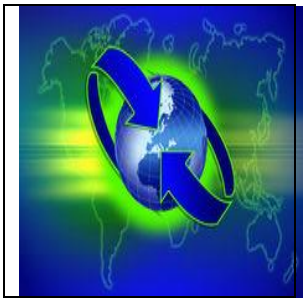

The Seasonal Variation of Well Water Physical and Chemical Properties in Gwagwalada Area Council, Abuja, Nigeria

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Abstract

A study on the seasonal variation of well water physical and chemical properties in Gwagwalada Area Council, Abuja, Nigeria is necessary because the composition of well water fluctuate with respect to time, season and climate. The objectives were to assess the physical and chemical properties of well water in the study area in both rainy and dry season and compare the physical and chemical properties of well water between the seasons. Survey research design was used for this study. Eighteen (18) well water samples were collected in dry and rainy season each in six purposely selected wards in the study area and analyzed in the laboratory for physiochemical properties. Data was analyzed from the laboratory result, while range, mean and t test statistical methods was further used. Result shows the concentration of parameters in dry season as follows: temperature (29.52-30.86), pH (6.83-7.86 Oc), EC (122-154 µs/cm3), TDS (119-144mg/l), turbidity (2.36-5.37 NTU), total hardness (12.13-30.46 mg/l), K (3.03-4.84 mg/l), Na (3.20-6.30 mg/l), Cl- (1.03-16.86 mg/l), Pb (0.002- 0.007 mg/l), Cr (0.016-0.086 mg/l),Cd (0.015-0.092 mg/l) and Cu (0.01-0.12 mg/l). But in rainy season they were: temperature (25.59-30.73Oc), pH (6.98-8.23), EC (222-354 µs/cm3), TDS (12.14-14.54mg/l), turbidity (0.26-0.93NTU), total hardness (13.58-39.72mg/l), K (3.05-5.09mg/l), Na (4.11-5.65mg/l), Cl- (4.29-8.93mg/l), Pb (0.001-0.02 1mg/l), Cr (0.006-0.021mg/l),Cd (0.002-0.039mg/l) and Cu (0.01-0.06mg/l).Though, all the parameters differ between seasons, only EC and TDS differs significantly at 0.05.It was concluded that well water in the study area are more polluted in dry season than in rainy season. Therefore, season is vital in water planning and exploration of other sources in dry season was recommended.

Keywords: Water quality, Seasonal variation, Well, Water pollution

Introduction

The quality of underground water which depends on the equilibrium between the physical, chemical, and biological characteristics of the surrounding environment is constantly changing in response to seasonal and climatic rhythms (Ioryue, Wuana and Augustine, 2018). Both natural and anthropogenic factors can cause seasonal variation in water quality. Natural

factors such as the geology of a place, climate and hydrological cycle can be agent of purification or pollution of given water source at given time (Able, Lekan, Adeyinka and Sylveste, 2017). Water quality can also be altered by human activities like industrial production, agricultural production and waste disposal (Kumpe, Alicea, Michel, de Waal and Ranjiv, 2017). These factors both human and natural varies with season and their influence on water quality is also season dependent (Ioryue *et al.*,2018). Human activities affect underground water quality in two major ways; namely: amount of withdrawal (volume) and introduction of pollutant.

Human factors drive water demand and pollution thereby create water crisis in a rapidly urbanizing area like Gwagwalada area council. Increase in population leads to an increase demand, withdrawal, and possible pollution due to increased economic activities and waste generation. According to (Makwe and Chup, 2013), increasing withdrawal, significant changes in land use pattern, vast industrial and agricultural effluents entering the hydrological cycle as well as seasonal variation, affect the quality and quantity of groundwater. Changes in groundwater recharge, due to seasonal variation, also affect the concentration of the water parameters. Rapid urbanization, especially in developing countries like Nigeria, has affected the availability and quality of groundwater due to waste and effluent disposal practice, especially in urban areas.

