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# EVALUATION OF HEAVY METALS' CONCENTRATION AND PHYSICOCHEMICAL PARAMETERS OF GROUNDWATER WITHIN JOS METROPOLIS OF PLATEAU STATE, NIGERIA

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**ABSTRACT**

This paper studied the quality of drinking water from borehole sources in Jos and its environs. The level of heavy metal concentrations and some physicochemical parameters were determined using standard methods. The result of heavy metal concentrations analyzed within the ten (10) sampling points shows that JS1 sampling point had a significantly high ($p<0.05$) concentration of copper (0.0064 mg/L) and lowest in JS1 sampling point (0.001 mg/L). Chromium had a significantly high ($p<0.05$) concentration in JS10 sampling point (0.718 mg/L) and lowest in JS1 (0.153 mg/L). Manganese had significantly high ($p<0.05$) concentration in JS4 sampling point (0.198 mg/L) and lowest in (JS6 0.020 mg/L). Iron was significantly high ($p<0.05$) in JS4 sampling point with the concentration of 1.388 mg/L and lowest value of 0.020 mg/L in JS5. Zinc had a significantly high ($p<0.05$) in JS4 sampling point with the concentration of 0.085 mg/L. Lead had significantly high ($p<0.05$) in JS8 sampling point with a concentration of 0.005 mg/L. Cadmium and nickel were not detected in all ten (10) sampling points. The electrical conductivity and pH and were found to be in the range of (0.000 - 350 µSv/cm) and (4.81 – 6.70), respectively. This research findings suggest that continued water quality monitoring should be carried out to check the concentration levels of copper, zinc, manganese, cadmium, nickel, lead and physicochemical parameters electrical conductivity and pH in those ten (10) sampling points to prevent them from been above the limit of World Health Organization (WHO) permissible limit and also creating awareness on the health risk of a high level of concentration of chromium and iron in those ten (10) sampling points which are above the World Health Organization permissible limit.

**Keywords**: Heavy metals, Boreholes, Physicochemical, WHO

## INTRODUCTION

The uniqueness of water to human existence on earth cannot be over emphasized. In fact, human survival on earth without water is impossible. The sources of water include rivers, streams, and springs, hand dug wells, boreholes and other freshwater bodies (Kalip *et al*., 2020). These sources supply water for several uses such as drinking, cooking and industrial amongst others. However, good water quality which implies safe (uncontaminated) water supplies is a fundamental factor that impacts human wellbeing (WHO, 2006; Varsha *et al*., 2019) is still not available to a vast proportion of the world's population. The contamination of groundwater may result from domestic sewage, feedlots and surface run-off, and other pollution sources such as quarrying activities or mining sites (Vaishnav and Dewangan, 2011). Subterranean aquifers may also become contaminated in areas where the subsurface geology allows for rapid downward movement of water source from the surface or where ground (well) water sources are tapped near the surface (Jabiri and Agumuo, 2007).

The pollution of water by toxic elements (heavy metals) has been studied in so many countries (WHO, 1996; Oyeku, and Eludoyin, 2010; Abdullahi *et al*., 2016). These studies indicate the major concern associated with it and its toxicity to humans and biological systems, even at low concentrations although some heavy metals are essential to life (Jabiri and Agumuo, 2007). But at high concentration they tend to be harmful due to their bioaccumulation which may result in heavy metal poisoning (Jabiri and Agumuo, 2007). These metals include lead, cadmium, zinc, chromium, mercury, arsenic, silver, copper, iron, platinum, and manganese.

Previous studies conducted on the Jos Plateau relating to heavy metals which include afuyai *et al*., (2020); Nyam and Ashano, (2017); Wapwera *et al*., (2015); Ogezi and Adiuku-Brown, (1987) were majorly in mined areas. For instance, Nyam and Ashano, (2017) determined heavy metal concentration in abandoned mine ponds and groundwater in some locations of the Jos Plateau. They obtained low concentrations for 93.3% of the study area, moderate concentration for 4.76% concerning iron (Fe), lead (Pb), and zinc (Zn), and 1.9% for considerable contamination of the area concern Lead (Pb). While, Ozoko, (2004) in the Jos-Bukuru-Rayfield area found that only lead and iron occurred in detectable concentrations; lead (Pb) varied from 0.0399 mg/l to 0.0679 mg/l (a mining pond); iron (Fe) ranged from 0.16 mg/l to 10.27 mg/l. It was observed that while iron exceeded the WHO limits for potable water lead (Pb) did not. Physicochemical parameters such as temperature, electrical conductivity (EC), hydrogen potential (pH) and total dissolved solids (TDS) assist in determining the quality of water from various sources for consumption and industrial uses (WHO, 1997).

