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WATER QUALITY OF SOME WATER SOURCES IN IGARRA AND THE ENVIRONS IN AKOKO - EDO, SOUTHERN NIGERIA

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ABSTRACT

Evaluation of the physico-chemical and microbiological characteristics of selected water sources from Igarra and environs in Akoko-Edo, Nigeria was carried out using standard methods. The results obtained for some of the parameters investigated were in the following range: pH (4.2 - 6.8), turbidity (0.01 – 0.75 NTU), conductivity (7.2 – 196.0 μScm^{-1}), dissolved oxygen (3.2 – 29.2 mgL^{-1}), biochemical oxygen demand (0.0 – 25.6 mgL^{-1}), chloride (10.23 – 106.36 mgL^{-1}), calcium (0.0 – 80.88 mgL^{-1}), sulphate (0.0 – 7.35 mgL^{-1}), nitrate (0.01 – 8.91mgL-1), copper (0.01 – 1.03 mgL^{-1}), zinc (0.0 – 1.43 mgL^{-1}), Iron (0.02 – 2.30 mgL^{-1}) and lead (0.0 – 0.33 mgL^{-1}). All samples harboured coliform organisms in numbers that exceeded the WHO standard for drinking water. Ranges of total heterotrophic bacteria (THB) count was 1.0×10^3 - 1.3×10^4 $cfuml^{-1}$; total heterotrophic fungi (THF) count 1.0×10^3 - 9.0×10^3 $cfuml^{-1}$; presumptive coliform count 0 - 2.9 MPN 100 ml^{-1} and *Escherichia coli* 0 - 2.7 MPN 100 ml^{-1}. This study revealed that magnesium hardness, microbial contamination, and acidity of the water sources which resulted in corrosivity of the water are some of the indicator parameters for Akoko-Edo water quality; and therefore concluded that the water sources were unsuitable for human consumption. Adequate and appropriate treatment of the water prior to consumption to maintain good public health is therefore recommended.

Keywords: Water Quality, Public Health, Coliform, Hardness, Corrosivity

INTRODUCTION

The majority of the populations in developing countries are not adequately supplied with potable water, and are thereby compelled to use water from sources like shallow wells and boreholes that render the water unsafe for domestic and drinking purposes due to high possibilities of contaminations (WHO, 2006; Dirisu and Olomukoro, 2015). This assertion is a true reflection of the water crisis in Akoko-Edo Local Government Area of Edo State, Nigeria which is located on a rocky geology.

Despite the construction of the Ojirami dam in 1974 that supplied potable pipe-borne water to majority of the towns and villages, its epileptic supply of water in recent times has forced the populace to rely on other sources of water for domestic and drinking purposes regardless of their quality. In many developing countries like Nigeria, unavailability of treated water for drinking and domestic usage has become a critical problem and a matter of great concern to communities that depend on public water supply system (Okonko *et al.*, 2008).

According to Federal Ministry of Health statistics, only about 30% of Nigerians have access to potable water while the WHO estimated that about 1.5 billion people do not have access to safe drinking water with all the consequences of water borne diseases such as cholera, typhoid, diarrhoea, and dysentery becoming potentially communicable (WHO, 2006). Many of the streams, ponds, springs, hand-dug wells and boreholes in Akoko-Edo are located either too close to locations where corpses are buried and/or septic tanks (soak-away pits) are dug, or around places where they are exposed to other anthropogenic pollution.

Communities which rely on untreated groundwater supply for domestic and agricultural uses are most exposed to the impact of poor water quality (Agbabiaka and Sule, 2010; Akpoveta *et al.*, 2011). No doubt, ensuring access to low cost water supply (improving access to clean water or making access more secure) will improve the people's welfare. During passage through the ground, water dissolves minerals in rocks, collect suspended particulate matter, particularly those of organic sources as well as pathogenic micro-organisms from faecal matters (Onuh and Isaac, 2009).

The objective of this study was to provide information on the water quality of Igarra and the environs using physico-chemical and microbiological characteristics of the selected water sources, and their suitability for human consumption based on water quality standards of the World Health Organisation (WHO) and Standard Organisation of Nigeria (SON).

MATERIALS AND METHODS

Study Area

Akoko-Edo (Figure 1) is located in the northern part of Edo State, Nigeria with its administrative headquarters (Igarra) at latitude 7° 16.9789' N and longitude 6° 6.134' E. There are a lot of communities and a few towns that constitute the Local Government Area. Some of the towns include: Okpe, Somorika, Ikpeshi, Ojirami, Uneme-Osu, Ibillo, Ososo, Ijaja. Ogbe, and so forth. The local government has an undulating and elevated topography; and it is endowed with caves, different rock types with diverse shapes and sizes, making it a tourist site yet to be harnessed. It is characterized by two major climatic seasons, dry season from October to May, and rainy season from June to September. The major sources of water in the locality are: streams, rivers, springs, ponds, rock-ponds, boreholes and hand-dug wells. The people are predominantly farmers and miners.