Thus, there are tendencies that water quality of same source differs between seasons. Owing to the recent global climate change and outstanding effects of heavy metal on water and its environment, several studies have been conducted on the seasonal variation of heavy metal concentration in water and a lot of findings have been made. Kumpe *et al* (2017) compared dry and rainy season water sources in the urban region of Port Harcourt, Nigeria. They found among other things that contamination by thermotolerant coliforms increased from 21% of drinking water sources in the dry season to 42% of drinking water sources in

the rainy season. Onuorah, Igwemadu and Odibo (2019) in a study to determine the effect of seasonal variation on the physicochemical characteristics of boreholes in Ogbaru Communities, Anambra collected and analyzed properties of fifteen drinking borehole water during the dry and wet seasons. The result showed that the pH values were in the range of 3.4-8.3; electrical conductivity, 15-238us/cm; total suspended solids, 0.00-0.25mg/l; total alkalinity, 4.0-27.0mg/l; total acidity, 2.5-7.5mg/l; total hardness, 30.0-84.0mg/l during the dry season while the pH ranged from 4.8 to 8.5; electrical conductivity, 41-910us/cm; total suspended solids, 0.03-2.01mg/l; total alkalinity, 12.0-40.0mg/l; total acidity, 5.0-22.5mg/l; total hardness, 45.0-94.0mg/l; during the wet season. They concluded that season had pronounced effect on the physicochemical characteristics of the water from the boreholes sampled.

Ishaku (2011) investigated seasonal variation of groundwater quality in Jimeta-Yola using selected chemical contaminants. The results indicated that pollutant loading occurred in the dry and rainy seasons. The groundwater is fresh and varied from slightly acidic to alkaline in both the dry and rainy seasons. The mean values of BOD, COD and chloride exceeded the recommended standards of drinking water quality in the rainy season from the shallow and deep aquifers (hand-dug wells and boreholes). Tsegay and Haftom (2016) carried out analysis of Physico-chemical parameters of reservoir water based on temperature, dissolved oxygen (DO), pH, transparency, electric conductivity, total dissolved solids (TDS), alkalinity, total hardness, phosphate and sulphate levels from August 2013 to July 2014 from three sampled stations to access the water quality. The water temperature ranged between *24.19– 27.30*^{0}C, dissolved oxygen ranged between 4.51 – 6.76 mg/l. The pH, transparency, conductivity and TDS were 7.14 – 8.64, 46.67 – 305.33 cm, 233.30 – 452.00 µs/cm and 0.91 – 1.77 g/L, respectively. There was significant difference ($p<0.05$) between all the parameters measured, except for water temperature between the seasons.

Ikhile (2011) investigated the seasonal variation of water quality of Orle River and its tributaries in South-West. The study revealed that the chemical indices of pollution such as Biochemical Oxygen Demand (BOD5), and Dissolved Oxygen (DO) vary significantly between the seasons. Likewise, Biochemical Oxygen Demand (BOD5), Dissolved Oxygen (DO) and Chemical Oxygen Demand (COD) show significant increase in the wet season and decrease in the dry season. On the other hand, total hardness show increase in the dry season and decrease in the wet season. The rivers are considered to be more polluted in the wet season than in the dry season.

Christiana and Amobichukwu (2014) examined the presence of arsenic and fluoride and the level of awareness of their presence in groundwater in Ibadan, Nigeria. The results showed arsenic concentration exceeding the WHO (2011) recommended level for drinking water in 98% and 100% for the dry and wet season samples. Concentration of Fluoride exceeded the recommended limits in 13% and 100% of the dry and wet season samples. The study recommends enlightenment on geogenic contamination and testing of wells for remediation purposes. Igibah and Tanko (2019) concluded that groundwater in the Abuja district is mainly hard to very hard and slightly acidic in nature, polluted by ion exchange, agricultural activities, anthropogenic activities, and weathering. The authors recommended routine monitoring of groundwater in Abuja to plan and improve water quality. According Igibah and Tanko (2019) groundwater is the main source of water for drinking, domestic, industrial and agricultural purposes in many nations. The semi-arid as well as arid zones of the world and Nigeria depend mostly on ground water for domestic purposes (Etteieb, Cherif and Tarhouni, 2017). Population growth and increasing generation of waste coupled with poor management has rendered the surface water useless for many uses at home. Thus, man has turned to sorting water from underground sources like well and borehole. However, it can be said that even the underground source are not free from pollutants been disposed on ground

and sometimes on surface water. The water cycle is a continuous process and polluted surface water can percolate into the aquifer leading to underground water pollution (Azhar, Ahmad, Mohd *et al.*, 2015).

Since, hydro-geochemical procedures that are responsible for inconsistencies in the chemical composition of groundwater, fluctuate with respect to time, thus the chemical physiognomies of groundwater which plays an essential role in classifying and evaluating the water quality need to be assessed in relation to season(Cao, Tang, Song, Liu and Zhang 2016; Li, Qian, Wu, Zhang and Zhang, 2013 cited in Igibah and Tanko (2019). It is reminded here that climatic condition influences several factors such as recharge water quality, geology, grade of chemical weathering of the different rock types, and water–rock interface which groundwater quality depends on (Emenike Tenebe, Omole *et al.* 2017; Aly, 2015).

