Physico-chemical and bacteriological assessments of shallow well water samples during the dry and rainy seasons

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ABSTRACT: There is need to study the impact of seasonal variations on well water quality especially in Ado – Ekiti metropolis as this will assist in creating awareness on groundwater quality for domestic consumption. The quality of groundwater obtained during dry and rainy seasons from 60 privately utilized hand-dug closed wells in Ado Ekiti metropolis were assessed. Physicochemical and bacteriological investigations were carried out according to required standards. The temperature, colour, turbidity, pH, total solids, chlorides, sulphate, calcium, magnesium, nitrate, and iron, which are physico-chemical parameters of the well water samples ranged from 24.7 to 25.6 ^{O}C, 4.1 to 7.3 HU, 3.7 to 6.9 NTU, 7.3 to 7.5, 95.7 to 211.1 mg/L, 38.6 to 74.6 mg/L, 34.3 to 64.9 mg/L, 24.3 to 49.4 mg/L, 48.1 to 89.0 mg/L, 0.4 to 0.8 mg/L and 0.05 to 1.0 mg/L respectively. Despite the fact that the parameters were within the acceptable ranges, bacteriological studies showed the presence of *E. coli* (ranged from 19.5 to 81.6 CFU) throughout the seasons, thus, individuals who rely on groundwater for their health are exposed to disease-causing organisms. Deductions from the correlation matrix equally, demonstrated the relative dependence of the parameters on one another as they variate according to the change in weather. Mostly during the rainy seasons, higher concentrations of the physicochemical and bacteriological parameters were observed than during the dry seasons, proving that the rainy seasons aid anthropogenic activities from the surface to transmit dissolved harmful waste materials to the subsurface which eventually finds its paths into the groundwater. Improper disposal of faeces, faulty soak-pits, latrines, dumpsites and burial grounds are part of the factors that contribute to bacteriological pollutants in the groundwater source.

KEYWORDS: Bacteriological investigation, Correlation matrix, Groundwater, Physico-chemical parameters, Pollutants.

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I. INTRODUCTION

The inaccessibility to potable water supply from government facilities creates an over-dependence on groundwater exploration and extraction for sustenance. Studies also showed that shallow wells, being a relatively more cost-effective and accessible source of water for an average household in developing countries, including Nigeria are frequently used without regard for their potability. This is attributed as the consumption of untreated water source, thus, a cause of waterborne diseases (Ale *et al*., 2015; Malla *et al*., 2018; Ogeleka & Emegha, 2021; Saxena, 2021).

Fagerli *et al*. (2017); Pal *et al*. (2018); Adnani et al. (2020); Bastaraud *et al*. (2020) and Afolabi *et al*. (2021) strongly viewed that the prevalence of gastrointestinal diseases (such as cholera, diarrhoea, dysentery typhoid and viral hepatitis) is caused by consumption of contaminated water. Although groundwater quality is affected by several factors such as hydrogeological environment, well construction, local and maintenance characteristics, climate and weather characteristics. Weather characteristics that are important to water quality are precipitation, solar radiation, wind speed, air temperature, relative humidity, potential evaporation, and air quality variables.

Ale *et al*. (2015); Aribisala *et al*. (2017), Ndububa & Ndububa (2018) agreed that for water to be considered as potable, it must be aesthetically accepted, odour free, bacteriological free from diseases causing organisms such as Salmonella, Shigella, Klebsiella spp., Staphylococcus aureus, Escherichia Coli and other enteric bacteria regularly discovered in water supplies. It must be chemically compliant with the acceptable limits set by the regulatory agencies such as the Standard Organization of Nigeria (SON), World Health Organization (WHO) etc. According to SON (2007) and WHO (2014), basic parameters such as colour, odour, taste, temperature, turbidity, pH, conductivity, iron, nitrates, aluminium, residual chlorine and E. coli should be routinely monitored in water samples before consumption.

Odonkor & Ampofo (2013); Afolabi *et al*. (2021) concluded in their studies that bacteriological examinations be carried out periodically to forestall the presence of diseases causing organisms in sources of water supply. An indicator of bacteriological compromised water source is the presence of faecal indicator bacteria in the water supply. Faecal coliform is used as a surrogate for the presence of real waterborne

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pathogens. The presence of E. coli in food or water does not necessarily mean that pathogenic microorganisms are present, but it does raise the chance of the presence of other faecal-borne bacteria and viruses such as Salmonella spp. or the hepatitis A virus, many of which are dangerous (Malla *et al*., 2018; Adetoro *et al*., 2022). As a result, E. coli is frequently employed as an indicator organism to identify food and water samples that may contain dangerously high quantities of faeces (Odonkor & Ampofo, 2013).

Groundwater quality appraisals by Aribisala *et al*. (2017); Oyedele *et al*. (2019) among others on some selected hand-dug well, boreholes and spring water within Ado Ekiti metropolis, generated results, that were at disagreement with the permissible limit for potability set by the World Health Organization (WHO) and Nigerian Standard for Drinking Water Quality (NSDWQ). Olowe *et al*. (2016) and others researched into the prevalence of water-related diseases arising from groundwater contaminations through anthropogenic activities in Nigeria and their works disabuse the conception that groundwater is impregnable to feacal coliform related contamination. The focus of this research is to study the impact of seasonal variations on well water quality especially in Ado – Ekiti metropolis as this will assist in creating awareness on groundwater quality for domestic consumption. It will help in corroborating past research works and foster future studies especially on groundwater of Ado-Ekiti metropolis.

The impact of weather variation was considered in this study with a focus on rainfall variations as it impacts groundwater quality (i.e. well water) within Ado Ekiti metropolis, Nigeria. Influences of weather differences on the physico-chemical and bacteriological qualities of water samples taken from well water were studied. Samples from privately used hand dug closed wells were periodically taken from domestically sourced well water during the dry and rainy seasons, and subjected to physico-chemical and bacteriological investigations for portability.

Ado-Ekiti experiences a tropical climate with distinct wet and dry seasons. These seasons are associated with the prevalence of maritimes south-westerly monsoon winds from the Atlantic Ocean and the dry continental north-easterly harmattan winds from the Sahara Desert. The city, therefore, enjoys a water surplus from March till October with a high substantial water deficit between November and February when all stream channels are completely dry while the main rivers are reduced to a chain of pools. The average annual temperature is 25.1 °C and rainfall averages 1334 mm. Rainfall abyss and peak is averagely 9 and 235 mm in January and September, respectively (Climate-Data.Org, 2017).

II. MATERIALS AND METHODS

A. Materials

Well water samples were obtained at random from 60 hand dug closed wells within Ado-Ekiti metropolis in Ekiti State, Nigeria. pH meter (Hanna model), digital thermometer (Hannah model), DR colourimeter (Hannah model), gravimetry apparatuses, titration apparatuses, petri dish, cotton wool, heating mantle, incubator and water bath heater were obtained from Environmental laboratory of the Federal Polytechnic, Ado-Ekiti. While Eosin Methylene Blue (EMB) agar, ethanol (95.6% purity), deionized water (100% purity) were obtained from Bisolab Chemicals, Ado-Ekiti for this study.

