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ASSESSMENT OF SEASONAL VARIATION IN PHYSICOCHEMICAL AND HEAVY METALS CONCENTRATION IN SURFACE AND GROUND WATER IN ONDO, ONDO STATE, NIGERIA

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Abstract
This study characterized the surface and ground water sources in Ondo town, Ondo State, Nigeria. It determined the physical properties, Nitrate compounds and Heavy metals in surface and ground water with regard to seasonal and spatial variations as well as bedrock geology in the study area. It also compared the investigated parameters with water quality of the samples with national and international regulatory standards. Fourteen (14) sampling stations comprising nine hand-dug wells, three bore-holes and two rivers were established for the study based on variations in bedrock geology, geographical spread, land use, urbanization and drainage pattern in the study area. Water samples were collected from each sampling area in dry and wet seasons. The physical parameters investigated were (temperature, turbidity and colour), nitrate, biological oxygen demand, dissolved oxygen, chemical oxygen demand) as well as heavy metals (lead, manganese, chromium, iron, zinc and copper). The parameters were determined using standard instrumental methods and non- instrumental methods with adequate quality assurance and quality control measures. Data obtained were subjected to appropriate descriptive, inferential statistics (ANOVA) and multivariate statistics (Cluster Analysis and Principal Component Analysis). This study revealed 64% of the parameters investigated had 100% compliance with the recommended values of World Health Organization (WHO) Drinking Water Quality and Nigerian Standard for Drinking Water Quality (NSDWQ) while among the heavy metals only Fe (210-1720 μg/L) had 25% compliance.

Keyword: Groundwater, Surface Water, Seasonal Variation, Heavy Metals

Introduction

Water is undoubtedly the most abundant natural resource that exists on our planet earth (With 70% surface cover), hence the planet is called the watery planet. The quality of water available and accessible to a community has tremendous impact on the living standard and well-being of the people, hence concerted global and local efforts are widespread at ensuring adequate provision of clean and safe water to the world's growing population (DWAF, 2003). Although water plays an essential role in supporting life and biodiversity, it also has a great potential for transmitting diseases when contaminated (WHO, 2007).

Groundwater is an important source of drinking water for humankind and it is considered among the healthiest sources of drinking water, but domestic, agricultural and industrial activities have led to the degradation of groundwater quality in different parts of the world today. One of the most important environmental issues today is groundwater contamination and among the wide range of contaminants affecting water resources, heavy metals receive particular concern considering their strong toxicity even at low concentrations (Marcovecchio *et al.*, 2007). Metals like cadmium, copper, lead, arsenic and zinc may occur in drinking water due to geogenic reasons or may be due to anthropogenic activities such as uncontrolled discharge of waste waters of different types of industries. Groundwater contamination is responsible for water related and water borne diseases in many developing countries like Nigeria, hence the evaluation of groundwater quality for human consumption is essential to human existence. The source of groundwater contamination could be natural through ground water-rock interaction or through anthropogenic activities. Groundwater pollution which is man-made is worse than natural pollution as it eventually renders water unsuitable for use than its original state (WHO, 2008). The provision of good quality water is needed as an urgent step that will ensure groundwater quality, protection and conservation. Groundwater, like any other water resource, is not just of public health but also of economic value (WHO, 2003). The quality of surface water is largely affected by natural processes (weathering and soil erosion) as well as anthropogenic inputs (municipal and industrial wastewater discharge). The anthropogenic discharges represent a constant polluting source, whereas surface runoff is a seasonal phenomenon, largely affected by climatic conditions (Vega 1996, Silampaa 2004).

It is important to note that once groundwater becomes contaminated, full restoration of its quality is very difficult and even impossible in some cases. Therefore, it is imperative that groundwater in Ondo metropolis, resources be protected adequately from the increasing threat of contamination, if they are to remain as important and dependable sources of water supply.