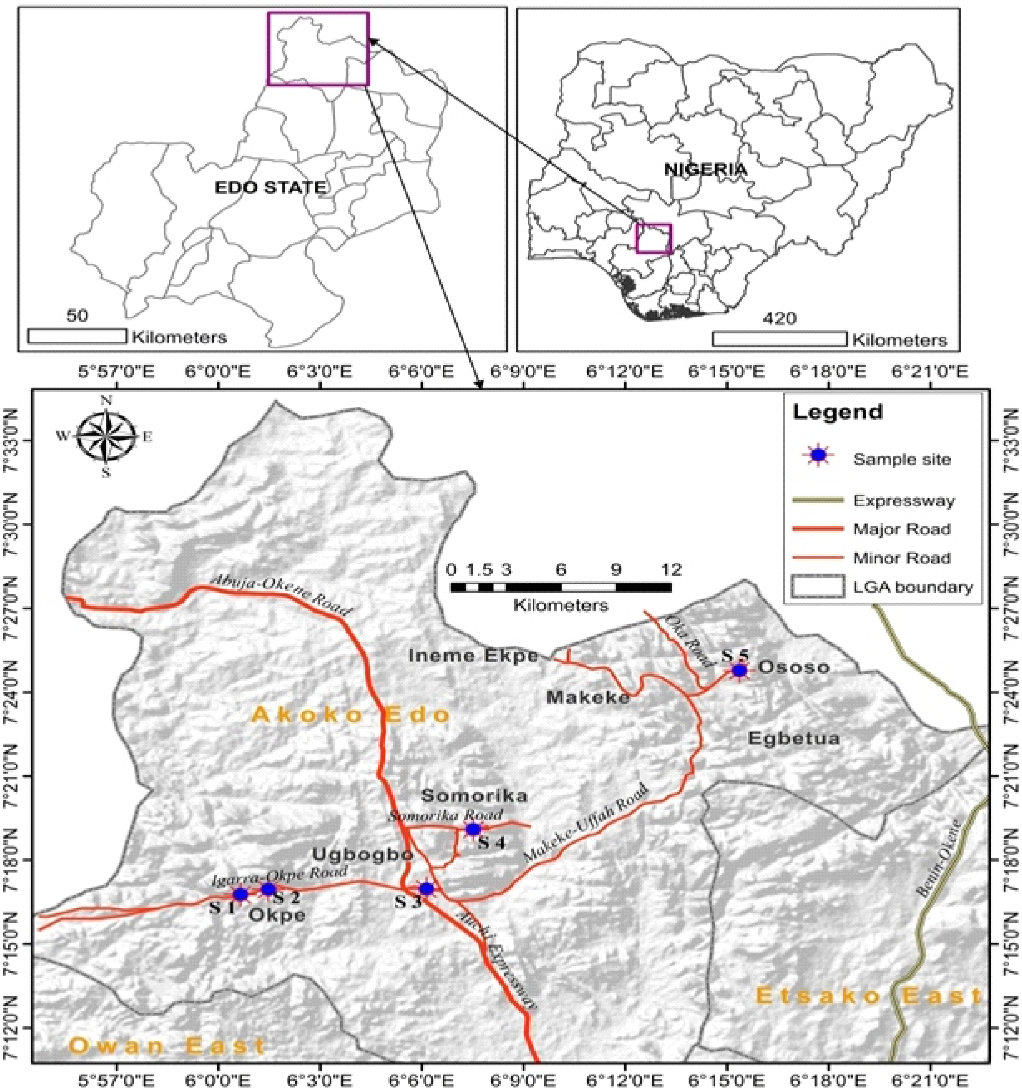

Figure 1: Map of the Study Area

Sample Collection and Analysis

Water samples were collected from the spring, pond, borehole, rock-pond and hand-dug well on a monthly interval for a period of eight (8) months, covering dry and wet seasons. Temperature (air and water), pH, electrical conductivity, dissolved oxygen and total dissolved solids were determined *in-situ* using handheld instrument (Hach pH/Conductivity/TDS meter sense ion 2 Model). Other physicochemical parameters analysed included: turbidity, biochemical oxygen demand, salinity, nitrate, chloride, nitrate, phosphate, sulphate, magnesium, calcium, potassium, sodium, iron, copper, zinc and lead using standard methods as described by APHA (2005). The results obtained were compared with the recommended limits by the World Health Organisation (WHO, 2006) and the Standard Organisation of Nigeria (SON, 2007) prescribed for drinking water. Data obtained were subjected to statistical analysis using a one way analysis of variance (ANOVA), and a *Posteriori* Duncan Multiple Range (DMR) test was used to determine the source of significant difference recorded among the stations. Water quality index (WQI) was calculated using the weighted arithmetic mean index as described by Yisa and Jimoh (2010) and on the basis of the suitability of the water sources for human consumption using the WHO and SON standards.