B. Methods

1) Demarcation of study area

The study area (i.e. Ado – Ekiti metropolis, Nigeria) was demarcated into zones for adequate sampling coverage. The geographical locations of all sampling places inside the Ado-Ekiti metropolis are depicted in Figure 1 as Z1, Z2, Z3, Z4, Z5 and Z6. Selection of water sources was done by random sampling.

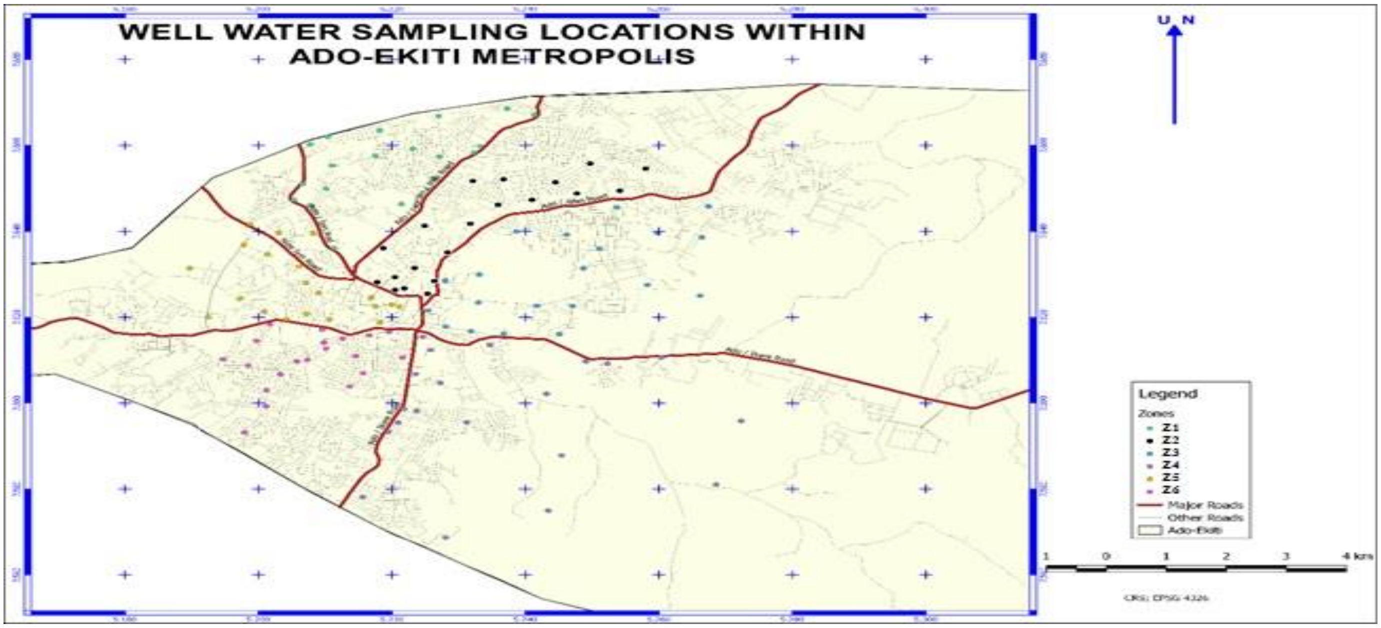


Figure 1.Demarcation of Ado Ekiti into 6 zones namely, Zone Z1, Z2, Z3, Z4, Z5, and Z6

Sampling points of ten (10) numbers were picked from each zone to arrive at a total of 60 locations or points. This will enhance objective and thorough coverage and analysis of the well water samples of the study area. The coordinates of all the well water examined within the study area are shown in Table 1 for easy identification.

Table 1: The coordinates of all the well water examined within the study area

S/No.	Zone	Coordinates		S/No.	Zone	Coordinates	
		Latitude	Longitude			Latitude	Longitude
1.	$Z.1_{1}$	7.6361	5.2187	31.	$Z.4_{1}$	7.6216	5.2254
2.	$Z.1_{2}$	7.6515	5.2272	32.	$Z.4_{2}$	7.6135	5.2347
3.	$Z.1_{3}$	7.6578	5.2324	33.	$Z.4_{3}$	7.6097	5.249
4.	$Z.1_{4}$	7.6664	5.2425	34.	$Z.4_{4}$	7.6092	5.2523
5.	$Z.1_{5}$	7.6471	5.2048	35.	$Z.4_{5}$	7.6107	5.2603
6.	$Z.1_{6}$	7.6499	5.2101	36.	$Z.4_{6}$	7.6161	5.2451
7.	$Z.1_{7}$	7.6576	5.2175	37.	$Z.4_{7}$	7.6166	5.2195
8.	$Z.1_{8}$	7.6361	5.2113	38.	$Z.4_{8}$	7.6128	5..2219
9.	$Z.1_{9}$	7.6744	5.2186	39.	$Z.4_{9}$	7.6225	5.2175
10.	$Z.1_{10}$	7.662	5.2104	40.	$Z.4_{10}$	7.6199	5.2212
11.	$Z.2_{1}$	7.6204	5.2273	41.	$Z.5_{1}$	7.6395	5.2082
12.	$Z.2_{2}$	7.6279	5.2269	42.	$Z.5_{2}$	7.6368	5.1978
13.	$Z.2_{3}$	7.6351	5.2283	43.	$Z.5_{3}$	7.6279	5.2071
14.	$Z.2_{4}$	7.6387	5.2331	44.	$Z.5_{4}$	7.6256	5.209
15.	$Z.2_{5}$	7.6474	5.2343	45.	$Z.5_{5}$	7.6178	5.2098
16.	$Z.2_{6}$	7.645	5.2465	46.	$Z.5_{6}$	7.6195	5.2042
17.	$Z.2_{7}$	7.6455	5.2532	47.	$Z.5_{7}$	7.6188	5.2017
18.	$Z.2_{8}$	7.6473	5.241	48.	$Z.5_{8}$	7.6102	5.1946
19.	$Z.2_{9}$	7.6293	5.2204	49.	$Z.5_{9}$	7.62	5.1925
20.	$Z.2_{10}$	7.6263	5.2205	50.	$Z.5_{10}$	7.6313	5.1897
21.	$Z.3_{1}$	7.6216	5.2254	51.	$Z.6_{1}$	7.607	5.2157
22.	$Z.3_{2}$	7.6161	5.2367	52.	$Z.6_{2}$	7.615	5.2126
23.	$Z.3_{3}$	7.6092	5.2523	53.	$Z.6_{3}$	7.5932	5.1979
24.	$Z.3_{4}$	7.6166	5.2195	54.	$Z.6_{4}$	7.6188	5.2182
25.	$Z.3_{5}$	7.6154	5.2201	55.	$Z.6_{5}$	7.6188	5.2182
26.	$Z.3_{6}$	7.6083	5.2199	56.	$Z.6_{6}$	7.6225	5.2175
27.	$Z.3_{7}$	7.6188	5.2182	57.	$Z.6_{7}$	7.6245	5.2169
28.	$Z.3_{8}$	7.6188	5.2182	58.	$Z.6_{8}$	7.6229	5.22
29.	$Z.3_{9}$	7.6224	5.2211	59.	$Z.6_{9}$	7.6224	5.2211
30.	$Z.3_{10}$	7.6199	5.2212	60.	$Z.6_{10}$	7.6199	5.2212

2) *Well water samples collection*

The samples were collected separately during dry seasons (i.e. November 2020 and January 2021) and wet season (July and September 2021). Before collection, the container was well washed and thoroughly rinsed with deionized water before sampling.

