).

Health and Environmental Implications

The ramifications of these seasonal changes for human health and agriculture have also been highlighted in a number of studies. During dry seasons, when fluoride concentrations were high, Chaturvedi and Yadava (2015) found that fluoride levels in groundwater in Madhya Pradesh showed seasonal change. This might pose a potential threat to public health. According to Raju et al. (2011), excessive saline levels during the pre-monsoon season have a negative impact on the quality of irrigation water, which adversely affects agricultural efficiency.

Study Area

The study area is located in **Anakapalli**, a satellite town within the state of Andhra Pradesh, India. Geographically, Anakapalli lies between the latitudes of 17°41' N and 17°54' N, and the longitudes of 83°00' E and 83°15' E. The total land area of Anakapalli is approximately 275 square kilometers. The city is bounded by Visakhapatnam to the north and Anantapuramu district to the east. A residential neighborhood is situated in close proximity to the **Anakapalli slaughterhouse (abattoir)**, which serves as the focal point of this study. Due to the type of waste generated at the facility, residents are potentially exposed to serious environmental and health risks. Effluents discharged from the abattoir flow directly into a

nearby stream, which acts as the recipient of these wastes. The stream is characterized by seasonal variations: its volume increases substantially during the rainy season, causing flash floods, and decreases markedly during the dry season (Balogun, 2001). These hydrological conditions exacerbate the dispersion of pollutants, raising further concerns about water contamination and public health hazards in the area.

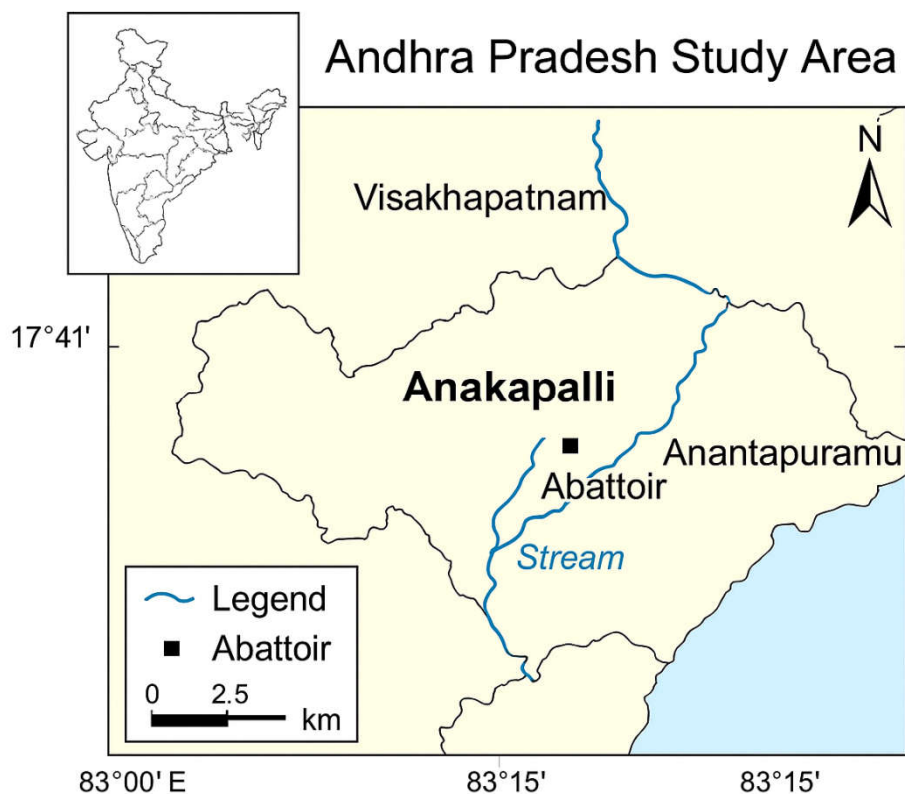


Figure 1 Location of the Study Area

Materials and Methods

Fifty-four water samples were taken from nine different wells that were already in existence in the vicinity of the slaughterhouse. Three of these wells were situated within the neighborhood of the slaughterhouse, three of them were situated around sixty meters away from the abattoir, and the remaining three were situated between two hundred and three hundred meters away from the abattoir. For the purpose of collecting water samples, plastic containers with a capacity of one liter were first treated with three to four milliliters of nitric acid, and then washed with the water samples that were to be taken. Following the drawing up of the well water and its subsequent pouring into the plastic containers, the containers were subsequently labeled and categorized into three distinct groups:

- Group A samples: within the confines of the slaughterhouse
- Group B samples: gathered sixty meters away from the slaughterhouse
- Group C samples: between 200 and 300 meters away from the slaughterhouse

Immediately following the collection of the samples, they were placed in a cooler that included ice blocks. For the sake of preservation, this was intended to keep the temperature between 3 and 4 degrees Celsius. During the wet season, which lasted from July to September 2011, and the dry season, which lasted from November 2011 to January 2012, water samples were collected for a period of six months. A determination was made regarding the temperature, turbidity, and electrical conductivity of the samples at the time that they were collected. The water samples were sent to the Sheda Science and Technology Complex (SHESTCO) in Abuja, where they were analyzed for a variety of physical, chemical, and biological qualities in accordance with the requirements. The following are some of the other characteristics that are analyzed: total dissolved solids, total suspended solids, pH, dissolved oxygen, biological oxygen demand, total hardness, iron content, nitrate, sulphate, coliform bacteria (*Escherichia coli*), and faecal streptococci. The parameters were subjected to statistical analysis, and the quality of the groundwater was also evaluated in comparison to the guidelines established by the World Health Organization (2008) for the quality of drinking water.

Methods of Analyses

When obtaining the reading for the temperature, a mercury-in-glass portable thermometer was dipped into the water samples in order to estimate the temperature; In order to determine turbidity, the nephelometric approach (using a HACH 2100AN turbid meter) (APHA, 1998) is utilized. The Gravimetric approach (Kazi et al., 2009) is utilized to determine total dissolved solids. The total suspended solids are determined by passing a certain quantity of the water sample through a filter. Using an oven, both the filter and the residue were dried. The total soluble solids (TSS) was then calculated by subtracting the weight of the filter from the weight of the filter and residue, and then dividing the result by the volume of water (Kazi et al., 2009). The electrical conductivity was measured with the Jenway conductivity meter (4510 model), by dipping the probe into the container containing the water samples until a stable reading was obtained and recorded. The pH level was measured with a HANNA pH meter (Model HI 28129). According to Ekwebelem (2010), total hardness may be determined by creating a standard solution of sulphuric acid and using solochrome black T as an indicator. Dissolved oxygen was determined using the Winkler azide method (Pejman et al, 2009); BOD was determined using the relationship $BOD = DO_1 - DO_2$ (Agbaire and Obi, 2009), same as in DO above (Winkler azide method) but was titrated after 24hours; Iron content, by the Atomic Absorption Spectrophotometry (ASS), the concentration was read using UV spectrophotometer (Model: 01-0960-00) at 510nm. Nitrate was evaluated using the cadmium reduction and ascorbic acid technique (using a HACH DR2800 spectrophotometer), and sulphate was assessed using the turbid metric method with barium chloride and concentration readings obtained from a UV spectrophotometer (Model: UV-1601) (Ademoriti, 1996). The approach of utilizing a membrane filter was utilized in order to identify the fecal bacteria, specifically *E. coli* and faecal streptococci. This method is used to calculate the number of colony forming units (cfu) that are present in a water sample that is 100 milliliters in volume (APHA, 1998). For each season, the mean of each of the parameters

was computed, and the results obtained were subjected to statistical analysis by means of the paired sample student t-test.