However, several recent studies on groundwater quality conducted centered on evaluating the natural concentrations of several metals and ions in groundwater with little or no attention to seasonal variation (Chen, Zhou WQ, Pickett *et al*. 2016; Cao *et al.* 2016; Ehya and Marbouti 2016; Gu, Wang Zheng *et al.* 2015). Moreover, previous studies (Arulbalaji and Gurugnanam 2017; Cao et al. 2016) concluded that rapid population growth, unplanned municipal development, agricultural activities, insufficient hydrogeochemical knowledge, and poor groundwater quality management, are some major factors responsible for groundwater quality control. Moreover, few studies exist on water quality in Abuja and majority of it focused on public tap, borehole, dam and river water (Alhassan and Uja, 2012; Enitan, 2018; Igibah and Tanko, 2019).

However, an upsurge of population growth in Gwagwalada area council has not been matched with public water supply. Thus, many households rely on well for domestic uses in both rainy and dry season. Nevertheless, the seasonality in well water quality has

not been carefully studied in the region. Thus, the seasonal variation of well water physical and chemical properties was assessed in this study. The objectives were to assess the physical and chemical properties of well water in the study in both rainy and dry season and compare the physical and chemical properties of well water in rainy and dry seasons. A null hypothesis (H_O): "there is no significant difference in the concentration of properties of well water between rainy and dry seasons" was formulated and tested at 95% significant level.

Materials and Methods

The study area, Gwagwalada Area Council is one of the six area councils in the Federal Capital Territory which, according to the master plan of the FCT, is designated as the industrial zone. Gwagwalada is located between latitude $8^0$55'mins and 9^0 00' North and longitude 7^0 00'N and 7^0 05'E (Figure 1).