3) *Analyses of well water samples*

Immediately after collecting the samples, the parameters such as pH and temperature were measured at the site using pH meter and digital thermometer. The remaining parameters were taken in the Environmental laboratory, Civil Engineering Department of the Federal Polytechnic, Ado-Ekiti within 24 hours of sampling using the APHA (2023) standard methods. From the dry season of November 2020 to January 2021 and the wet season of July to September 2021, sixty (60) water samples from privately used hand dug wells within the study area were examined four (4) times for their Physico-chemical and Bacteriological (faecal coliform, specifically *E. coli*) properties. Criteria for sample sites are primarily based on the density of clustered residential buildings, government and private institutions, hotels, businesses centres, etc. All the wells are lined, covered, and used as domestic sources of water supply. The summary of all parameters and their methods of analyses are portrayed in Table 2.

Table 2: The summary of all parameters and their methods of analyses

S/No	Parameters	Methods of Determination
1.	Temperature ^{O}C	Digital Thermometer
2.	Colour (HU)	Colour Comparator Method
3.	Turbidity (NTU)	Colourimetry Method
4.	pH	pH Meter
5.	Total Solid, Sulphate (SO_4), Nitrate and Iron (Fe^{2+}) - (mg/L)	Gravimetry and Colourimetry method
6.	Total Alkalinity and Chloride - (mg/L)	Titration Method
7.	Calcium (Ca^{2+}) and Magnesium Hardness - (mg/L)	EDTA Titration Method
8.	E-Coliform (CFU/100 mL)	Filtration Membrane Method

***CFU – Coliform Forming Unit; NTU – Nephelometric Turbidity Unit; HU – Hazen Unit; EDTA – Ethylene Diaminetetraacetic Acid**

4) *Statistical analyses*

All the data obtained were analysed using Microsoft Excel software. Charts and correlation matrix were produced from the software for the analysis's purposes. to other nodes on the network. It gives room for full-type topology without a coordinator (Krapivina *et al*., 2019).

III. RESULTS AND DISCUSSION

A. Results of Physico-Chemical and Bacteriological Analyses

Figures 2 to 13 show results of the physico-chemical and bacteriological analyses of the water samples and rainfall days observed during the dry and wet season, alongside the permissible limit specified by the Nigerian standard for drinking water quality (SON, 2007) and the World Health Organization (WHO, 2014; 2022). From Figure 2, it is observed that the mean temperature values of the groundwater samples lowered from the initially observed temperature of 25.6 $^{\mathrm{O}}$C in November 2020 to 24.7 $^{\mathrm{O}}$C in January 2021 (dry season) and increase to 25 $^{\mathrm{O}}$C in July 2021 with a consequential drop in temperature to 24.9 $^{\mathrm{O}}$C in September 2021 (wet season).

This fluctuation in water temperature follows a similar pattern of variation with rainfall days - as the rainfall days reduced from 8 to 4 days, water temperature reduced, while a further increase in rainfall days from 4 to 30 days, resulted to a rise in temperature up to July 2021, thereafter reduction in water temperature from July 2021 to September 2021.

This observed fluctuation agreed with the work of Dey *et al.* (2020), who attributed the variations to reduce days of rainfall during the harmattan seasons causing cold air to cool over the surface and into well water. Temperature variations are strongly influenced by environmental conditions related to the geographical location of the locality, the geology of the terrain crossed, the hydrology of the ecosystem and especially the climate (Maher & Chowdhury, 2017).

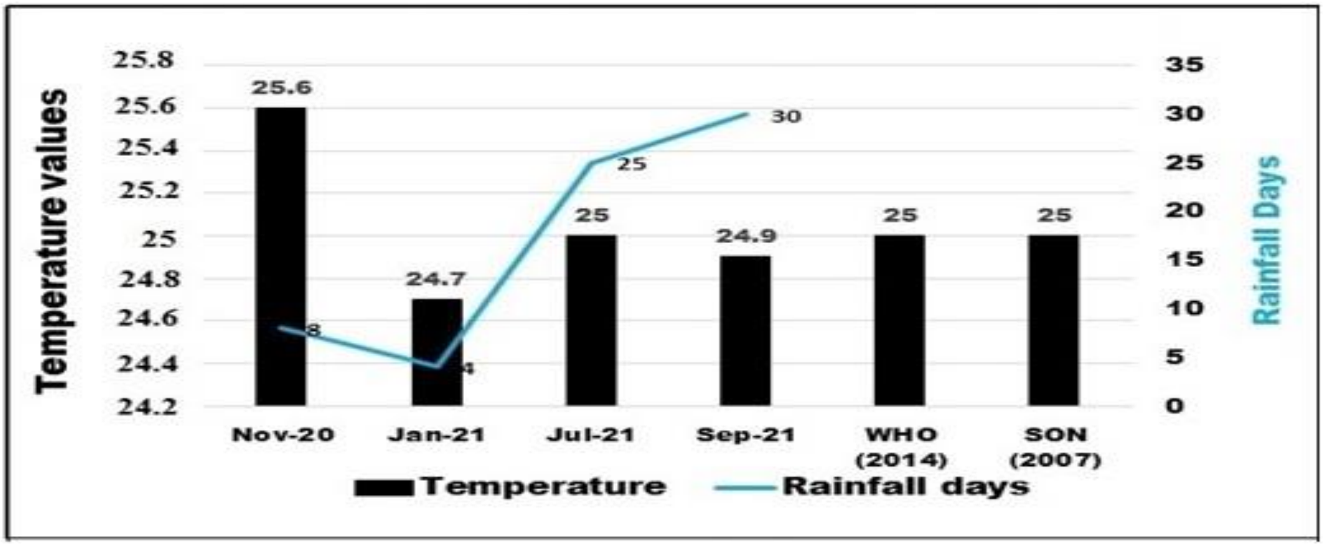


Figure 2. Results of the temperature of the well water samples against variation in rainfall days

The measurement of colour values of water samples assists in the physical assessment of water for potability, the clearer a sample the lower the cost of treatment. Figure 3 shows that colour values followed the rainfall days trend – it reduced from 5.5 H.U (November 2020) to 4.1 H.U (January 2021) as rainfall days reduced from 8 to 4 days during dry season. It increased when there was change from dry to rainy season (i.e. January to July 2021) from 4.1 H.U in January 2021 to 6.4 H.U in July 2021; while there was further increase in colour up to 7.3 H.U in September 2021 during rainy season as rainfall days equally, increases from 25 to 30 days.