Ozoko, (2004), conducted measurements of EC, PH, and TDS among others within the Jos-Bukuru Rayfield area. Water samples were collected from handdug wells, mining ponds and a river. The results indicate $P^H$ values ranging from 5.06 to 7.85, with most of the values hovering around 6.5 (a tendency towards alkaline conditions). EC values ranged from $3\mu s/m$ to $95\ \mu s/m$, while values of TDS ranged from 4 mg/$\iota$ to 66 mg/$\iota$. This work was restricted only to two out of the six major mining fields in the state and Global Positioning System (GPS) was not used to obtain specific sample locations.

From the foregoing, it is obvious that reported studies on heavy metals and physicochemical parameters in most residential areas of the Jos-Bukuru-Rayfield area are not available. This study was therefore intended to fill this gap.

Hence, the specific objectives of this work were as follows: To determine the levels of some selected heavy metals in well and borehole water samples compare the values with those of international and national regulatory bodies and also determine some selected physicochemical parameters that may assist in evaluating the quality of the water samples.

## MATERIALS AND METHOD

### Description of the Study Area

The area known as Jos is the capital of Plateau State, located in North Central Nigeria. The study area comprises Jos North, Jos South and Jos East Local government areas (LGA), and is located between the latitudes of 9°30ᴵ - 10°10ᴵ N and the longitudes 8°15ᴵ - 9°15ᴵ E. It has an average elevation of 1,150 m rising to a peak of 1,777 m above sea level. The average temperature ranges from 15.5 ℃ to 18.5 ℃ in the coolest months to 27.5 ℃ to 30.5 ℃ during the hottest months, while rainfall averages 1,411 mm per year. The study area is characterized as tropical savannah (but close to temperate) and consists of a series of highlands and flat topography (Schoeneich. and Mbonu, 1991).

The Jos Plateau is underlain by three groups of rocks. The oldest is the basement complex Precambrian which comprises of the older granites, gneisses, and migmatites. The second group is the younger granites (Jurassic to Triassic) which are majorly alkaline. The third is the older and newer basalts quaternary (Nyam and Ashano, 2017). The younger granites form ring complexes throughout the plateau which have been associated with tin occurrence. The most dominant type among the younger granites are biotite granites which have three distinct groups (Olade, 1980). They are (from the oldest to youngest); the Rayfield Gona biotite granites, N'Gell biotite granite, and Jos biotite granite (Macleod *et al*., 1971; Olade, 1980).

**Table 1: Sampling Points and their Coordinates**

| S/n | Site code | Sampling points | Coordinates |
|---|---|---|---|
| 1 | JS1 | Land & Survey Head Qtr | 09°54'21.6"N 08°53'21.4"E |
| 2 | JS2 | Tudun Wada Park | 09°54'13.6"N 08°52'10.0"E |
| 3 | JS3 | Alheri Area | 09°56'06.6"N 08°52'10.5"E |
| 4 | JS4 | Odus, Bauchi by Pass | 09°56'28.0"N 08°54'26.1"E |
| 5 | JS5 | Fudawa, Opp. Nasarawa area | 09°56'03.3"N 08°54'59.6"E |
| 6 | JS6 | Abbatoir, Jos South | 09°53'15.0"N 08°53'15.1"E |
| 7 | JS7 | Namua, Bukuru Road | 09°52'39.5"N 08°53'08.6"E |
| 8 | JS8 | Sabon Barki, Bukuru Road | 09°49'31.7"N 08°51'51.3"E |
| 9 | JS9 | TCNN, Bukuru | 09°47'52.2"N 08°52'58.8"E |
| 10 | JS10 | Zang SEC. Sch. Bukuru | 09°48'20.1"N 08°52'00.1"E |