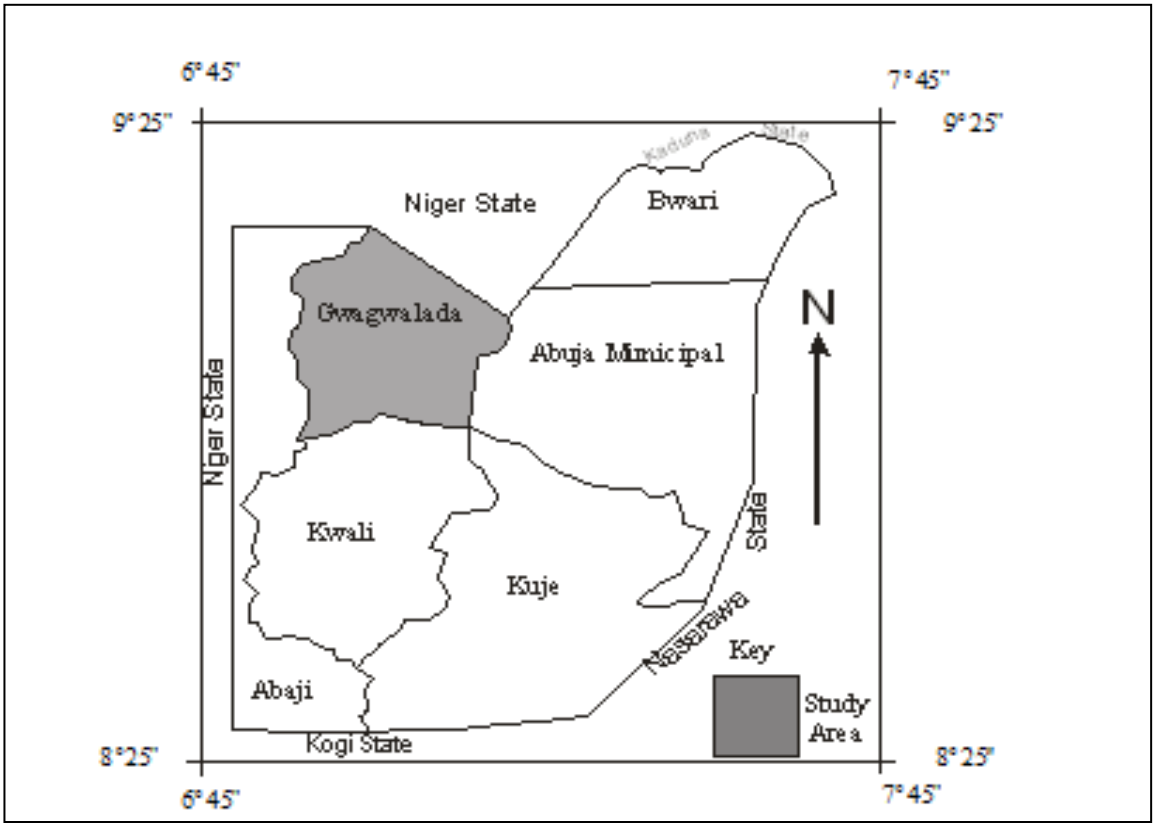

Figure 1: The Study Area
Source: Coordinate System (GCS WGS 88

The area council has ten political wards (Adeniyi and Abdullateef, 2015). The centrality of the town in relation to other Area Council Headquarters makes it influential and important in various socio-economic activities. It is where the University of Abuja, Abuja University Teaching Hospital and School of the Gifted are located. Thus, supposedly have access to good quality water for domestic uses.

This study employed survey and sequential design for data collection and analysis. Field survey was embarked on sequentially in dry and rainy seasons for collection of water samples from the study area. Sample was collected and analyzed in the laboratory in dry season to get dry season data and also in rainy season to get rainy season data. Eighteen (18) well water samples were collected in dry and rainy season each. A total of thirty-six (36) water samples were collected from wells in six purposely selected wards in the study area. The selections of the wards for well sampling were based on heavy reliance of well water for domestic use among wards that currently lack public water supply. Thus, Dobi, Ibwa, Paikon-Kore, Tungan Maje, Zuba and Ikwa were selected. Three water samples were spatially collected from each of the six selected wards in dry and rainy seasons. The water samples were stored in 75cl plastic bottles pre-cleaned with distilled water (Mokisopropyl Alcohol) and rinsed three times with the sample water, before taking the sample for analysis. Each sample was labeled with the name of the ward and transported to the laboratory for analysis.

Parameters like pH, temperature, turbidity conductivity and TDS were measured in-situ with hydro lab kit. Temperature was measured using thermometer; pH, EC and TDS were determined using a multimeter, turbidity was determined by spectrophotometric method. Metals (Calcium, Sodium Na, Potassium K. iron Fe, zinc Zn, lead Pb, chromium Cr, Cadmium Cd, Copper Cu, Manganese and Mn) and hardness were measured in the laboratory with Atomic Absorption Spectrophotometer (AAS) and by titration with an

EDTA solution respectively. The result for each season was analyzed using range and mean after which both seasons were compared using t test.

Results and Discussions

Tables 1 and 2 present the physical and chemical properties of well water in the study area for dry and rainy seasons respectively.

Tables 1: The Physical and Chemical Properties of Well Water in Dry Season

Parameter	Dobi	Ibwa	Paikon-Kore	Tungan Maje	Zuba	Ikwa	Range	Mean
Temp.(Oc)	30.66	29.83	30.86	29.52	29.97	31.92	29.52-30.86	30.57
Ph	7.26	7.86	7.52	6.97	6.83	6.91	6.83-7.86	7.06
E.C(µs/cm3)	122	142	154	154	140	137	122-154	146.25
TDS(Mg/l)	144	131	129	130	121	119	119-144	124.75
Turb.(NTU	5.37	2.71	2.36	2.65	2.57	0.67	2.36-5.37	3.81
Total Hard.(Mg/l)	21.58	29.72	30.46	8.26	16.12	12.13	12.13-30.46	19.24
K Mg/l	3.11	3.62	3.03	3.06	3.01	4.86	3.03-4.84	3.49
Na Mg/l	4.54	3.42	3.20	5.00	6.30	3.86	3.20-6.30	4.59
Cl- Mg/l	1.03	0.83	16.86	6.21	10.22	13.72	1.03-16.86	11.75
Ca Mg/l	28.03	43.75	22.86	34.25	18.04	21.62	18.04-43.75	24.19
Mg Mg/l	10.83	10.76	11.62	12.23	11.35	10.07	10.07-12.23	11.32
Fe Mg/l	0.83	0.92	0.81	0.72	0.65	0.64	0.53-0.96	0.76
Si Mg/l	0.016	0.04	0.06	0.017	0.05	0.05	0.016-0.06	0.039
Zn Mg/l	0.029	0.021	0.034	0.023	0.039	0.041	0.021-0.051	0.031
Lead Mg/l	0.003	0.005	0.006	0.007	0.005	0.006	0.002- 0.007	0.005
Cr Mg/l	0.038	0.086	0.041	0.015	0.031	0.036	0.016-0.086	0.041
Cd Mg/l	0.015	0.059	0.049	0.018	0.071	0.092	0.015-0.092	0.051
Cu Mg/l	0.11	0.12	0.06	0.07	0.02	0.08	0.01-0.12	0.077