This agreed with the work of Talabi *et al.* (2014), who stated that intensity of rainfall causes dissolution of mineral composition of soil into groundwater with a consequential effect on the colouration of the water sample. Colour values of all samples examined were within the acceptable limit for potability as specified by SON (2007) and (WHO, 2014; 2022).

Turbidity is the measure of the extent to which light is either absorb or scatter by suspended materials in water. It is a tool for assessing the acceptability of water for potability (Maroubo *et al.*, 2021). Results of the seasonal variation (Figure 4) shows that turbidity was highest (6.9 NTU) in the month of September 2021 (rainy season) and lowest (3.7 NTU) in January 2021 (dry season), which is in agreement with Bastaraud *et al.* (2020) work. The result showed that the turbidity of all the well water sampled is not within the permissible limits of 5 NTU except in January 2021 (SON, 2007; WHO, 2014; 2022). The measurement of pH is one of the most frequently used tests in water chemistry (Saxena, 2021). In Figure 5, the mean seasonal pH variation was recorded to be highest in September during rainy season) at 7.5 and lowest in January during dry season at 7.3. Results showed that the pH of all the well water varied between 7.3 and 7.5, which is within the permissible limits of 6.5 to 8.5 (SON, 2007; WHO, 2014; 2022). The high pH recorded during the rainy season can be attributed to increase in rainfall days, which resulted in high dissolution of soil organic contents (alkalinity) as agreed by Touhidul (2017) and Jamuna (2018).

Results of the Total Solids (Figure 6) describes the mean seasonal variation of Total Solids in the well water sample. The Total Solids (i.e. Total Dissolved Solids) is the summation of the Total Suspended and Total Dissolved matters in the well water sources (Dickerson, 2013).

The highest value of 211 mg/L was observed in September 2021 (rainy season) when rainfall days was at the peak and the lowest value of 95.7 mg/L in January 2021 (dry season) when rainfall days was at the least. The results agreed with the work

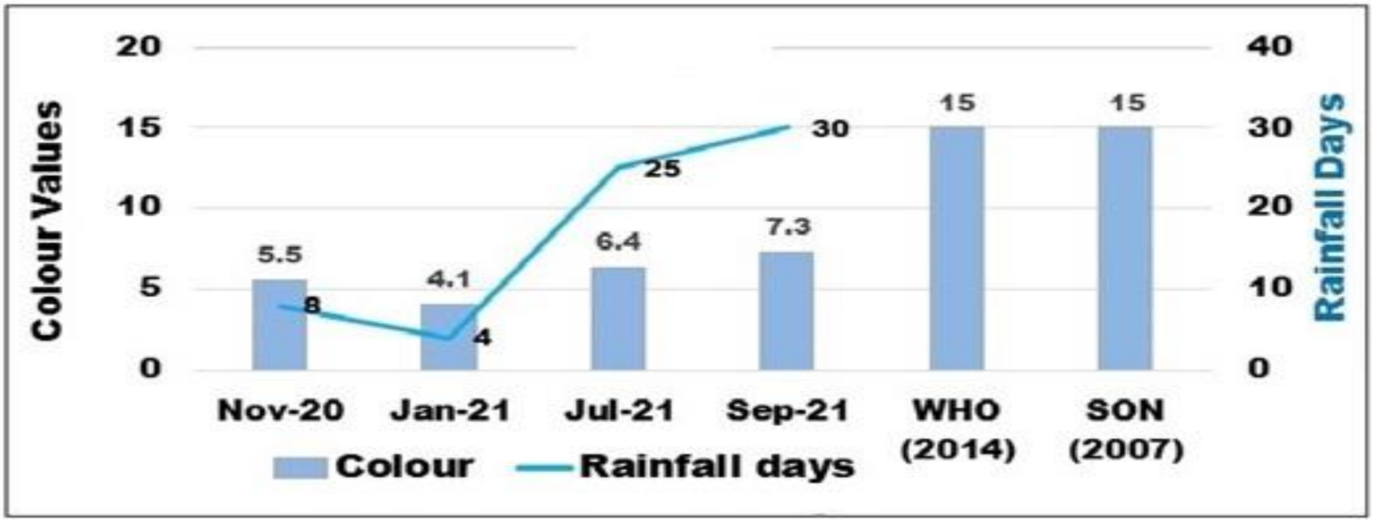


Figure 3. Results of the colour of the well water samples against variation in rainfall days

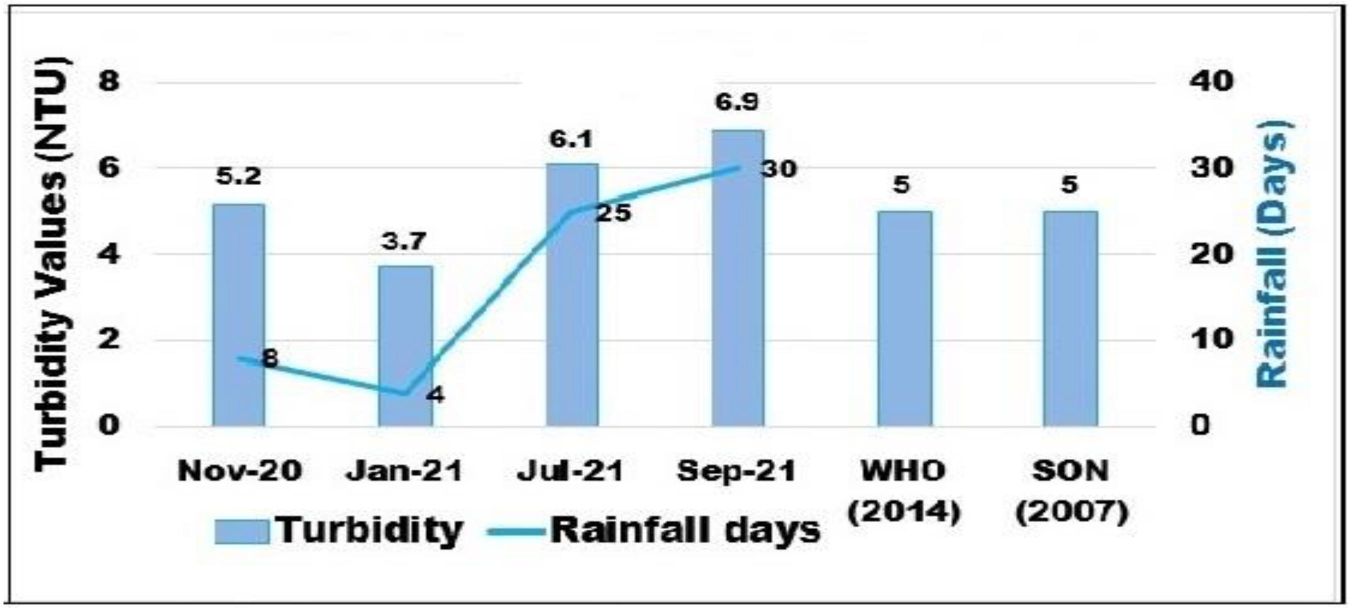


Figure 4 Results of the turbidity of the well water samples against variation in rainfall days