Materials and Methods

Study Area

The study was carried out on the surface and groundwater sources in Ondo, Ondo West Local Government Area of Ondo State in Southwest Nigeria. Ondo lies within longitudes 004° 47' 29" E - 004° 54' 17" E and latitudes 07^0 02' 17" N - 07°08' 32" N. The geographical location of the sampling sites was determined using a Geographic Positioning System (GPS) Garmin product. Based on the 2006 national census, it has a population of about 288,868 people.

Sampling

Samples were collected in precleared and labelled plastic container of 2.5 litre capacity. Well water samples were collected using a plastic container attached to a long twine line as fetched by the local people and from the borehole using the distribution tap connection. Water samples were collected directly from the rivers at about 1m depth. Proper preservation and handling techniques were taken into consideration from the time of sample collection in the field to the time of analyses in laboratory in order to avoid biological changes. Measurement of ambient and water temperatures was carried out on site using mercury-in-glass-bulb thermometer, water depth was measured using a sechi-disc attached to graduated line. Shortly after the samples were collected in the field, Samples for dissolved oxygen (DO) and five-day biochemical oxygen demand (BOD_5) were collected in oxygen bottles (250 ml reagent bottles).

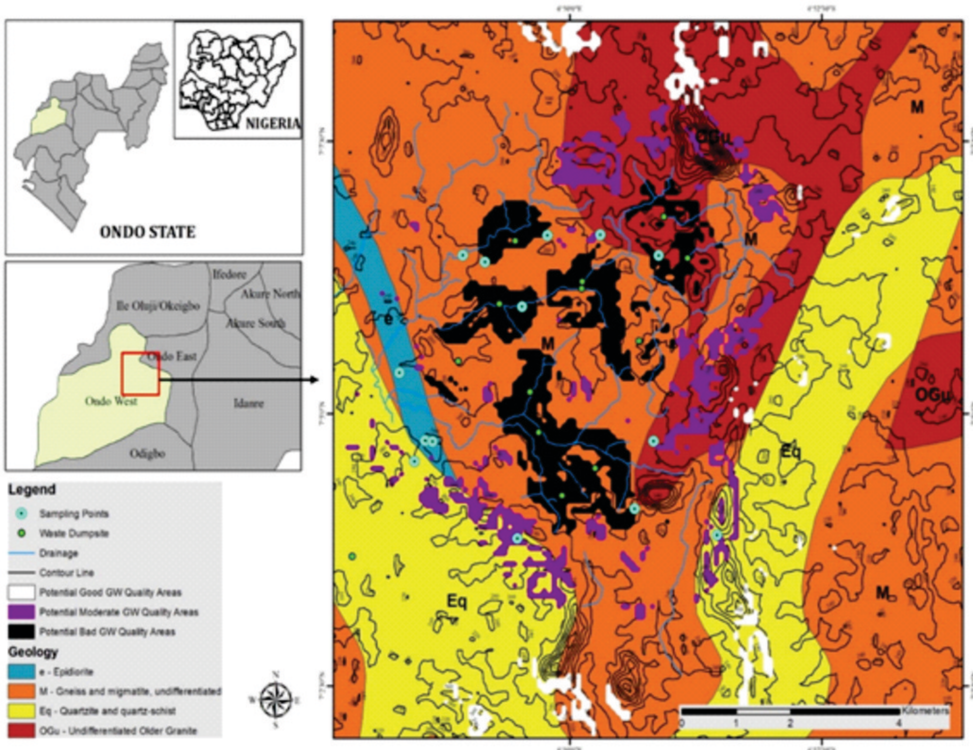

Figure 1: Map of the Study Area in Ondo West LGA, Ondo State and Nigeria (inset)