Results and Discussion

When it comes to the dry and wet seasons, the results of the examination of chosen factors (physical, chemical, and biological) are reported in Tables 1, 2, and 3, respectively. In addition, these demonstrate statistical inferences drawn from the data set. As can be seen in Table 1, the mean values of temperature, total dissolved solids, total soluble solids, pH, DO, total hardness, iron, E. coli, and faecal streptococci are greater during the rainy season in the water samples that belong to Group A. On the other hand, the mean values of electrical conductivity, biological oxygen demand, nitrate, and sulphate are higher during the dry season. It is important to note that the mean values for turbidity remain the same during both the rainy and dry seasons. The results of the paired sample student t-test for Group A water samples are presented in Table 1. The results indicate that the calculated values ($t_{\text{calculated}}$) for the majority of the parameters, including turbidity, total dissolved solids, conductivity, dissolved oxygen, biological oxygen demand, nitrate, sulphate, iron content, E. coli, and faecal streptococci, are lower than the table values (at a significance level of $P \leq 0.05$). This indicates that there is no significant seasonal variation. On the other hand, other parameters like temperature, total suspended solids, pH, and total hardness have calculated values that are higher than the table values, indicating that they exhibit significant seasonal variation. This might be the cause for the non-significant seasonal change in the concentration of the majority of the groundwater parameters for Group A. The percolation of water into the soil is accompanied with filtration, and this could explain why this variation occurs. Some of the parameters that have higher mean values during the wet season for Group B water samples are temperature, turbidity, total dissolved solids (TSS), electrical conductivity, pH, biological oxygen demand (BOD), total hardness, E. coli, and faecal streptococci. On the other hand, other parameters such as total dissolved solids (TDS), dissolved oxygen (DO), nitrate, sulphate, and iron have higher mean values during the dry season. The results are presented in Table 2. The results of the paired sample student t-test for Group B are presented in Table 2. The results indicate that certain parameters, including total dissolved solids (TDS), conductivity, pH, dissolved oxygen (DO), biological oxygen demand (BOD), total hardness, nitrate, sulphate, and iron content, have calculated values ($t_{\text{calculated}}$) that are lower than the table values at a significance level of $P \leq 0.05$. However, other parameters, including temperature, turbidity, total soluble solids (TSS), E. coli, and Faecal streptococci, have calculated t values that are higher than the table values, indicating that there is a significant seasonal variation.

Table 1 Wet and dry season groundwater parameters were compared using a paired sample t-test to see whether there was a difference in concentration (GROUP A)

Parameter	Pair	Mean± Std. Error	N	Std. Dvtion	d. f	t calculat ed	$P \leq 0.05$	Rmks
Temperature	Wet season	29.44±0.18	9	0.53	8	4.051	2.31	S

	Dry season	27.83±0.24	9	0.71				
Turbidity	Wet season	2.33±0.24	9	0.71	8	0.00	2.31	NS
	Dry season	2.33±0.17	9	0.50				
TDS	wet season	38.67±4.55	9	13.65	8	1.616	2.31	NS
	dry season	34.89±3.22	9	9.65				
TSS	wet season	48.78±1.98	9	5.93	8	6.615	2.31	S
	dry season	24.89±2.10	9	6.31				
Conductivity	wet season	358.33±20.51	9	61.54	8	-1.765	2.31	NS
	dry season	422.11±22.59	9	67.77				
pH	wet season	7.28±0.23	9	0.68	8	3.200	2.31	S
	dry season	6.48±0.13	9	0.38				
DO	wet season	20.70±1.95	9	5.86	8	1.474	2.31	NS
	dry season	19.53±1.71	9	5.14				
BOD	wet season	5.21±0.30	9	0.90	8	-0.346	2.31	NS
	dry season	5.36±0.42	9	1.27				
T/Hardness	wet season	145.56±8.24	9	24.73	8	5.098	2.31	S
	dry season	135.11±8.39	9	25.18				
Nitrate	wet season	0.014±0.005	9	0.014	8	-0.512	2.31	NS
	dry season	0.016±0.004	9	0.013				
Sulphate	wet season	7.87±0.21	9	0.62	8	-4.146	2.31	NS
	dry season	8.99±0.16	9	0.50				
Iron	wet season	0.06±0.02	9	0.05	8	0.159	2.31	NS
	dry season	0.05±0.02	9	0.05				
E. coli	wet season	101.33±4.77	9	14.31	8	1.459	2.31	NS
	dry season	89.11±5.26	9	15.78				
F. streptococci	wet season	59.89±6.18	9	18.55	8	1.603	2.31	NS
	dry season	47.44±3.52	9	10.55				

Table 2 Groundwater Parameters: A Paired Sample t-test to Compare Concentrations During the Wet and Dry Seasons (GROUP B)