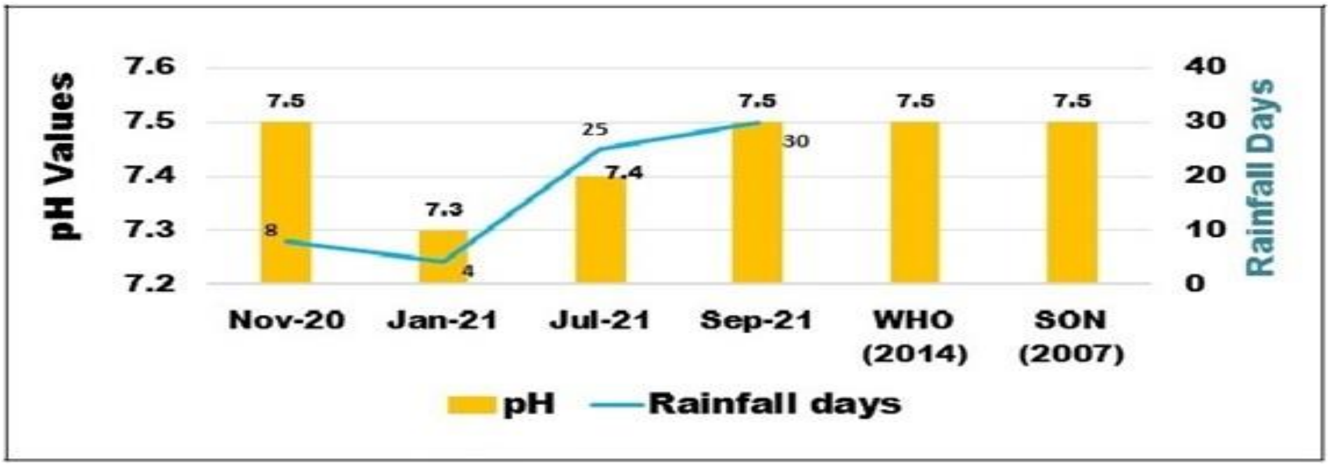


Figure 5. Results of the pH of the well water samples against variation in rainfall days

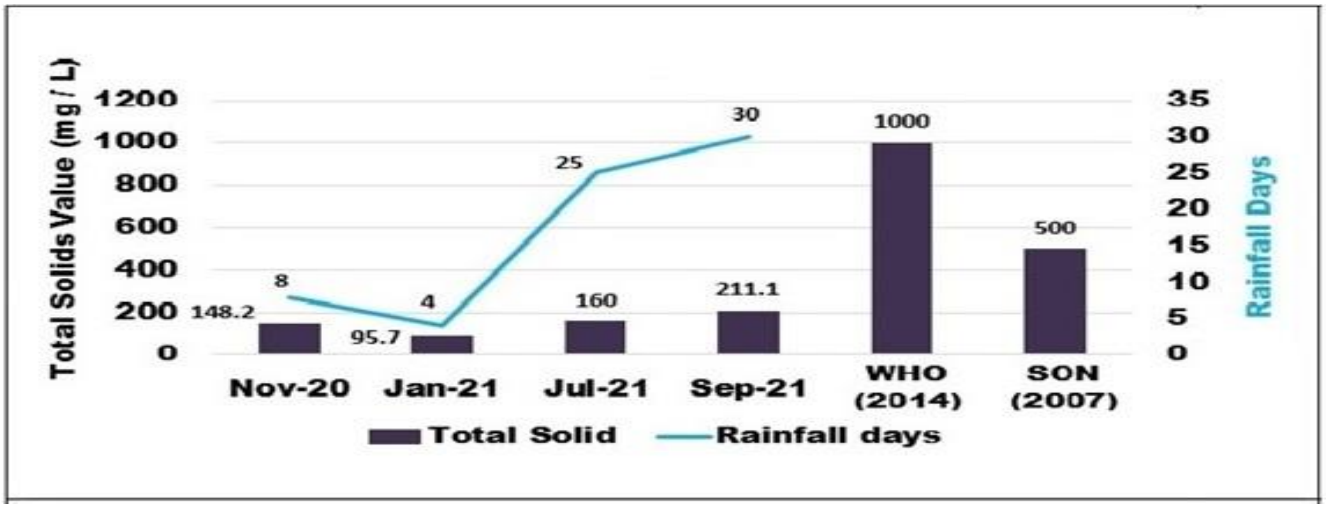


Figure 6. Results of the total solids of the well water samples against variation in rainfall days

of Adnani *et al*. (2020), that the increased concentration of Total Solids may be associated with the influx of sediments into the groundwater during the rainy season thereby creating room for contamination. Though, the Total Solids of all the samples examined were within the acceptable limits of potability set by SON (2007) and WHO (2014; 2022).

According to the SON (2007), water is considered “hard” when the measured hardness exceeds 150 mg/L. Hard water can cause calcium carbonate scale deposits in automated watering systems, which can lead to drinking water valve leaks and other operational problems (Dhok *et al*., 2013). The seasonal variation in calcium and magnesium hardness of the well water samples (Figures 7 and 8) were observed to be highest in the rainy season at 49.4 and 89.0 mg/L; become lowest in the dry season at 24.3 and 48.1 mg/L respectively.

This can be attributed to calcium and magnesium sediments transported through the pore spaces of the geological formation into the well water, which are assisted by high rainfall days. Both metals concentration is within the tolerable limits in accordance with SON (2007) and WHO (2014; 2022), though that of magnesium is higher than calcium.

Nitrate seasonal variation (Figure 9) has highest record in the rainy season (i.e. September 2021) at 0.8mg/L and lowest record at 0.4 mg/L during the dry season (i.e. January 2021). All recorded values are negligible and within the acceptable limits of 50 mg/L for potability (SON, 2007; WHO, 2014; 2022). Hamlin et al. (2022) attributed this to the chemical composition and quality of groundwater, mostly on the soils accumulated in groundwater.

Iron seasonal variation (Figure 10) ranged from 0.005 mg/L in November 2020 and reached 0.10 mg/L (maximum) in July 2021. Thereafter, there was drop in concentration to 0.07 mg/L in September, 2021, revealing that the highest value was recorded during the rainy season. All recorded values are negligible and within the acceptable limits of 0.3 mg/L for potability (WHO, 2014; 2022).