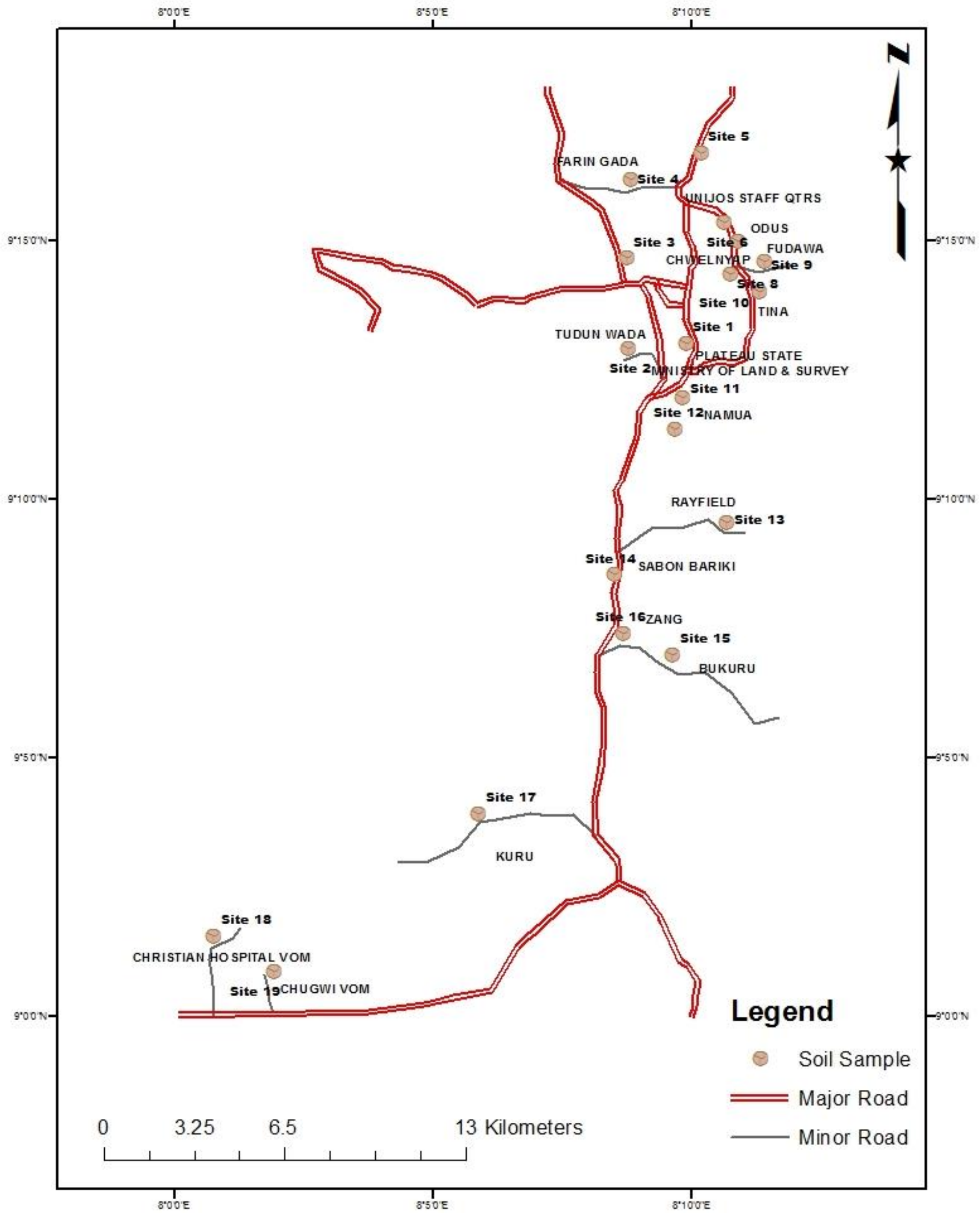


Figure 1: Map of Jos and Envrions identifying soil sampling locations
Source: (KADGIS, 2020)