Table 1: Geographical Location of Study Area

S/N	Ref. Code	Longitude (E)	Latitude (N)	Geology
1	Borehole 1	004°48.464'	07°04.561'	Quartzite
2	Well 1	004°51.464'	07°03.884'	Quartzite
3	Well 2	004°49.484'	07°03.853'	Quartzite
4	Well 3	004°50.834'	07°04.746'	Undifferentiated
5	Borehole 2	004°50.306'	07°06.641'	Undifferentiated
6	Well 4	004°50.885'	07°06.450'	Undifferentiated
7	Borehole 3	004°49.161'	07°06.393'	Gneiss
8	Well 5	004°49.781'	07°06.636'	Gneiss
9	Well 6	004°50.647'	07°04.124'	Gneiss
10	Well 7	004°48.315'	07°05.374'	Epidiorite
11	Well 8	004°48.643'	07°04.744'	Epidiorite
12	Well 9	004°48.570'	07°04.751'	Epidiorite
13	River 1	004°48.942'	07°06.453'	Gneiss
14	River 2	004°49.532'	07°05.983'	Gneiss

Dissolved oxygen samples were fixed *in situ* with ml each of Winkler's reagents A ($MnSO_4.5H_2O$) and B (NaOH-KI). The brownish- white precipitate was acidified by adding 1 ml of concentrated H_2SO_4. Using a pipette, 50ml of each sample was transferred into a conical flask and 5 drops of starch indicator solution added. The blue-black solution formed was immediately titrated against sodium thiosulphate reagent (N/40 $Na_2S_2O_3.5H_2O$) until a colourless solution was formed and titre values were immediately recorded. BOD_5 samples were collected in black reagent bottles, wrapped in a black nylon and kept in dark cupboard at room temperature (about 27±2^{0}C) for 5 days after which the oxygen concentration was determined as described above. The surface and groundwater samples were analyzed in the laboratory for physical parameters that included: turbidity, true colour and apparent colour, nutrient compounds (nitrate, biological oxygen demand (BOD), dissolved oxygen (DO), chemical oxygen demand (COD) as well as heavy metals (lead, manganese, chromium, iron, zinc and copper) were also determined using atomic absorption spectroscopy.

Results

Table 2: ANOVA Statistics of Variation in Physical Parameters of Water Quality of investigated Boreholes, Wells and Rivers in the Study Area

Water body		Air Temp (°C) (Mean±S.E)	Air Temp (°C) (Mean±S.E)	Apparent Colour (Mean±S.E)	Apparent Colour (Mean±S.E)	Turbidity (NTU) (Mean±S.E)
BH 1		27.1±0.8	27.2±0.3	27.4±16.7	1.1±0.3	1.0±0.0
BH 2		29.4±1.2	27.5±0.4	15.5±7.8	10.8±9.1	2.0±1.0
BH 3		31.5±1.6	30.1±1.1	42.2±41.3	10.2±9.3	1.5±0.5
WELL 1		30.1±1.7	28.4±1.1	187.5±174.5	82.2±81.3	10.4±7.3
WELL 2		27.1±0.3	27.2±0.4	19.7±10.6	18.2±17.3	2.0±0.6
WELL 3		28.0±0.4	27.7±0.6	19.4±10.7	10.1±9.3	1.5±0.5
WELL 4		30.2±1.1	29.2±0.1	4.1±1.1	1.8±0.1	2.0±1.0
WELL 5		28.5±0.8	28.6±1.2	18.4±17.2	11.9±8.7	1.5±0.5
WELL 6		26.1±0.9	26.8±0.7	28.7±9.3	1.0±0.3	1.5±0.5
WELL 7		30.5±0.7	29.8±1.1	34.7±33.1	26.9±25.1	3.4±2.4
WELL 8		26.0±2.9	27.5±0.6	4.9±2.2	1.5±0.4	2.0±1.0
WELL 9		29.6±2.9	28.5±2.9	10.4±9.2	10.4±9.2	1.5±0.5
RIVER 1		32.7±1.7	29.0±0.7	36.0±23.6	19.4±10.7	5.3±1.0
RIVER 2		30.2±1.5	27.3±0.3	69.0±27.0	4.9±1.3	7.2±1.3
ANOVA	**F**	**2.291**	**0.955**	**0.851**	**0.750**	**1.569**
	P	**0.021***	**0.09**	**0.607**	**0.705**	**0.134**

S.E = Standard Error of mean P≤ 0.05 = * Significant difference

Table 3: ANOVA Statistics of Intra-seasonal Variation in Physical Parameters of Water Samples Collected in the Study Area