Bacteriological Characteristics Determination

The media (nutrient agar) used for bacteriological analysis were weighed out and prepared according to manufacturers' instructions and directions. The plate count method was used which relies on bacteria growing a colony on a nutrient agar medium, so that the colony becomes visible to the naked eyes and the number of colonies on a plate can be counted. Presumptive coliform count was determined by MacConkey broth; positive result was indicated by acid and gas production on incubation at 37 °C for 48 hours (Edema *et al*., 2001). Eosin methylene blue medium was used to determine *E. coli*; organisms with greenish metallic sheen were indicative of positive results. This was further confirmed by the ability of the organism to ferment lactose at 44 °C. The pour plate technique was used to determine aerobic mesophillic count using standard methods (APHA, 2005).

Estimation of Water Quality Index

Drinking water quality index (WQI) is intended to provide an easy-to-understand ranking of water quality. It is also a very useful tool for communicating the information on the overall quality of water (Yisa and Jimoh, 2010). In this study, sixteen important parameters were adopted in the calculation of WQI. The parameters include: pH, turbidity, conductivity, total dissolved solid, dissolved oxygen, biochemical oxygen demand, chloride, sulphate, nitrate, magnesium, iron, lead, copper, zinc, *E. coli* and total coliform count.

Water quality index was calculated using the weighted arithmetic index method as described by Yisa and Jimoh, (2010). The values obtained were compared to the water quality scale (Table 1). The different water quality components were multiplied by a weighting factor and then aggregated using simple arithmetic mean (Cude, 2001).

Table 1: Water Quality Index (WQI) and Status of Water Quality

Water Quality Index Level	Water Quality Status
50	Excellent water quality
50–100	Good water quality
100–200	Poor water quality
200–300	Very poor water quality
$>$300	Water unsuitable for drinking purposes

Source: (Ramakrishniah *et al*., 2009)

Quality rating or sub index for the n^{th} parameter (Qn) was calculated using the following expression;

$Qn = 100(Vn - V_{10}) / (Sn - V_{10})$

Where,

Qn = Quality rating of the parameter for a total of n water quality parameters

Vn = Actual value of the water quality parameter obtained from laboratory analysis

V_{10} = Ideal value of that n^{th} water quality parameter in pure water. V_{10} = 0 for all parameters, except pH and DO which are 7 and 14.6 mgL^{-1} respectively.

Sn = Recommended Federal Ministry of Environment permissible standard for the n^{th} water quality parameter.

The unit weight was calculated by a value inversely proportional to the recommended standard value (Sn) of the corresponding parameter:

$Wn = K/Sn$

Where:

Wn = unit weight for the n^{th} parameters

Sn = standard value for the n^{th} parameters

K = proportionality constant

The proportionality constant (K) was calculated by a value inversely proportional to the inverse of the aggregate of the recommended standard value for all the parameters used.

i.e. $K = 1 / \sum(1/Sn)$

The overall water quality index was calculated by aggregating the quality rating with the unit weight linearly, such that:

$WQI = \Sigma WnQn / \Sigma Wn$

RESULTS

Physico-chemical Parameters of the Water Samples

The result of the physico-chemical characteristics of the water samples collected from the various sources are presented in table 2. There was a distinct pattern in seasonal variations in the measured air and water temperature values. Air temperature values were always higher and they ranged from 21 – 31 °C to 23 – 31 °C across the study stations. Peak value was recorded in the dry season and lowest during the rainy season across the stations. There was no significant variation in the pH values recorded across the stations. The pH range of 4.2 - 6.8 showed acidic trend regardless of seasonal variations. The conductivity values recorded in this study ranged from 7.2 to 196.0 μScm^{-1}. Total dissolved solids mean values were quite below the standard values for drinking waters. Its mean concentrations were between 51.55 mgL^{-1} at station 4 and 22.31 mgL^{-1} at station 1 respectively. Dissolved oxygen mean concentration was lowest at station 1 (9.37 mgL^{-1}) and highest at station 5 (13.29 mgL^{-1}) throughout the study. Biochemical oxygen demand (BOD_5) recorded mean concentrations that were greater than 6 mgL^{-1} when compared to the limit. The values were between 6.13 mgL^{-1} and 9.47 mgL^{-1} at stations 2 and 5. Chloride ions concentration in this study were far below the WHO and SON limits for drinking water. The mean concentrations varied from 30.62 mgL^{-1} at station 4 to 51.98 mgL^{-1} at station 1. Salinity mean values were relatively high across the stations and had its range of values from 55.62 mgL^{-1} at station 4 to 105.02 mgL^{-1} at station 3. The overall nutrient concentration values were within the WHO and NIS limit for drinking waters.