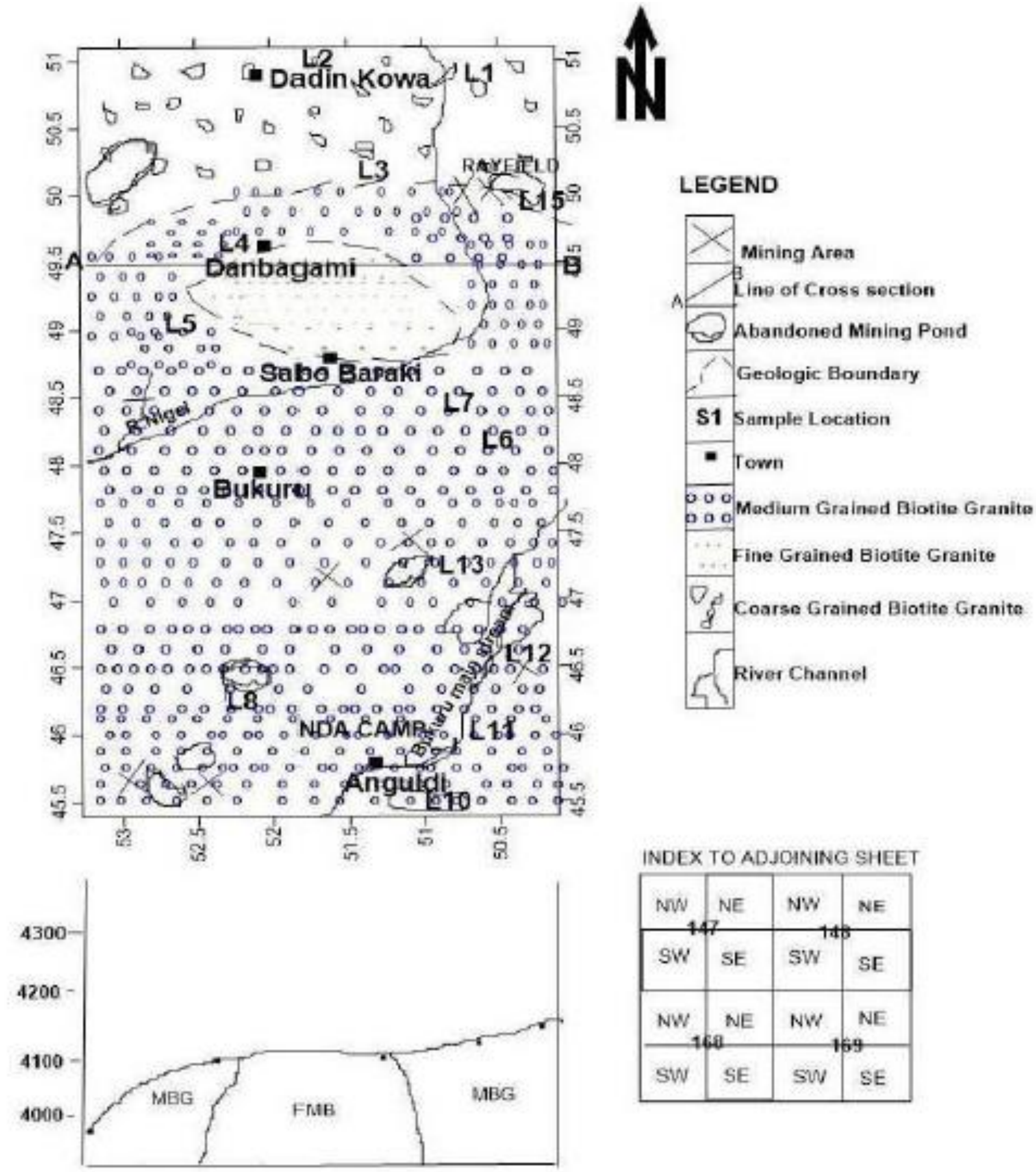


Figure 2: Geological map of Bukuru Rayfield area (Naraguta Sheet 158 NE)

**Water Sampling and Analysis for Heavy Metals**

Water samples were collected from ten (10) boreholes from different sampling points. The sampling bottles were pre-soaked overnight with 10 % HCl and rinsed with distilled water and also rinsed with the water to be examined before sample collection. Preservation was done by adding two (2) drops of concentrated $HNO_3$ to each water sample before storage below 4 °C, which was maintained until the analysis was done so that the dissolved metals were kept in ionic form to enable their detection by the Atomic Absorption Spectrometry (AAS) at the Chemistry Department Ahmadu Bello University (ABU) Zaria. The metals analyzed were lead (Pb), copper (Cu), cadmium (Cd), chromium (Cr), nickel (Ni), zinc (Zn), iron (Fe), and manganese (Mn). The locations of the sampling points were taken using a portable Global Positioning System (G.P.S) device, the (*Vartian AA650FS model*).