Parameter	Season				ANOVA Statistics	
	Early Dry (Mean±S.E)	Late Dry (Mean±S.E)	Early Rain (Mean±S.E)	Late Rain (Mean±S.E)	F	P
Air Temp (°C)	30.7±1.0	29.4±0.7	29.0±0.8	27.2±0.3	**3.745**	**0.016***
Water Temp (°C)	29.4±0.7	28.1±0.6	27.7±0.4	27.5±0.4	**2.456**	**0.037***
Apparent Colour (Pt-Co)	41.4±10.9	17.4±6.0	77.0±50.7	12.2±5.7	**1.248**	**0.297**
Turbidity (NTU)	1.8±0.6	2.0±0.6	4.9±2.2	3.5±0.8	**1.357**	**0.266**

S.E = Standard Error of mean P≤ 0.05 = * Significant difference

Table 4: Descriptive Statistics of Some Oxygen Parameters of Water Samples Collected from Wells, Boreholes and Rivers Samples in the Study Area

Statistics	Dissolved Oxygen (mg/L)	DO Saturation (%)	Biological Oxygen Demand (mg/L)	Chemical Oxygen Demand (mg/L)
N	56	56	56	56
Minimum	1.5	18.7	0.6	0.4
Maximum	7.6	97.8	5.0	17.8
Median	4.9	61.1	1.6	3.6
Mean	5.0	61.7	1.8	4.6
Std. Error	0.2	2.6	0.1	0.6
Std. Deviation	1.8	19.1	0.9	4.3
Skewness	0.8	-0.04	1.7	1.7
Kurtosis	1.4	-0.4	3.7	2.7
Coeff.Var (%)	36.0	31.0	50.0	93.5

N= Number of Samples

Table 5: ANOVA Statistics of Variation in Oxygen Parameters in the water samples in the water samples

Water body		Dissolved Oxygen (ppm) (Mean±S.E)	DO Saturation (%)	Biological Oxygen Demand (ppm) (Mean±S.E)	Chemical Oxygen Demand (ppm) (Mean±S.E)
BH 1		4.8±0.5	60.5±6.0	1.5±0.2	3.9±1.0
BH 2		4.8±0.4	60.9±5.2	2.0±0.2	4.4±1.5
BH 3		5.7±1.4	55.6±5.0	1.2±1.0	3.6±1.6
WELL 1		5.2±0.8	66.6±10.5	2.5±0.7	3.6±1.3
WELL 2		5.2±0.6	63.2±6.8	1.1±0.2	3.5±1.3
WELL 3		4.2±0.8	54.2±10.3	1.3±0.3	2.3±0.9
WELL 4		5.5±0.1	72.2±0.9	1.7±0.2	2.0±1.0
WELL 5		6.3±0.6	82.1±8.0	2.2±0.2	4.2±1.1
WELL 6		5.1±0.5	65.4±6.3	1.7±0.3	5.1±2.2
WELL 7		4.8±0.8	63.8±11.2	1.6±0.5	7.8±3.1
WELL 8		3.9±0.5	49.4±6.9	1.4±0.2	6.7±3.5
WELL 9		3.7±0.9	48.7±14.2	1.5±0.9	4.7±2.4
RIVER 1		6.2±1.7	72.3±16.4	2.2±0.7	6.1±3.4
RIVER 2		5.1±2.0	49.2±12.1	3.0±0.7	6.9±3.8
ANOVA	F	**0.676**	**1.083**	**1.974**	**0.587**
	P	**0.774**	**0.399**	**0.048***	**0.850**

S.E = Standard Error of mean P≤ 0.05 = * Significant difference

Table 6: Descriptive Statistics of Heavy Metal Concentration in the water samples