Amongst the four heavy metals we investigated (Fe, Zn, Cu and Pb), it was only Cu that had its mean values across the study stations within the limits of WHO and NIS. Iron mean values were between 0.13 and 1.18 mgL^{-1} at stations 3 and 2 respectively. Zn had its mean values ranging from 0.10 mgL^{-1} at station 3 to 0.61 mgL^{-1} at station 2. The recorded mean values for lead was from 0.03 mgL^{-1} at stations 1, 2 and 5 respectively to 0.08 mgL^{-1} at station 4.

Table 2: Summary of the Physico-chemical Characteristics of Water from the Study Area

PARAMETER	UNIT	N	STATION 1 (SPRING)	STATION 2 (POND)	STATION 3 (BOREHOLE)	STATION 4 (ROCK-POND)	STATION 5 (HAND-DUG WELL)	WHO LIMIT	NIS
			MEAN ± SE	MEAN ± SE	MEAN ± SE	MEAN ± SE	MEAN ± SE		
Air Temp.	^{o}C	8	25.5 ± 0.82	25.88 ± 0.72	27.13 ± 0.99	24.75 ± 0.82	26.00 ± 1.56	-	-
Water Temp.	^{o}C	8	27.13 ± 0.58	28.25 ± 0.70	27.38 ± 0.94	27.75 ± 0.80	26.88 ± 0.77	-	-
pH		8	5.04 ± 0.15	5.60 ± 0.20	5.20 ± 0.12	5.15 ± 0.19	5.11 ± 0.30	6.5 - 8.5	6.5 - 8.5
Cond.	μScm^{-1}	8	103.75 ± 6.90	48.53 ± 7.61	160.88 ± 13.0	52.13 ± 5.28	71.38 ± 7.84	250	250
Turbidity	NTU	8	0.06 ± 0.04	0.1 ± 0.07	0.05 ± 0.02	0.12 ± 0.09	0.03 ± 0.01	5	5
TDS	mgL^{-1}	8	51.55 ± 3.45	28.31 ± 2.64	83.70 ± 5.70	22.31 ± 2.58	35.69 ± 3.92	500	500
DO	mgL^{-1}	8	9.37 ± 1.17	9.59 ± 1.65	11.10 ± 1.18	11.67 ± 3.46	13.29 ± 2.81	>30	-
BOD5	mgL^{-1}	8	6.42 ± 1.48	6.13 ± 1.63	6.27 ± 1.56	8.25 ± 3.22	9.47 ± 2.91	>6	-
Chloride	mgL^{-1}	8	51.98 ± 12.47	35.48 ± 11.41	50.13 ± 8.73	30.62 ± 9.44	37.47 ± 8.75	250	250
Salinity	mgL^{-1}	8	83.86 ± 19.33	61.25 ± 20.97	105.02 ± 20.56	55.62 ± 17.04	66.82 ± 16.18	600	600
Nitrate	mgL^{-1}	8	1.98 ± 0.67	1.34 ± 0.47	1.17 ± 0.42	1.13 ± 0.38	1.52 ± 1.07	10	50
Phosphate	mgL^{-1}	8	2.75 ± 1.00	1.10 ± 0.41	2.26 ± 0.54	0.36 ± 0.11	0.96 ± 0.35	-	100
Sulphate	mgL^{-1}	8	0.84 ± 0.37	2.55 ± 0.73	0.13 ± 0.11	1.91 ± 0.66	0.71 ± 0.39	500	500
Magnesium	mgL^{-1}	8	3.73 ± 0.81	13.52 ± 8.25	25.08 ± 4.61	9.86 ± 3.29	10.02 ± 4.15	-	0.2
Calcium	mgL^{-1}	8	4.05 ± 1.75	5.72 ± 2.55	3.95 ± 0.61	12.79 ± 9.83	2.81 ± 1.20	300	-
Potassium	mgL^{-1}	8	18.66 ± 4.11	10.23 ± 2.51	25.13 ± 7.75	10.74 ± 2.27	12.31 ± 3.33		
Sodium	mgL^{-1}	8	17.78 ± 1.80	7.69 ± 1.59	19.90 ± 5.73	7.63 ± 2.01	11.55 ± 1.99	-	-
Iron	mgL^{-1}	8	0.25 ± 0.12	1.18 ± 0.20	0.13 ± 0.07	0.44 ± 0.07	0.46 ± 0.27	0.3	0.3
Zinc	mgL^{-1}	8	0.34 ± 0.11	0.61 ± 0.16	0.10 ± 0.06	0.25 ± 0.06	0.32 ± 0.14	5.0	3.0
Copper	mgL^{-1}	8	0.13 ± 0.07	0.38 ± 0.14	0.04 ± 0.01	0.10 ± 0.03	0.18 ± 0.08	1.3	1.0
Lead	mgL^{-1}	8	0.03 ± 0.01	0.03 ± 0.01	0.07 ± 0.04	0.08 ± 0.04	0.03 ± 0.01	0.00	0.01