**Sample Analysis for Physicochemical Parameters**

Two physical Parameters EC and pH of the water samples were measured at the sampling sites using a portable conductivity meter and a portable PH meter respectively, which were obtained from the Postgraduate Chemistry Laboratory, University of Jos, Nigeria in December 2018.

## RESULTS AND DISCUSSION

**Heavy Metals' Concentrations**

The heavy metals' concentration for ten (10) different sampling points within the Jos metropolis are shown in Table 2. The results are compared with the World Health Organization WHO (2011) maximum permissible limits for drinking water. The result showed that JS10 sampling point had the highest copper (0.0064 mg/L) concentration while JS1 sampling point had the lowest (0.001 mg/L) concentration. The copper levels of sampling points JS1, JS3, and JS5 were not significantly ($p>0.05$) different from each other. In the same vein, the copper levels in sampling points JS4, JS7 and

JS9 had statistically similar concentrations. Also, the copper levels in JS2, JS6, JS8 and JS10 sampling points were statistically similar. The concentration of copper in all ten (10) sampling points is within the maximum permissible limits for drinking water of the World Health Organization WHO (2011).

The chromium level was higher in JS10 (0.718 mg/L) while JS1 sampling point had the lowest concentration of 0.153 mg/L. Sampling points JS3 and JS4, JS5 and JS8 were not significantly ($p>0.05$) different from each other in their chromium concentrations; likewise JS7 and JS9 sampling points. Also, sampling points JS1, JS2, JS6 and JS10 were statistically similar. The concentration of chromium in all ten (10) sampling points is above the maximum permissible limits for drinking water recommended by the World Health Organization WHO (2011).

The manganese was significantly ($p<0.05$) higher in JS4 sampling point (0.198 mg/L) and lowest in JS6 (0.020 mg/L). However, sampling points JS3 and JS8 were not different from each other in manganese concentration; likewise JS7 and JS10 sampling points. The manganese levels of sampling points JS1, JS2, JS5 and JS9 differed significantly ($p<0.05$) from each other. All the concentrations of the sampling points are within the maximum permissible limits for drinking water of the World Health Organization WHO (2011) except for sampling point JS4 which is above the permissible limit.

The iron was higher in JS4 sampling point with concentration of 1.388 mg/L and lowest in JS5 (0.020 mg/L). The sampling points JS1 and JS3 had statistically similar iron concentrations. In the same vein, sampling points JS2, JS5, JS6, JS7, JS8, JS9 and JS10 did not significantly ($p>0.05$) differ from each other. All the concentrations of the sampling points were above the maximum permissible limits for drinking water recommended by the World Health Organization WHO (2011) except for sampling point JS5 which is within the permissible limit.

The zinc level was higher in JS4 sampling point with the concentration of 0.085 mg/L while the remaining sampling points did not differ significantly. All the sampling points are within the maximum permissible limits for drinking water recommended by the World Health Organization WHO (2011).

The lead levels of all ten (10) sampling points did not significantly ($p>0.05$) differ from each other and their concentrations are within the maximum permissible limits for drinking water of the World Health Organization WHO (2011). Cadmium and nickel were not detected in all ten (10) sampling points.

The electrical conductivity and pH of all the ten (10) sampling points were within the maximum permissible limit of drinking water as recommended by the World Health Organization WHO (2011).

**Statistical Analysis**

The data obtained were in triplicates and the results were subjected to one-way analysis of variance and expressed as mean with standard deviation. The differences between means were separated by Duncan's Multiple Range Test using IBM SPSS Statistics Programme, Version 19.0 (Illinois, USA). Significant differences were expressed at a 5% level.