Table1 present the concentrations of well properties in dry season as follows: temperature (29.52-30.86), pH (6.83-7.86 Oc), EC (122-154 µs/cm3), TDS (119-144mg/l), turbidity (2.36-5.37 NTU), total hardness (12.13-30.46 mg/l), K (3.03-4.84 mg/l), Na (3.20-6.30 mg/l), Cl- (1.03-16.86 mg/l), Ca (18.04-43.75 mg/l), Mg (10.07-12.23 mg/l), Fe (0.53-0.96 mg/l), Si (0.016-0.06 mg/l), Zn (0.021-0.051 mg/l), Pb (0.002- 0.007 mg/l), Cr (0.016-0.086 mg/l),Cd (0.015-0.092 mg/l) and Cu (0.01-0.12 mg/l).

The concentrations of these physical and chemical properties in the rainy season are presented in table 2.

Tables 2: The Physical and Chemical Properties of Well Water in Rainy Season

Parameter	Dobi	Ibwa	Paikon-Kore	Tungan Maje	Zuba	Ikwa	Range	Mean
Temp.(Oc)	26.96	27.32	28.98	30.73	26.59	25.59	25.59-30.73	27.94
pH	8.23	7.17	7.41	7.92	8.01	6.98	6.98-8.23	7.59
E.C(µs/cm3)	240	222	254	254	354	242	222-354	254.60
TDS(Mg/l)	14.45	13.16	12.97	13.08	12.14	21.54	12.14-14.54	13.53
Turb.(NTU	0.37	0.29	0.26	0.45	0.47	0.93	0.26-0.93	0.47
T. Hard.(Mg/l)	22.06	13.58	39.72	19.46	19.26	29.12	13.58-39.72	26.36
K	4. 03	4.06	4.13	4.16	5.09	3.05	3.05-5.09	4.15
Na	4.11	5.62	5.03	5.06	5.01	5.65	4.11-5.65	5.13
Cl-	6.54	5.42	4.29	7	8.93	7.54	4.29-8.93	6.16
Mg	2.03	2.83	17.86	6.21	11.22	17.04	2.03-17.86	10.23
Ca	20.03	10.75	21.86	13.25	8.04	12.08	4.32-48.43	16.08
Fe	0.62	0.75	0.62	0.55	0.53	0.64	0.43-0.75	0.64
Si	0.01	0.02	0.017	0.03	0.02	0.06	0.01-0.06	0.02
Zn	0.01	0.031	0.013	0.09	0.021	0.017	0.01-0.090	0.027
Lead	0.001	0.003	0.004	0.02	0.004	0.003	0.001-0.02 1	0.003
Cr	0.014	0.006	0.011	0.011	0.013	0.021	0.006-0.021	0.012
Cd	0.005	0.002	0.013	0.031	0.042	0.039	0.002-0.039	0.018
Cu	0.02	0.01	0.03	0.02	0.02	0.06	0.01-0.06	0.033

Table 2 present the concentration of well properties in dry season as follows: temperature (25.59-30.73Oc), pH (6.98-8.23), EC (222-354 µs/cm3), TDS (12.14-14.54mg/l), turbidity (0.26-0.93NTU), total hardness (13.58-39.72mg/l), K (3.05-5.09mg/l), Na (4.11-5.65mg/l), Cl- (4.29-8.93mg/l), Ca (2.03-17.86mg/l), Mg (4.32-48.43mg/l), Fe (0.43-0.75mg/l), Si (0.01-0.06mg/l), Zn (0.01-0.090mg/l), Pb (0.001-0.02 1mg/l), Cr (0.006-0.021mg/l), Cd (0.002-0.039mg/l) and Cu (0.01-0.06mg/l).

The Seasonal Variation in Properties of Well Water in the Study Area

There are differences in the concentrations of well water properties in the study area between dry and rainy season. Student t test was used to determine which parameter(s)

differ significantly (Table 3). Tables 3 present the result of t –test for seasonal variation in properties of well water in the study area.