Parameter	Pair	Mean ±Std. Error	N	Std. Dv tion	d. f	t calculat ed	P≤0.05	Rmks
Temperature	Wet season	29.28± 0.24	9	0.71	8	4.243	2.31	S
	Dry season	27.78±0.17	9	0.51				
Turbidity	Wet season	2.56±0.18	9	0.53	8	4.400	2.31	S
	Dry season	1.33±0.67	9	0.50				
TDS	Wet season	25.67±1.97	9	5.92	8	-2.388	2.31	NS
	dry season	29.67±3.13	9	9.39				

TSS	wet season	40.00±1.97	9	5.92	8	6.837	2.31	S
	dry season	23.44±1.38	9	4.13				
Conductivity	wet season	356.33±29.57	9	88.70	8	1.537	2.31	NS
	dry season	292.00±18.09	9	54.27				
pH	wet season	6.46±0.22	9	0.67	8	1.154	2.31	NS
	dry season	6.17±0.13	9	0.39				
DO	wet season	12.64±0.59	9	1.76	8	-0.565	2.31	NS
	dry season	12.87±0.76	9	2.28				
BOD	wet season	5.16±0.42	9	1.26	8	0.052	2.31	NS
	dry season	5.12±0.40	9	1.20				
T/Hardness	wet season	111.56±20.64	9	61.93	8	0.245	2.31	NS
	dry season	110.44±19.92	9	59.77				
Nitrate	wet season	0.03±0.009	9	0.03	8	-2.419	2.31	NS
	dry season	0.08±0.016	9	0.05				
Sulphate	wet season	6.47±0.13	9	0.39	8	-1.762	2.31	NS
	dry season	6.89±0.21	9	0.65				
Iron	wet season	0.05±0.02	9	0.06	8	-1.142	2.31	NS
	dry season	0.10±0.03	9	0.08				
E.coli	wet season	24.44±2.58	9	7.73	8	11.852	2.31	S
	dry season	4.00±1.37	9	4.12				
F. streptococci	wet season	17.67±1.76	9	5.27	8	12.309	2.31	S
	dry season	1.00±0.71	9	2.12				

Table 3 A paired sample t-test was used to compare the concentrations of groundwater parameters during the wet and dry seasons (GROUP C)

Parameter	Pair	Mean± Std. Error	N	Std. Dvction	d.f	t calculat ed	P≤0.05	Rmks
Temperature	wet season	28.83±0.17	9	0.50	8	4.00	2.31	S
	dry season	27.83±0.17	9	0.50				
Turbidity	wet season	1.44±0.18	9	0.53	8	0.426	2.31	NS
	dry season	1.33±0.17	9	0.50				
TDS	wet season	19.22±1.06	9	3.19	8	1.540	2.31	NS
	dry season	17.89±0.70	9	2.09				
TSS	wet season	27.89±1.62	9	4.86	8	3.878	2.31	S
	dry season	21.56±1.24	9	3.71				
Conductivity	wet season	333.56±26.01	9	78.03	8	-3.837	2.31	NS
	dry season	511.67±27.98	9	83.93				
pH	wet season	6.16±0.18	9	0.53	8	1.475	2.31	NS

	dry season	5.90±0.06	9	0.17				
DO	wet season	9.10±0.36	9	1.07	8	-1.349	2.31	NS
	dry season	9.40±0.34	9	1.03				
BOD	wet season	3.79±0.28	9	0.84	8	2.705	2.31	S
	dry season	3.33±0.26	9	0.79				
T/Hardness	wet season	241.11±4.46	9	13.38	8	2.588	2.31	S
	dry season	233.11±5.34	9	16.03				
Nitrate	wet season	0.008±0.004	9	0.01	8	0.00	2.31	NS
	dry season	0.008±0.003	9	0.01				
Sulphate	wet season	3.84±0.16	9	0.49	8	-6.020	2.31	NS
	dry season	4.99±0.18	9	0.53				
Iron	wet season	0.11±0.0	9	0.06	8	-0.839	2.31	NS
	dry season	0.13±0.02	9	0.06				
E. coli	wet season	0.00±0.00	9	0.00	8	0.00	2.31	NS
	dry season	0.00±0.00	9	0.00				
F .streptococci	wet season	0.00±0.00	9	0.00	8	0.00	2.31	NS
	dry season	0.00±0.00	9	0.00				