**Table 2: Result of Heavy Metal Concentrations in mg/L**

| Heavy Metals | JS1 | JS2 | JS3 | JS4 | JS5 | JS6 | JS7 | JS8 | JS9 | JS10 | WHO, 2011 – MPLDW (Mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cu | $0.001^{e} \pm 0.007$ | $0.011^{cd} \pm 0.001$ | $0.001^{e} \pm 0.001$ | $0.0036^{b} \pm 0.002$ | $0.002^{e} \pm 0.028$ | $0.040^{de} \pm 0.006$ | $0.034^{b} \pm 0.001$ | $0.014^{c} \pm 0.001$ | $0.0036^{b} \pm 0.008$ | $0.064^{a} \pm 0.005$ | 0.000 - 2.00 |
| Cr | $0.153^{e} \pm 0.011$ | $0.261^{d} \pm 0.008$ | $0.591^{c} \pm 0.090$ | $0.599^{c} \pm 0.043$ | $0.633^{bc} \pm 0.001$ | $0.710^{a} \pm 0.065$ | $0.690^{abc} \pm 0.013$ | $0.670^{bc} \pm 0.041$ | $0.0695^{abc} \pm 0.033$ | $0.718^{ab} \pm 0.076$ | 0.000 - 0.05 |
| Mn | $0.076^{bc} \pm 0.018$ | $0.093^{b} \pm 0.093$ | $0.051^{d} \pm 0.001$ | $0.198^{a} \pm 0.000$ | $0.072^{c} \pm 0.006$ | $0.020^{e} \pm 0.004$ | $0.058^{cd} \pm 0.006$ | $0.049^{d} \pm 0.006$ | $0.042^{de} \pm 0.005$ | $0.059^{cd} \pm 0.012$ | 0.000 - 0.40 |
| Fe | $0.926^{b} \pm 0.021$ | $0.624^{f} \pm 0.011$ | $0.939^{b} \pm 0.006$ | $1.388^{a} \pm 0.001$ | $0.020^{g} \pm 0.003$ | $0.665^{def} \pm 0.044$ | $0.733^{d} \pm 0.018$ | $0.712^{de} \pm 0.047$ | $0.859^{c} \pm 0.011$ | $0.654^{ef} \pm 0.060$ | 0.000 - 0.30 |
| Zn | $0.001^{b} \pm 0.001$ | $0.001^{b} \pm 0.001$ | $0.002^{b} \pm 0.003$ | $0.085^{a} \pm 0.002$ | $0.003^{b} \pm 0.004$ | $0.002^{b} \pm 0.003$ | $0.004^{b} \pm 0.006$ | $0.004^{b} \pm 0.006$ | $0.004^{b} \pm 0.006$ | $0.01^{b} \pm 0.001$ | 0.000 -3 |
| Pb | $0.001^{a} \pm 0.001$ | $0.002^{a} \pm 0.002$ | $0.002^{a} \pm 0.001$ | $0.001^{a} \pm 0.001$ | $0.003^{a} \pm 0.004$ | $0.001^{a} \pm 0.001$ | $0.004^{a} \pm 0.005$ | $0.005^{a} \pm 0.006$ | $0.002^{a} \pm 0.002$ | $0.003^{a} \pm 0.004$ | 0.000 - 0.40 |
| Cd | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | 0.000 - 0.03 |
| Ni | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | 0.000 - 0.02 |

Values are Mean ± standard deviation of triplicate determinations. Means with the same superscript in a row are significantly not different ($p>0.05$).
ND = Not Detected

**Table 3: Drinking Water Contaminants and Maximum Admissible Limit Set by Different National and International Organizations**