The chlorides concentration in the samples examined (Figure 11) ranged from 38.6 to 74.6 mg/L, with the highest value of 74.6 mg/L recorded in September 2021 during the peak of rainy days and the lowest record of 38.6 mg/L recorded in dry season of January 2021. Alkhateeb (2014) and WHO (2022) opined that when sodium chloride concentrations is above 250 mg/L, they produce a salty taste.

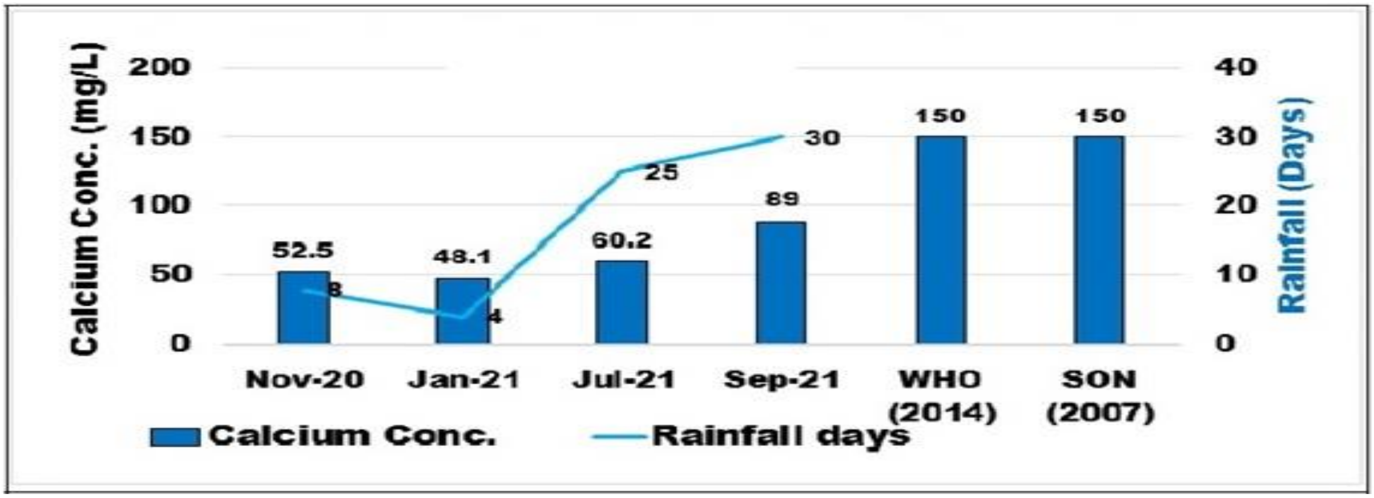


Figure 7. Results of the calcium concentration of the well water samples against variation in rainfall days

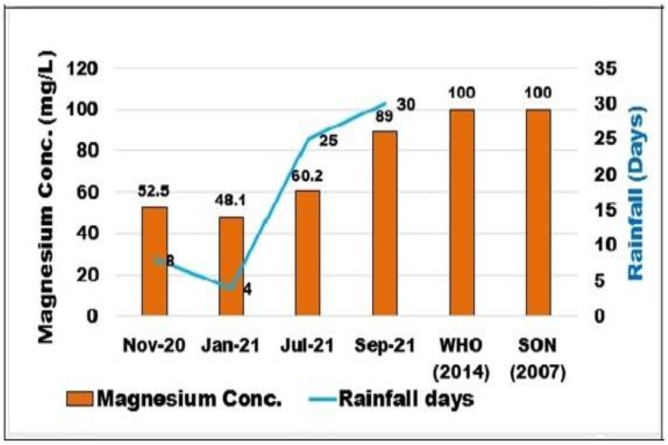


Figure 8. Results of the magnesium concentration of the well water samples against variation in rainfall days

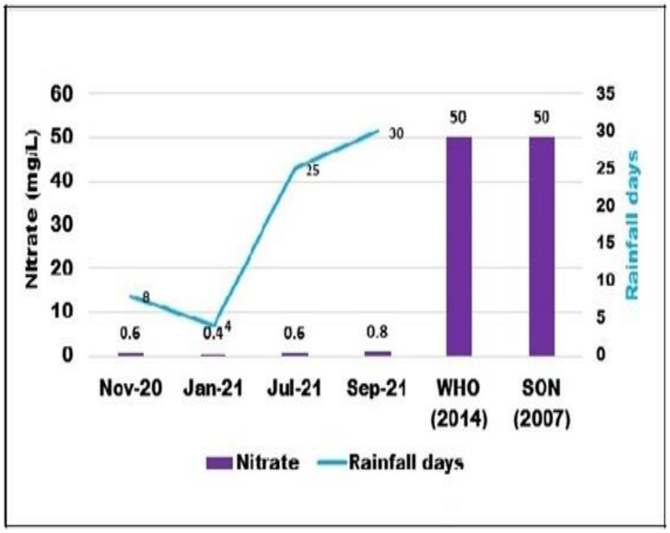


Figure 9. Results of the nitrate concentration of the well water samples against variation in rainfall days

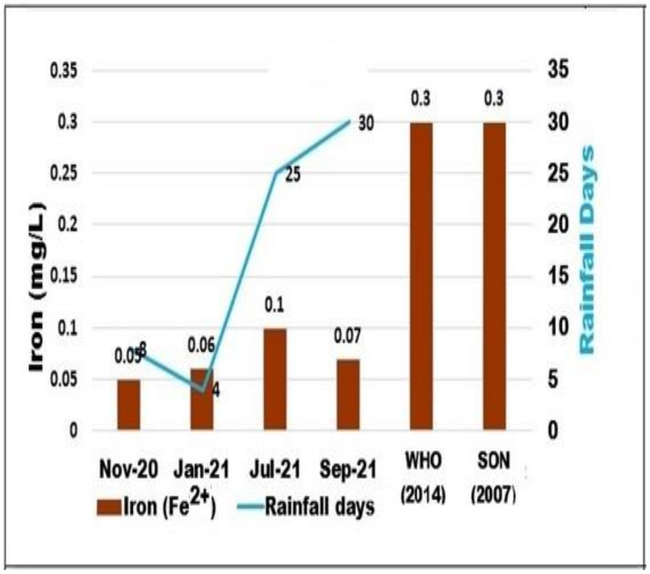


Figure 10. Results of the iron concentration of the well water samples against variation in rainfall days

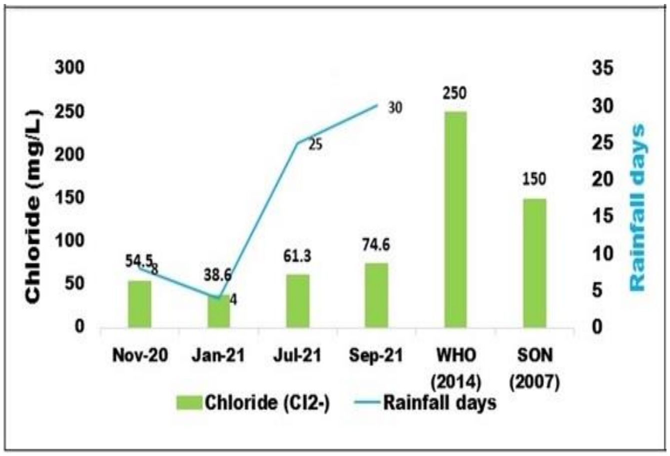


Figure 11: Results of the chloride concentration of the well water samples against variation in rainfall days

These give water a salty taste. The finding is in agreement with the works of Neal and Kirchner (2000) on the impact of rainfall with chloride inflow.