Table 3: The Result of t –test for Seasonal Variation in Properties of Well Water in **the Study Area**

Parameters	**Unit**	**Mean**		**Calculated 't' value**		
		Dry Season	**Rainy Season**		**df(n1+n2)-2**	**Table t value**
Temp.	Oc	30.57	28.04	0.04	10	2.23
pH	μ^s/cm^3	6.06	7.81	0.03	10	2.23
E.C	Mg/l	146.25	261.00	2.33	10	2.23
TDS	Mg/l	124.75	14.56	3.12	10	2.23
Turbidity	NTU	3.81	0.46	0.25	10	2.23
Total Hardness		19.24	23.87	0.03	10	2.23
K		3.49	4.10	0.06	10	2.23
Na		4.59	5.08	0.09	10	2.23
Cl-		11.75	6.62	0.12	10	2.23
Mg		24.19	9.53	0.23	10	2.23
Ca	Mg/l	11.32	14.34	0.78	10	2.23
Fe		0.76	0.61	0.008	10	2.23
Si		0.039	0.003	0.002	10	2.23
Zn		0.031	0.003	0.43	10	2.23
Lead		0.005	0.003	0.08	10	2.23
Cr		0.041	0.013	0.51	10	2.23
Cd		0.051	0.022	0.07	10	2.23
Cu		0.077	0.028	0.13	10	2.23

Table 3 presents the seasonal variation of well water properties of Gwagwalada area council as follows:

Seasonal Variation in Temperature

The mean record of temperature in dry season is 30.57^0c but in rainy season 28.04^0c which suggest that temperature is higher in dry season. The mean temperature is relatively higher than the $28\text{-}29^0$C in dry season and $25\text{-}28^0$c reported by Onuorah *et al.*, (2019) however it agreed with Onuorah *et al.*, (2019) that temperature is higher during dry season. The higher value of temperature in the study when compared to Onuorah *et al.*, (2019) is due to locational factor. However, the calculated t-test being 0.04 is less than table t value of 2.23. Since the calculated 't' is less than table value, the Ho, there is no significant difference in

water quality properties between rainy and dry season samples at 95% significant level is accepted for temperature. Thus, temperature of well water in Gwagwalada area council did not differ significantly between dry and rainy seasons.

Seasonal Variation in pH

The mean concentration of pH in dry season is 6.06 but 7.81 in rainy season which suggest that pH is higher in rainy season. Onuorah *et al.*, (2019) also reported higher pH in rainy than dry season. However, the calculated t value of 0.03 is less than calculated t value of 2.23. Since the calculated 't' is less than the table t value, the Ho, there is no significant difference in well water quality properties between rainy and dry season samples at 95% significant level is accepted for pH. Though, well water is more acidic in dry season due to high concentrations of heavy metals, pH of water in Gwagwalada area council did not differ significantly between dry and rainy seasons.

Seasonal Variation in EC

The mean concentration of is 146.25 μ^s/cm^3 in dry season is but 261.00μ^s/cm^3 in rainy season which suggest that EC is higher in rainy season. Onuorah *et al.*, (2019) also reported higher EC in rainy than dry season. Moreover, the calculated t value of 2.33 is greater than table t value of 2.23. Since the calculated 't' is greater than table value, the Ho, there is no significant difference in water quality properties between rainy and dry seasons samples at 95% significant level is rejected for EC. Thus, EC of well water in Gwagwalada area council differ significantly between dry and rainy season.

Seasonal Variation in TDS

The mean concentration of TDS in dry season is 124.75Mg/l but 14.56Mg/l in rainy season which suggest that TDS is higher in dry season. This agreed with many previous studies (Ngabirano, 2016; Ocheri and Oklo, 2017) but disagreed with Makwe and Chup, (2013) that reported higher TDS in rainy season. Though, source of TDS like rock

weathering may be higher in rainy season but the high withdrawal of well water in dry reason may be the cause of higher TDS in dry season. This is because, the volume is drastically reduced in dry season. Moreover, the calculated t value of 3.12 is greater than table t value 2.23. Since the calculated 't' is greater than table t, the Ho, there is no significant difference in water quality properties between rainy and dry season samples at 95% significant level is rejected for TDS. Thus, TDS of well water in Gwagwalada area council differ significantly between dry and rainy season.

Seasonal Variation in Turbidity

The mean concentration of turbidity in dry season is 3.81 Mg/l but 0.46 Mg/l in rainy season which suggest that turbidity is higher in dry season. Higher turbidity in dry season have also been record by Ocheri and Oklo, (2017). However, the calculated t value of 0.25 less than table t value of 2.23. Since the calculated 't' is less than table t, the Ho, there is no significant difference in water quality properties between rainy and dry season samples at 95% significant level is accepted for turbidity. Thus, turbidity of well water in Gwagwalada area council did not differs significantly between dry and rainy season.