| | *EC (µS/cm)* | *TDS (mg/L)* | *pH* | *Turbidity* | *Heavy Metals (µg/L)* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | *As* | *Cd* | *Co* | *Cr* | *Cu* | *Fe* | *Mn* | *Ni* | *Pb* | *Zn* |
| USEPA, 2008 | NM* | 500 | 6.5 - 8.5 | 0.5- 1 | 10 | 5 | 100 | 100 | 1300 | 300 | 50 | 100 | 15 | 5000 |
| EU, 1998 | 2500 | NM | 6.5 – 9.5 | NM | 10 | 5 | NM | 50 | 2000 | 200 | 50 | 20 | 10 | NM |
| WHO, 2008 | 250 | NGL** | NGL** | NGL$^{a}$ | 10 | 3 | NM | 50 | 2000 | NGL*** | 400 | 70 | 10 | NGL** |
| Iranian, 1997 | NM | 500 | 6.5 - 8.5 | 25 | 50 | 10 | NM | 50 | 1000 | 1000 | 500 | NM | 50 | Nm |
| Australian, 1996 | NM | 500$^{c}$ | 6.5 - 8.5 | 5.0 | 7 | 2 | NM | 50$^{c}$ | 2000 | 300$^{c}$ | 500 | 20 | 10 | 3000$^{b}$ |
| Indian, 2005 | NG | 1500 | 6.5 – 9.2 | 10 | 50 | 10 | NM | 50$^{c}$ | 1500 | 300 | 100 | 20 | 100 | 5000 |
| New Zealand, 2008 | NM | 1000 | 7.0 – 8.5 | 2.5 | 10 | 4 | 1000 | 50 | 2000 | 200 | 400 | 80 | 10 | 1500 |

*NM = Not mentioned,
** NGL= No Guideline, because it occurs in drinking-water at concentrations well below those at which toxic effects may occur,
*** No Guideline, because it is not of health concern at concentrations normally observed in drinking water, but may affect the acceptability of water at concentration above 300 µg/L,
NGL$^{a}$ No Guideline but desirable less than 5,
$^{b}$ based on quality (Aesthetic) not safety (Health risk),
$^{c}$ Chromium as $Cr^{+6}$ not total Cr.

**Table 4: The maximum admissible limit set by different national and international organizations for safe drinking water**

| | Concentration of Heavy metals in mg/L | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Cu** | **Co** | **Cu** | **Pb** | **Fe** | **Mn** | **Hg** | **Ni** |
| **NSDWQ** | 0.003 | NM | 1.0 | 0.01 | 0.3 | 0.2 | 0.001 | 0.02 |
| **NAFDAC** | 0.0 | NM | NM | 0.0 | NM | NM | 0.0 | NM |
| **USEPA** | 0.005 | 0.1 | 1.3 | 0.015 | 0.3 | 0.05 | 0.002 | 0.1 |
| **WHO** | 0.003 | NM | 2.0 | 0.01 | 0.3 | 0.4 | 0.001 | 0.07 |

NM: Not mention.

**Physicochemical Parameters of the Water Quality**

The result of physicochemical parameters is shown in Table 5 below**.** The pH of the groundwater samples was found to range between 4.97 and 5.58 with a mean of 5.25, which indicates an acidic nature of the groundwater sample and does not fall within the internationally accepted WHO, (1997) standard range (6.5- 8.5) and the national regulatory agency USEPA, (2008) range (6-9) for drinking water and the Nigerian Industrial Standard, (Ndudi, 2015) 6.5-8.5 Standard pH values.

All the water samples have values lower than the desirable limit of 6.0 as per the Nigerian (NIS, 2007) standard for drinking water pH. The lowest pH value of 4.97 was acidic, and could be due to $CO_2$ which dissolves to form carbonic acid and the reaction of water with chlorine to form hypochlorous and hypochlorite acids (Aktar, 2010). However, the high pH of the groundwater may result in the reduction of heavy metal toxicity (Jimoh *et al*., 2017). About 80 % of the pH values were in agreement with the values ranging between 5.06 and 7.85 reported by Ozoko, (2004). However, none of the pH values was within the range for a study done in Nsukka, South East Nigeria, in which the values ranged between 5.6 and 6.14 (Jimoh *et al.*, 2017).

The EC values for the groundwater samples were in the range of 0 $\mu$s/cm and 350 $\mu$s/cm for sampling points between JS1 and JS10, with sampling point JS9 having 0$\mu$s/cm value and sampling point JS2 having the highest value of 350 $\mu$s/cm, all other sampling points had relatively low EC values, which may suggest low values of TDS. The zero value of the EC for JS9 sampling point may be due to the detection limit of the measuring device that is the conductivity meter used, or possibly due to the very high resistivity of the host rock from which the borehole water emanates when compared with the 1.500$\mu$s/cm reported by Orebiye *et al*., 2010.