Analyses of water samples from Group C reveal that during the rainy season, values for temperature, turbidity, total dissolved solids (TDS), total suspended solids (TSS), pH, biological oxygen demand (BOD), and total hardness are greater on average, whereas during the dry season, values for conductivity, dissolved oxygen (DO), sulphate, and iron are higher on average. Table 3 shows that regardless of the season, the average levels of nitrate, E. coli, and faecal streptococci are constant. Table 3 shows that temperature, total solids, biochemical oxygen demand (BOD), and total hardness are the parameters that exhibit significant seasonal change according to the findings of the paired sample student t-test for the water samples from Group C. At $P \leq 0.05$, the computed values ($t_{\text{calculated}}$) of these parameters are higher than the values in the table. However, since the computed values of the parameters are lower than the table values, there is no discernible seasonal change in their performance. These metrics include turbidity, total dissolved solids (TDS), conductivity, pH, dissolved oxygen (DO), nitrate, sulphate, iron content, E. coli, and faecal streptococci. The lack of substantial seasonal fluctuation in these values might be explained by the filtering process that takes place during groundwater recharge, as mentioned before. Another possible cause is the distance of 200-300m between the slaughterhouse and the Group C sample stations; at this distance, the effluents from the abattoir have little effect on the groundwater. Factors including precipitation, groundwater recharge, distance, and weather are shown by comparing the seasonal fluctuation in the parameter concentrations among the three groundwater sample groups (A, B, and C). During the rainy season, the average temperatures of the groundwater samples collected from all of the groups were between 28.83 and 29.44 degrees Celsius, but during the dry season, they were between 27.78 and 27.83 degrees Celsius. The Harmattan cold likely lowers water temperatures, which is why we get cooler weather during the dry season. Both the rainy and dry seasons show identical mean turbidity levels (2.33NTU) for Group A groundwater samples. As seen in Tables 1-3, however, the mean turbidity levels in

Groups B and C are greater during the wet season. It is possible that the closeness of the abattoir to Group A samples explains the little difference in turbidity levels compared to the other samples. During the dry season, there is likely less groundwater recharge and filtration, which results in lower turbidity readings. According to the World Health Organization (WHO, 2008), the turbidity readings in all of the groups fall below the acceptable range of 5 NTU. Tables 1-3 reveal that whereas the dry season had mean total dissolved solids in the samples of the Groups at 34.89 mg/l, B at 25.67 mg/l, and C at 17.89 mg/l, the wet season had greater mean total dissolved solids (A=38.67 mg/l, B=29.67 mg/l, and C=19.22 mg/l). Weathering intensity and enhanced groundwater recharge might be responsible for the seasonal increases in TDS. Additionally, the TDS decreases as one moves away from the slaughterhouse. Both seasons' TDS readings fall under the 1000 mg/l tolerance limits set by the World Health Organization (2008). Tables 1-3 demonstrate that during the rainy season, the amount of suspended particles in the groundwater samples from all of the Groups is increased. Once again, this may be because of the groundwater recharge and intensified weathering that occurs during the rainy season. Filtration of water reduces total suspended solids (TSS) during the dry season. Just like the TDS, the TSS decreases as one moves away from the slaughterhouse. As shown in Tables 1-3, the mean total suspended solids (TSS) for Groups A and B during the rainy season exceed the 30mg/l drinking water recommendation set by the World Health Organization (2008). In contrast, Group C's mean TSS and all Groups' mean TSS during the dry season fall within this recommendation. Wet electrical conductivity values of 358.33 μ S cm/l, 356.33 μ S cm/l, and 333.56 μ S cm/l were not constant over the two seasons for the groundwater samples. The dry values of A, B, and C are 422.11 μ S cm/l, 292.00 μ S cm/l, and 511.67 μ S cm/l, respectively. Nonetheless, during the rainy season, electrical conductivity drops from Group A to Group C. During the rainy season, the acidity of the water samples rises across all groups, with average pH values of 7.28, 6.46, and 6.16 for Groups A, B, and C, respectively, compared to 6.48, 6.17, and 5.90 for the groups during the dry season. The acidic conditions caused by increased precipitation might be the cause of this. Additionally, the acidity rises as one moves further away from the slaughterhouse. Group A samples taken during the rainy season are the only ones that are suitable for human consumption since the pH range for this type of water is 6.5 to 8.5 (WHO, 2008). Group A groundwater samples with dissolved oxygen levels of 20.70 mg/l and Group B groundwater samples with dissolved oxygen levels of 12.87 mg/l are both more than the dry season levels of 19.53 mg/l and 12.64 mg/l, respectively. For the Group C samples, though, things work backwards. There is a minor decrease in BOD during the wet season (A=5.21mg/l, B=5.12mg/l and C=3.33mg/l), but during the dry season, all three sets of groundwater samples had greater BOD values (A=5.36mg/l, B=5.16mg/l and C=3.79mg/l). The decreased recharging of groundwater during the dry season may explain the increased BOD. The BOD levels in every single water sample are above than the 0.0 mg/l standard set by the World Health Organization in 2008. Tables 1-3 demonstrate that, across all categories, the total hardness values of the groundwater samples taken during the rainy season are greater than those of the dry season samples. While samples from Groups A and B are closer to the slaughterhouse effluent discharge site (200-300 meters away), Group C samples (wet and dry season) exhibit significantly higher mean total hardness values. Other than being so close to the slaughterhouse, there may be other environmental variables at play here. Within the 100-