Seasonal Variation in Total Hardness

The mean concentration of total hardness in dry season is 23.87 Mg/l but 19.24Mg/l in rainy season which suggest that total hardness is higher in dry season. However, the calculated t value of 0.03 is less than table t value of 2.23. Since the calculated 't' is less than table t, the Ho, there is no significant difference in well water quality properties between rainy and dry season samples at 95% significant level is accepted for total hardness. Thus, total hardness of well water in Gwagwalada area council did not differ significantly between dry and rainy season.

Seasonal Variation in Potassium (K)

The mean concentration of potassium (K) in dry season is 2.48 Mg/l but 4.15 Mg/l in rainy season which suggest that potassium (K) is higher in rainy season. Moreover, the calculated t value of 0.004 t is less than table t value of 2.23. Since the calculated 't' is less than table 1, the Ho, there is no significant difference in well water quality properties between rainy and rainy season samples at 95% significant level is accepted for total hardness. Thus, potassium (K) concentration in well water in Gwagwalada area council did not differs significantly between dry and rainy seasons.

Seasonal Variation in Sodium (Na)

The mean concentration of sodium (Na) in dry season is 4.59 Mg/l but 5.08 Mg/l in rainy season which suggest that sodium (Na) is higher in rainy season. Moreover, the calculated t value of 0.09 is less than table t value of 2.23. Since the calculated 't' is greater than table t, the Ho, there is no significant difference in well water quality properties between rainy and rainy season samples at 95% significant level is accepted for sodium (Na). Thus, sodium (Na) concentration in well water in Gwagwalada area council did not differ significantly between dry and rainy seasons.

Seasonal Variation in Chloride (Cl-)

The mean concentration of chloride (Cl-) in dry season is 11.75Mg/l but 6.62Mg/l in rainy season which suggest that chloride (Cl-) is higher in rainy season. Moreover, the calculated t value of 0.12 means is less than table t value of 2.23. Since the calculated 't' is less than table value, the Ho, there is no significant difference in well water quality properties between rainy and rainy season samples at 95% significant level is accepted for chloride (Cl-). Thus, chloride (Cl-) concentration in well water in Gwagwalada area council did not differs significantly between dry and rainy seasons.

Seasonal Variation in Magnesium (Mg)

The mean concentration of magnesium (Mg) in dry season is 24.19Mg/l but 9.53Mg/l in rainy season which suggest that magnesium (Mg) is higher in rainy season. However, the calculated t value of 0.23 is greater than table t value of 2.23. Since the calculated 't' is greater than table t, the Ho, there is no significant difference in well water properties between dry and rainy season samples at 95% significant level is rejected ted for magnesium (Mg). Thus, magnesium (Mg) concentration in well water in Gwagwalada area council differs significantly between dry and rainy seasons.

Seasonal Variation in Calcium (Ca)

The mean concentration of calcium (Ca) in dry season is11.32Mg/l but 14.34Mg/l in rainy season which suggest that calcium (Ca) is higher in rainy season. However, the calculated t vale of 0.23 is less than table t value of 2.23. Since the calculated 't' is less than table t, the Ho, there is no significant difference in well water properties between dry and rainy season samples at 95% significant level is accepted for calcium (Ca). Thus, calcium (Ca) concentration in well water in Gwagwalada area council did not differs significantly between dry and rainy seasons.

Seasonal Variation of Iron (Fe)

The mean concentration of iron (Fe) in dry season is 0.76Mg/l but 0.61 0Mg/l in rainy season which suggest that iron (Fe) is higher in dry season. However, the calculated t value of 0.008 is less than table t value of 2.23. Since the calculated 't' is less than 2.23, the Ho, there is no significant difference in well water quality properties between rainy and dry season samples at 95% significant level is accepted for Fe. Thus, iron (Fe) concentration in well water in Gwagwalada area council did not differ significantly between dry and rainy season.

Seasonal Variation of Silicon (Si)

The mean concentration of silicon (Si) in dry season is 0.020Mg/l but0.021 Mg/l in rainy season which suggest that silicon (Si) is higher in dry season. However, the calculated t value of 0.002 less than table t value of 2.23. Since the calculated 't' is less than table t, the Ho, there is no significant difference in well water quality properties between rainy and dry season samples at 95% significant level is accepted for silicon (Si). Thus, silicon (Si) concentration in well water in Gwagwalada area council did not differ significantly between dry and rainy season.