Statistics	Pb (μg/L)	Mn (μg /L)	Cr (μg /L)	Fe (μg /L)	Zn (μg /L)	Cu (μg /L)
N	28	28	28	28	28	28
Minimum	0.0	0.0	0.0	210	120	10.0
Maximum	1.0	20.0	1.0	1720	1460	90.0
Median	0.0	10.0	0.0	665	820	20.0
Mean	0.07	10.20	0.43	744.6	746.10	27.50
Std. Error	0.05	1.20	0.1	82.92	75.72	3.70
Std. Deviation	0.26	6.34	0.5	438.77	400.66	19.56
Skewness	3520.0	145.0	305.0	730.0	79.0	1754
Kurtosis	11183	-548	-2060	-226	-1238.0	3163
Coeff.Var (%)	371.43	62.16	116.28	58.93	53.70	71.13

N= Number of Samples

Table 7: ANOVA Statistics of Heavy Metal Concentration of Water Samples Collected from the Study Area

Water body		Pb (µg/L) (Mean±S.E)	Mn (µg/L) (Mean±S.E)	Cr (µg/L) (Mean±S.E)	Fe (µg/L) (Mean±S.E)	Zn (µg/L) (Mean±S.E)	Cu (µg/L) (Mean±S.E)
BH 1		0.0±0.0	10.0±0.0	0.0±0.0	240.0±30.0	215.0±95.0	40.0±20.0
BH 2		0.0±0.0	15.0±5.0	0.0±0.0	550.0±80.0	595.0±175	35.0±15.0
BH 3		0.0±0.0	10.0±0.0	0.0±0.0	615.0±190	815.0±435	25.0±5.0
WELL 1		0.0±0.0	10.0±0.0	0.0±0.0	300.0±30.0	315.0±125	30.0±10.0
WELL 2		0.0±0.0	1.0±0.00	0.0±0.0	840.0±260	610.0±340	20.0±10.0
WELL 3		0.0±0.0	10.0±0.0	0.0±0.0	665.0±65.0	675.0±155	15.0±5.0
WELL 4		0.0±0.0	10.0±0.0	0.0±0.0	860.0±160	870.0±470	20.0±10.0
WELL 5		0.0±0.0	1.0±0.0	1.0±0.0	260.0±40.0	795.0±515	30.0±10.0
WELL 6		0.0±0.0	15.0±5.0	1.0±0.0	465.0±45.0	890.0±350	25.0±5.0
WELL 7		0.0±0.0	10.0±0.0	1.0±0.0	1520±190	1200±260	25.0±5.0
WELL 8		0.0±0.0	10.0±0.0	1.0±0.0	1075±165	935.0±35.0	15.0±5.0
WELL 9		0.0±0.0	20.0±0.0	0.5±0.0	975.0±95.0	860.0±50.0	15.0±50.0
RIVER 1		0.5±0.0	15.0±5.0	0.5±0.0	1520±200	1100±110	40.0±30.0
RIVER 2		0.5±0.0	15.0±5.0	1.0±0.0	540.0±290	570.0±350	50.0±40.0
ANOVA	**F**	**0.923**	**4.764**	**6.308**	**7.066**	**0.870**	**0.436**
	P	**0.555**	**0.003****	**0.001*****	**0.000*****	**0.596**	**0.928**

S.E = Standard Error of mean, P≤0.01 = **Highly Significantly difference, P≤ 0.001 = ***Very highly significantly difference

Discussion

Air and Water temperature vary with seasonal conditions and location. Average water temperature was significantly higher (P≤0.05) in the dry season (28.8±0.5^{0}C) than in the rainy season (27.6±0.3^{0}C) probably due to the fact that there was higher air temperature in dry season (30.1±0.1^{0}C) than in the rainy season (28.1±0.1^{0}C). It could also probably be a result of the reduction in water level during dry season compared to rainy season. Water temperature is influenced by seasonality and by time of the day (especially very early in the morning).

Most aquatic organism requires on definite temperature range for optimal growth (APHA 1992) and the normal temperature range to which a fish is adapted in the tropics vary between 8 °C and 30 °C (Alabaster and Lloyd, 1980) as in line with the present study.