Sulphate variation (Figure 12) ranged from 34.3 mg/L to 64.9 mg/L. The highest record of 64.9 mg/L was observed in September 2021 at the peak of rainy season, while the lowest record of 34.3 mg/L was observed in January 2021.

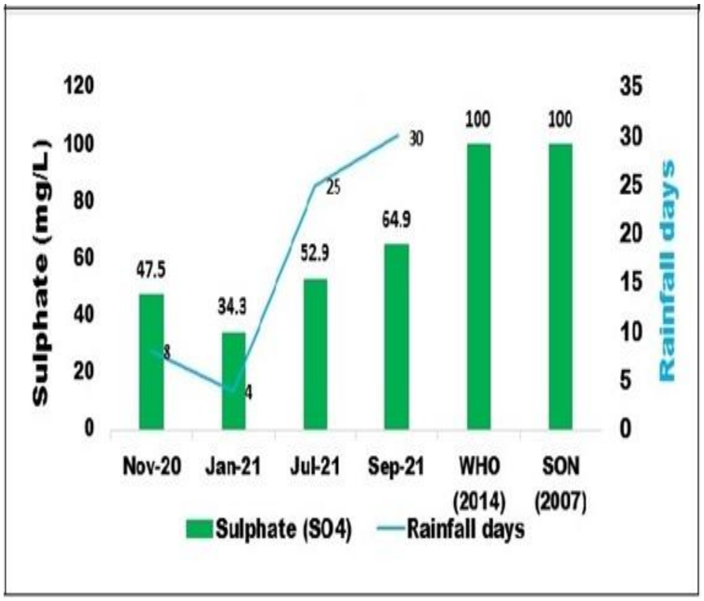


Figure 12: Results of the sulphate concentration of the well water samples against variation in rainfall days

E.coli is frequently employed as an indicator organism to identify food and water samples that may contain dangerously high quantities of faeces (British Columbia Groundwater Association, 2007; Odonkor & Ampofo, 2013). The presence of faecal indicator bacteria in the water is used as a surrogate for the presence of real waterborne pathogens. *E.coli* seasonal variation is depicted in Figure 13. It was recorded at the highest level in September 2021 (Rainy Season) as 81.6 mg/L and lowest level in January 2021 (dry season) as 19.5 mg/L, which are not within the acceptable limits as stipulated by SON (2007) and (WHO, 2014; 2022). The results of *Escherichia* coliform counts in the well water samples agreed with the works of Aribisala *et al*. (2017); Ibe *et al*. (2019); Oyedele *et al*. (2019); Adeosun & Omietimi (2020) among others on the fate of the bacteriological state of groundwater in Ado Ekiti metropolis, believing that a state of bacteriological deterioration exists.

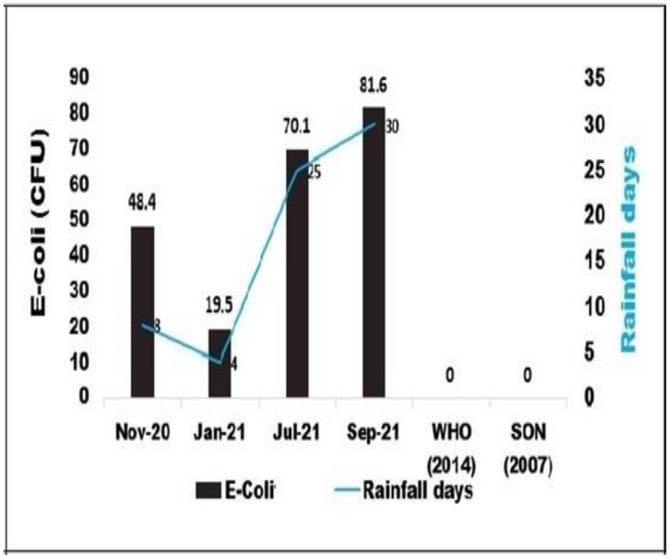


Figure 13: Results of the *E. coli* counts of the well water samples against variation in rainfall days

B. *Results of Correlation Matrix*

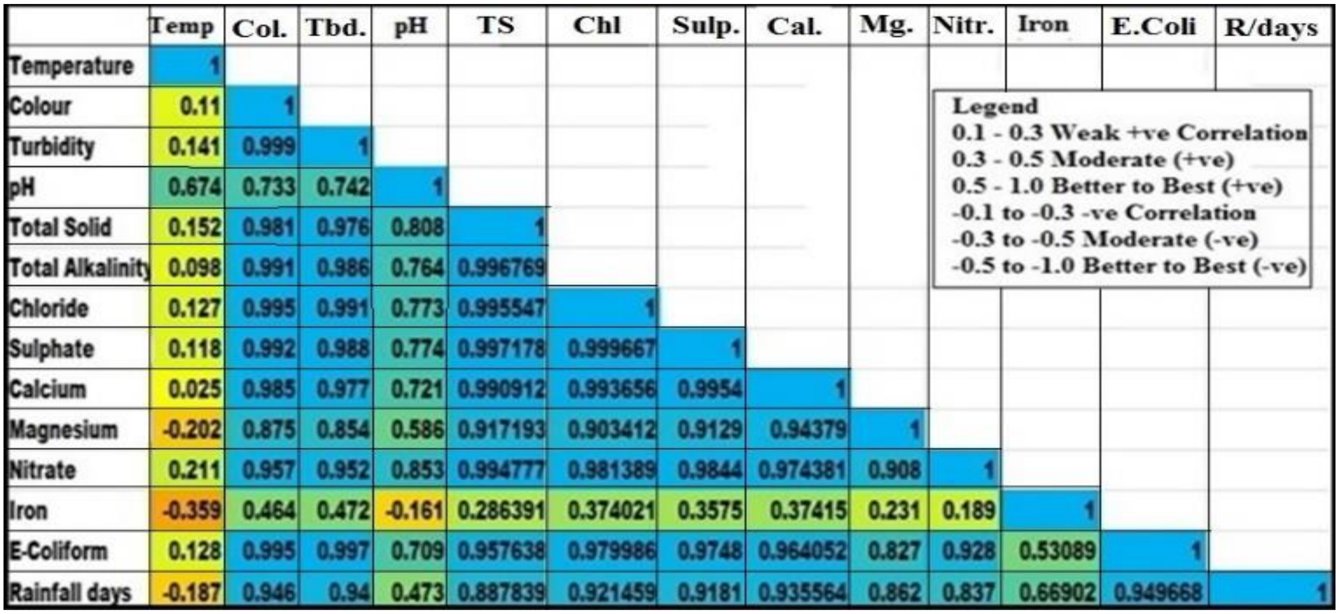
The correlation matrix of all the selected well water qualities is shown in Table 3. The correlation matrix between temperature and all other parameters ranged from -0.187 to 0.211 except pH, which is 0.674 as shown in Table 3. This shows a weak relationship with all other parameters examined except pH with strong relationship. It means that there is very little or no dependency between temperature and other parameters, but one of determinants of temperature is pH. This corroborated the relationship between temperature and rainfall days as shown in Figure 2.