Seasonal Variation in Zinc

The mean concentration of zinc (Zn) in dry season is 0.039 Mg/l but 0.003 Mg/l in rainy season which suggest that zinc (Zn) is higher in dry season. Moreover, the calculated t value of 0.43 is less than table t value of 2.23. Since the calculated 't' is less than table t, the Ho, there is no significant difference in well water quality properties between dry and rainy season samples at 95% significant level is accepted for zinc (Zn). Thus, zinc (Zn) concentration in well water in Gwagwalada area council did not differs significantly between dry and rainy seasons.

Seasonal Variation in Lead (Pb)

The mean concentration of lead (Pb) in dry season is 0.005 Mg/l but 0.003Mg/l in rainy season which suggest that lead (Pb) is higher in dry season. Moreover, the calculated t value of 0.08 is less than table t value of 2.23. Since the calculated 't' is less than table t, the Ho, there is no significant difference in well water quality properties between dry and rainy season samples at 95% significant level is accepted for lead (Pb). Thus, lead (Pb) concentration in well water in Gwagwalada area council did not differs significantly between dry and rainy seasons.

Seasonal Variation in Chromium (Cr)

The mean concentration of chromium (Cr) in dry season is 0.041 Mg/l but 0.013Mg/l in rainy season which suggest that chromium (Cr) is higher in dry season. Moreover, the calculated t value of 0.51 is greater than table t value of 2.23. Since the calculated 't' is greater than table t, the Ho, there is no significant difference in well water quality properties between dry and rainy season samples at 95% significant level is accepted for chromium (Cr). Thus, chromium (Cr) concentration in well water in Gwagwalada area council did not differs significantly between dry and rainy seasons**.**

Seasonal Variation in Cadmium (Cd)

The mean concentration of cadmium (Cd) in dry season is 2.231 Mg/l but 0.022Mg/l in rainy season which suggest that cadmium (Cd) is higher in dry season. Moreover, the calculated t value of 0.07 is less than table t value of 2.23. Since the calculated 't' is less than table t, the Ho, there is no significant difference in well water quality properties between dry and rainy season samples at 95% significant level is rejected for cadmium (Cd). Thus, cadmium (Cd) concentration in well water in Gwagwalada area council differs significantly between dry and rainy seasons.

Seasonal Variation in Copper (Cu)

The mean concentration of copper (Cu) in dry season is 0.077 Mg/l but 0.028Mg/l in rainy season which suggest that copper (Cu) is higher in dry season. Moreover, the calculated t value of 0.13 is less than 2.23. Since the calculated 't' is less than table value, the Ho, there is no significant difference in well water quality properties between dry and rainy season samples at 95% significant level is rejected for copper (Cu). Thus, copper (Cu) concentration in well water in Gwagwalada area council differs significantly between dry and rainy seasons.

From the discussion so far, it was observed that most the pollution indices like TDS, turbidity, total hardness and heavy metals (Fe, Si, Zn, Cr and Cu) have higher concentration dry samples than in rainy season samples while EC and mineral elements like K, Na, and Cl- are higher in rainy season samples. The result is line with finding many previous studies (Onuorah *et al,* 2019; Igibah and Tanko, 2019). Well water usually has higher turbidity and TDS in dry season due to higher rate of withdrawal and reduction in volume. More concentration of heavy metal may be due higher economic activities and waste generation during dry season.

From the discussion so far, it was observed that most the pollution indices like TDS, turbidity, total hardness and heavy metals (Fe, Si, Zn, Cr and Cu) have higher concentration in dry than in rainy season samples while EC and mineral elements like K, Na, and Cl- are higher in rainy season samples. The result is in line with findings of many previous studies (Onuorah *et al,* 2019; Igibah and Tanko, 2019). Well water usually has higher turbidity and TDS in dry season due to higher rate of withdrawal and reduction in volume. More concentration of heavy metal may be due to higher economic activities and waste generation during dry season.

Conclusion and Recommendations

The Ho **"**there is no significant difference in the concentration of properties of well water between rainy and dry seasons at 95% significant level was rejected for all parameters except temperature, pH, total hardness, Fe and Si. Thus, all parameters temperature, pH, TDS, turbidity, total hardness, K, Na, Cl-,Mg, Ca, Fe, Si, Zn, Cr and Cu differs significantly between dry and rainy season except for temperature, pH, total hardness, Fe and Si. Therefore, there is a significant variation in well water properties in Gwagwalada area council between dry and rainy season. Moreover, well water is more polluted in dry season.

It was therefore recommended that resident of Gwagwalada area council should device other sources of water supply such as advanced rain water harvesting to reduce high dependency on well during the dry season. The Abuja water body should also extend the public top to the un-served wards in Gwagwalada area council.

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