The colour measured in water that contains suspended matter is defined as apparent colour while colour measured in water sample from which particulate matter has been removed by centrifugation or filtration is true colour. However, the presence of colour in water does not necessarily indicate that the water is not potable (APHA *et al.*, 1976). Seepage of leachates, sewages and domestic runoff release into the surrounding may be responsible for the high colour value in Well 1. The result of the seasonal variation revealed that the mean value of apparent colour recorded during dry season was significantly (P>0.05) lower than the value recorded in the rainy season may be due to the fact that there is increase in the rate of runoff and residue from activities in the surroundings than in dry season. It could also be due to the level of anthropogenic activities such as farming, leaching going on in the study area. The mean values recorded for apparent colour was above the range of WHO GDWQ (2011) standard while true colour mean values was within the range stipulated by World Health especially as agriculture discharge waste runoff percolates through soil reaching the underground water. With WHO (2011) guide standards for Cu concentrations in drinking water being 2.0 mg/L, all water samples in the area occurred within the WHO permissible limit.

Lead is a highly toxic naturally occurring metal that is present in soils, surface waters and groundwater (Olutona *et al.*, 2012). The values of lead obtained in this study were low/not detected in most of the boreholes and wells all over the study area. The WHO standards (2011) suggest the permissible range of Pb for drinking and domestic water to be 0.01 mg/l/10.0 µg/L. Among the sampling stations, the highest mean values of lead concentration were recorded in River 1 and River 2 (0.5±0.0 µg/L) whereas lead was not detected in other sampling stations. The values in the two river stations were within the permissible limit of WHO. The relatively high result obtained from the two rivers may be due to runoff of residue of herbicide and materials used for painting that contain lead concentrations. It is reported by different scientists that, high concentration of Pb (> 0.01mg/L) has been implicated in causing anemia, kidney damage and cerebral oedema to human (Townsend, 1991; Samir and Ibrahim, 2008). Indeed, high concentrations of lead in the body can cause death or permanent damage to the central nervous system and brain (NSDWQ, 2007), It is believed to be one of the causes of cancer (NSDWQ, 2007), it is also capable of interfering with Vitamin D metabolism, affecting mental development in infants and toxic to the central and peripheral nervous systems (NSDWQ, 2007)

The study showed that Iron (Fe) levels in the investigated water samples ranged from 210 µg/L to 1720 µg/L, with an overall mean ± S.D of 744.6 ± 438.77 µg/L. The latter is higher than the WHO (2011) permissible limit of 0.3mg/L/300 µg/L (Figure5.4). The mean value recorded in River 1 (1520± 200 µg/L) and Well 7(1520±190 µg/L) were about five times the WHO guide limit. The result could be due to manifestation of the presence of toxic wastes and discharge from a dumpsite observed close to the area. Toxic effects have resulted from the ingestion of large quantities of iron, but there is no evidence to indicate that concentrations of irons commonly present in food or drinking water constitute any hazard to human health, hence, a maximum acceptable concentration has not been set (APHA, 1992). At concentrations above 0.3 mg/L (drinking water standard), iron presence in natural water is a combination of contribution from weathering of rocks and minerals, dumpsite leachates, sewage effluents and farming activities (Aiyesanmi *et al.,* 2006; Adefemi *et al.,* 2007). It has been reported that iron occurs at high levels in Nigeria soils and could manifest in surface waters that flow over them (Aiyesanmi, 2005; Aiyesanmi *et al.*, 2006).

The concentration of manganese (Mn) in water samples collected from the investigated sampling stations over the study period ranged from 0.0 µg/L to 20.0 µg/L, with an overall mean ± S.D of 10.20 ± 6.34 µg/L. The highest mean value of manganese concentration was recorded in Well 9 (20.0±0.0 µg/L) which were within WHO (2011) maximum permissible value of 0.5 mg/L/500 µg/L which is still tolerable, above 0.5 mg/L/ 500 µg/L, manganese will impair portability. It was remarked that its excessive concentration would result in taste and precipitation problems (Longe & Balogun, 2010). This agreedwith the findings of Ogedengbe and Akinbile (2004) who reported the impact of industrial pollutants on quality of ground and surface waters at Oluyole industrial estate, Ibadan, Nigeria.