None of the water samples had EC values that measured up to the limit. Though EC is related to the amount of dissolved minerals in water (TDS), it does not indicate which element is present. But the higher value of Electrical Conductivity is a good indicator of the presence of contaminants such as Sodium, Potassium, Chloride, and Sulphate which is an indirect measure of the level of pollution (Chapman, 1996; Das *et al*., 2005; Musa *et al*., 2014). However, TDS was not measured in this study.

**Table 5: Results of Physicochemical Parameters for Jos and environs**

| S/N | Sampling points | pH | EC ($\mu$S/cm) |
|---|---|---|---|
| 1 | JS1 | 4.98 | 120 |
| 2 | JS2 | 4.97 | 350 |
| 3 | JS3 | 5.09 | 200 |
| 4 | JS4 | 5.58 | 110 |
| 5 | JS5 | 5.41 | 170 |
| 6 | JS6 | 5.32 | 80 |
| 7 | JS7 | 5.10 | 110 |
| 8 | JS8 | 5.33 | 230 |
| 9 | JS9 | 5.40 | 00 |
| 10 | JS10 | 5.35 | 90 |

**Table 6: Comparison of measured Physico-chemical parameters in Jos and environs with other locations (Ozoko, 2004; Aktar *et al*., 2010; Orebiye *et al*., 2010; Ezeribe *et al*., 2012; Gebrekidan and Samuel, 2011)**

| Locations | pH | | | EC (μSv/cm) | | |
|---|---|---|---|---|---|---|
| | **Min.** | **Max.** | **Mean** | **Min.** | **Max.** | **Mean** |
| Dass | 7.61 | 7.87 | 7.74 | 38.40 | 39.00 | 38.70 |
| Kaltungo | 7.79 | 7.80 | 7.80 | 29.64 | 30.76 | 30.20 |
| Langtang | 6.87 | 8.65 | 7.76 | 38.40 | 39.20 | 38.80 |
| Obajana | 6.40 | 7.40 | 6.90 | 0.001 | 226.000 | 0.09-15.15 |
| Kaduna | 4.70 | 9.40 | 7.05 | 73.25 | 119.4 | 96.33 |
| Ethiopia | 6.80 | 9.04 | 7.92 | 44.1 | 2050 | 1047.05 |
| Kenya | 5.10 | 9.21 | 7.16 | 6.85-8.55 | | |
| Jos(Previous) | 5.06 | 7.85 | 5.96 | 3 | 95 | 40.6 |
| This study | 4.97 | 5.58 | 5.25 | 0 | 350 | 146 |

The minimum value of the pH of the study area when compared with those of other locations, indicates that it is less than those of Dass, Kaltungo, Langtang, Ethiopia and Obajana, but falls in the same range (closer) to those of Kaduna, Kenya and Jos (previous). The maximum value for the study area falls below the WHO limit (6.5-8.9), and is also less than those of Dass, Kaltungo, Langtang and Jos (previous) and Obajana which fall within the WHO limit. However, the maximum pH values for Kaduna, Ethiopia and Kenya were greater than the WHO limit.

The geometric mean computed for the study area was in the same range as that of Jos (previous) but less than those of all the other locations.

Similar, comparisons were made for the electrical conductivity of the water samples; the minimum measured EC for the study area was less (zero) than those of all other locations. The zero reading of the instrument may be attributed to an error in the device (or due to low detection and arithmetic mean computed for all limits). The maximum and the mean values of the EC for this study were greater than those of all other places except Ethiopia, which had the highest values respectively.

## CONCLUSION

The copper, zinc and lead concentrations of all the sampling points were within the maximum permissible limit of drinking water recommended by the World Health Organization. However, chromium levels were above the maximum permissible limit of drinking water in all the sampling points. Manganese was within the limit in all the sampling points except forJS4 which was above the limit. Also, iron was above the maximum permissible limit of drinking water in all the sampling points with the exception JS5 which was within the limit. The electrical conductivity and pH of all the ten (10) sampling points were within the maximum permissible limit of drinking water as recommended by World Health Organization.

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