300 mg/l total hardness level set by the World Health Organization (2008), all of the groups' groundwater tests fall.

All groups demonstrate an increase in nitrate and sulphate levels in their groundwater samples throughout the dry season (Tables 1-3). Group B, on the other hand, has a larger nitrate content than Groups A and C. One possible explanation is that during the dry season, there is less precipitation, greater temperatures, and more evaporation, all of which reduce groundwater recharge (nitrate and sulphate). Neither the nitrate nor the sulphate levels are higher than the 50 mg/l or 250 mg/l standards set down by the World Health Organization in 2008. Group C's groundwater samples show a greater mean iron content (0.11% wet and 0.12% dry) compared to Groups A and B, whose samples had lower concentrations (0.06% wet and 0.05% dry) and lower iron contents (0.12% dry). Groups B and C water samples show a greater concentration during the dry season, likely because groundwater replenishment is restricted during this time, leading to an increase in concentration. All of the averages are under the 0.3 mg/l WHO (2008) maximum allowable range. Since Group C is further away from the abattoir's effluent discharge site, other variables may explain the greater concentration in that group's samples. Tables 1-3 reveal that during the rainy season, there is an increase in the presence of *E. coli* and faecal streptococci in groundwater samples from Groups A and B. The abundance of water during the rainy season may encourage the migration and reproduction of these coliform bacteria, which may explain why their numbers are so high during that time of year. One possible explanation for the lack of *E. coli* and faecal streptococci in Group C water samples is the distance between them. Both Groups A and B had more *E. coli* and faecal streptococci than what the World Health Organization (2008) considers to be an acceptable level (0cfu/100 ml of water).

Conclusion

The current research emphasizes the need of determining the significance of seasonal fluctuation in the physicochemical characteristics of groundwater in order to guarantee the safe and sustainable utilization of this resource. The findings demonstrated that the quality of groundwater does not remain same throughout the year but is subject to major changes as a consequence of hydrological cycles, rainfall, evaporation, and activities that are carried out by humans. Samples taken before the monsoon season often displayed greater concentrations of total dissolved solids, hardness, chloride, and other ions. This was mostly attributable to decreased recharging and increased evaporation. On the other hand, monsoon recharge brought about dilution effects, which improved the quality of groundwater, but post-monsoon readings represented partial recovery and leaching from soil and rock layers. Not only do these findings highlight the dynamic character of groundwater systems, but they also highlight the necessity of continual monitoring rather than one-time evaluations. The seasonal studies offer crucial insights into the temporal changes in water quality, which is necessary for determining whether or not the water is suitable for drinking, irrigation, and industrial applications. The study also highlights the importance of localized management techniques taking into account seasonal fluctuations in order to reduce over-exploitation and pollution hazards, particularly in places that are highly dependent on groundwater. To summarize, in order to achieve sustainable groundwater management, it is necessary to implement policies

that are particular to the region and incorporate hydrogeological conditions and seasonal monitoring. In order to ensure that groundwater continues to be a dependable resource for future generations, it is important to conduct regular water quality assessments, raise awareness within the community, and put protection measures into place.

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