Results from Table 3 also depicts that there exists a strong relationship (0.733 to 0.999) between colour values of well water samples and the other parameters examined, except the iron concentration (0.464), which has moderate correlation. there is also strong relationship with other parameters examined for the turbidity (0.742 to 0.997), ph (0.586 to 0.853), total solids (0.888 to 0.997), chloride (0.903 to 0.999), sulphate (0.913 to 0.995), calcium (0.936 to 0.974), magnesium (0.827 to 0.908) and nitrate (0.837 – 0.928).

All these portrayed that there is strong dependency among all the parameters except Iron, which ranged from -0.161 to 0.472; this shows little or no dependency on other parameters. Thus, while all the other parameters have influence over one another, Iron has little or no influence over others. The correlation matrix in Table 3 also illustrated that there is strong relationship between *E. Coli* and most of the parameters (i.e. 0.531 to 0.995) – colour, turbidity, ph, total solids, chloride, sulphate, calcium, magnesium, nitrate, iron and rainfall days. Its relationship with temperature is very weak (0.128). The results from table 3 assist in confirming the existence of *E. coli* in the well water due to the presence of the other parameters on one hand and the results from Figures 2 to 13 on the other hand.

This exposes the health of individuals depending on the groundwater to diseases causing organisms. Deductions from the core correlation matrix also equally, demonstrated the relative dependence of the parameters to one another as they variate according to the variation in weather. Mostly during the rainy season, higher concentrations of the parameters were observed than during the dry season, proving that the rainy season aids anthropogenic activities in transmitting dissolved harmful waste materials to the subsurface which eventually finds its paths into the groundwater (Adeniran *et al*., 2019; Oyedele *et al*., 2019). Talabi & Ogundana (2014); Adeosun & Omietimi (2020) strongly believed that contributing factors to high *E. coli* in the well water samples are indiscriminate waste dumps and improper disposal of faeces.

Table 3: The correlation matrix of the well water parameters



	Temp	Col.	Tbd.	pH	TS	Chl	Sulp.	Cal.	Mg.	Nitr.	Iron	E.Coli	R/days
Temperature	1												
Colour	0.11	1											
Turbidity	0.141	0.999	1										
pH	0.674	0.733	0.742	1									
Total Solid	0.152	0.981	0.976	0.808	1								
Total Alkalinity	0.098	0.991	0.986	0.764	0.996769								
Chloride	0.127	0.995	0.991	0.773	0.995547	1							
Sulphate	0.118	0.992	0.988	0.774	0.997178	0.999667	1						
Calcium	0.025	0.985	0.977	0.721	0.990912	0.993656	0.9954	1					
Magnesium	-0.202	0.875	0.854	0.586	0.917193	0.903412	0.9129	0.94379	1				
Nitrate	0.211	0.957	0.952	0.853	0.994777	0.981389	0.9844	0.974381	0.908	1			
Iron	-0.359	0.464	0.472	-0.161	0.286391	0.374021	0.3575	0.37415	0.231	0.189	1		
E-Coliform	0.128	0.995	0.997	0.709	0.957638	0.979986	0.9748	0.964052	0.827	0.928	0.53089	1	
Rainfall days	-0.187	0.946	0.94	0.473	0.887839	0.921459	0.9181	0.935564	0.862	0.837	0.66902	0.949668	1

Legend
0.1 - 0.3 Weak +ve Correlation
0.3 - 0.5 Moderate (+ve)
0.5 - 1.0 Better to Best (+ve)
-0.1 to -0.3 -ve Correlation
-0.3 to -0.5 Moderate (-ve)
-0.5 to -1.0 Better to Best (-ve)

***Temp – Temperaure, Col. – Colour, Tbd. – Turbidity, TS – Total Soild, Chl. – Chloride, Sulp. – Sulphate, Cal. – Calcium, Mg. – Magbesium, Nitr. – Nitrate, R/days – Rainfall days**

This study has revealed that higher concentrations in the physico-chemical and bacteriological parameters of the well water were observed during the rainy than dry season. The bacteriological quality of well water in Ado Ekiti has gradually deteriorated over the years with the presence of *E. coli* being observed in virtually all the samples tested. Sanmi & Abbas (2017) believed that owners of these privately used well may not be aware of the fact that their wells are contaminated. The sources of the pollution can be further related to indiscriminate solid waste disposal, faulty soak-away and septic tank, burial sites amongst others. These pollution sources should be identified so that appropriate measures can be taken.

IV. CONCLUSION

The fundamental concern found and established in this study is that well water quality in Ado Ekiti depends on the variation in season. Nevertheless, results obtained revealed that the physical and chemical parameters (i.e. temperature, colour, turbidity - partially, pH, total solids, chlorides, sulphate, calcium, magnesium, nitrate and iron contents) of the well water samples were within the tolerable limits during dry and rainy seasons. The bacteriological results revealed the presence of *E.coli* at quantity higher than the required limits during both seasons, though higher in rainy season than dry one. This exposes the health of individuals depending on the groundwater to diseases causing organisms. Therefore, the susceptibility to contamination and transportation of harmful dissolved materials into the groundwater is majorly dependent on variation in seasons. Observation wells should be established inside the research regions for periodic water quality assessments in developed countries. Based upon the above findings, periodic treatment of groundwater should be carried out in order to reduce the groundwater contamination level in the study area.

AUTHOR CONTRIBUTIONS

O. O. Ayeni: Conceptualization, Methodology, Software, Resources, Field work, Laboratory analysis, Data collation, Validation, Writing – original draft. **O. I. Ndububa:** Conceptualization, Methodology, Supervision, Writing - reviewing and editing. **S. O. Oyegoke:** Conceptualization, Methodology, Supervision**. A. E. Adetoro:** Data collation, Methodology, Software, Resources, Field work, Laboratory analysis, validation. Writing - reviewing and editing

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