Conclusion

The parameters investigated for water quality

Organisation drinking water standard (2011).

The turbidity of water is influenced by the type and concentration of suspended matter such as clay, silt, colloidal organic particles in the environment. It decreases the ability of water to transmit light due to suspended particulate matter and phytoplankton (Asante *et al.*, 2008). In this investigation, turbidity values were found to be high in Well 1 (10.4±7.3 NTU) while the lowest mean value was observed in borehole 1 (0.975±0.00 NTU). The overall mean turbidity values obtained in sampling stations is lower than the Nigerian Standard for Drinking Water Quality (NSDWQ, 2007) and World Health Organization GDWQ (WHO, 2011) which is 5 NTU except for Well 1, River 1 and River 2 whose mean values were above the drinking water standard. Statistical analysis of the seasonal variation revealed that the mean value (4.2±1.5 NTU) of water turbidity recorded during rainy season was significantly ($P \leq 0.05$) higher than the value (1.9±0.4 NTU) recorded in the wet season. This increase during the rainy season was possibly due to effect of runoff discharges which carry with it several suspended solids, hydrocarbons and heavy metals, these substancesoare known to impede the rays of light entering the river (Chinwe *et al.*, 2010)

The Biological Oxygen Demand (BOD_5) pattern of seasonal variation revealed that the highest mean value (1.9±0.2 mg/L) BOD_5 was recorded during dry season while the lowest (1.6±0.1 mg/L) BOD_5 value was recorded in the rainy season but there were no significant seasonal differences ($P > 0.05$). The low mean value (1.1±0.2 mg/L) BOD_5 in Well 2 in the study area is an indication that the well have low nutrients levels, in line with report of Anhwange *et al.*, (2012) that water with low BOD_5 have low nutrient levels which implies high concentration of dissolved oxygen (DO). Unpolluted, natural waters should have a BOD_5 of 5 mg/L or less. Although there are no direct health implications for BOD_5, it is an important indicator of overall water quality (IEPA, 2001).

The highest mean value of zinc concentration among the investigated sampling stations was for Well 7 (1200±260 µg/L) while the lowest mean value of 215±95 µg/L was recorded for Borehole 1. The high concentrations of zinc elsewhere were attributed to the pollution due to persistent leaching along the top layers of the soil and its widespread dispersion through the use of liquid manure and agro-chemicals (Srinivas and Govil, 2007). The result of this study shows Zn levels to be within the WHO (2011) guide limits and also suitable for other uses such as sanitation and irrigation. All samples met the WHO permissible limit of Zn in drinking water which is 3.0 mg/L (3000 µg/L). Also, the concentration recorded during the dry season (935.7±80.0 µg/L) was statistically higher ($P \leq 0.05$) than the value of 556± 108 µg/L recorded in the rainy season. The increased concentration in the dry season could probably be due to concentration effects caused by reduced volume associated with higher evaporation rate during the dry season. Idodo- Umeh (2002) and Oguzie (2003) attributed similar results from a river to increase in evaporation rate during the dry season.

Cu is an essential trace metal to human life at moderate levels, functioning as part of several enzymes such as tyrosinase, cytochrome oxidase, super-oxide dismutase, amine oxidases and uricase (Oyekunle *et al.*, 2012). Copper (Cu) concentration in the water samples collected ranged from 10.0 µg/L to 90.0 µg/L, with an overall mean ± S.D of 27.50 ± 19.56 µg/L. The source of copper may be due to the intrusion of agricultural and domestic wastes (Aggarwal *et al.*, 2000) in Boreholes, Wells and Rivers collected from Ondo town was compared with the Guidelines for Drinking Water Quality of the World Health Organization (WHO, 2011) and the Nigerian Standard for Drinking Water Quality (NSDWQ, 2007) reveals that most of the physical, nitrate compounds and heavy metals fall within the range stipulated by WHO and NSDWQ. However, only Iron was found above the standard recommended by the World Health Organization (2011) and the Nigerian Standard for Drinking Water Quality (NSDWQ, 2007).

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