Microbiological Parameters

Mean microbiological counts of the investigated species are presented in table 3. The mean total heterotrophic bacterial count (THBC) ranged in values from 3.625 x 10^3 CFU ml^{-1} at station 3 to 6.275 x 10^3 CFU ml^{-1} at station 5. Also the result of the total heterotrophic fungi count (THFC) varied from a low of 1.75 x 10^3 CFU ml^{-1} at station 3 to a high of 4.375 x 10^3 CFU ml^{-1} at station 5. Coliform bacteria count had values between 0.315 MPN 100ml^{-1} (at station 3) and 1.64 MPN 100ml^{-1} (at station 5). Still in the same trend, the lowest and highest values of *E. coli* (measured in MPN 100 ml^{-1}) was from 0.139 at station 3 to 0.619 at station 5. The mean values recorded for presumptive coliform, total heterotrophic bacteria and *E. coli* showed no significant difference ($P > 0.05$) across the stations. There was a significant difference ($P < 0.05$) in the total heterotrophic fungal count recorded. A *posteriori* DMR revealed that the spring and hand-dug wells were the source of significant differences observed.

Table 3: Mean Population Density Count of Bacteria and Fungi in Water from the Study Area

Parameter	STN 1	STN 2	STN 3	STN 4	STN 5	WHO
THBC CFUml^{-1}	4.37x10^3	5.75x10^3	3.625x10^3	4.25x10^3	6.275x10^3	10
THFC CFUml^{-1}	3.0x10^3	2.875x10^3	1.75x10^3	2.25x10^3	4.375x10^3	0
Coliform MPN100ml^{-1}	0.774	1.144	0.315	0.395	1.64	0
E. coli MPN100ml^{-1}	0.406	0.641	0.139	0.300	0.619	0

Note: STN 1 to STN 5 implies stations 1 to 5 (as defined in Table 2 above).

Water Quality Index

A non-parametric analysis of variance for the water quality index revealed that there was no significant difference in the mean values recorded across the stations. The summary of the water quality index (Table 4) revealed that the mean values ranged from 349.59 - 1185.40. The overall water quality index as compared with WQI standard range showed that the water from the sampled stations were unsuitable for human consumption.

Table 4: Summary of the Mean WQI Values of the Sampled Stations

Station	STN 1	STN 2	STN 3	STN 4	STN 5
Mean WQI	349.59	571.04	1185.4	788.40	537.85
Remark	Unsuitable for human consumption	Unsuitable for human consumption	Unsuitable for human consumption	Unsuitable for human consumption	Unsuitable for human consumption

Note: STN 1 to STN 5 implies stations 1 to 5 (as defined in Table 2 above).

DISCUSSION

The water quality of the stations was compared with the World Health Organisation (WHO, 2006) and Standard Organisation of Nigeria (SON, 2007) acceptable limits for drinking water.

The temperature of a water body is affected by a number of factors such as climate or temperature of the geographical area, extent of shade from direct sunlight and depth of the water (Ekhaise and Anyansi, 2005). Low pH values increases the corrosivity of water, the leaching of metal ions such as Fe, Mn, Cu, Pb, and Zn from the aquifer and the solubility of metals in water (USGS, 2015).

The acidic pH recorded for water samples during the study were not within the WHO (2006) and SON (2007) acceptable limits for drinking water.

Conductivity is often affected by the geology of the area through which the water flows; however temperature and rainfall had been known to be a factor (APHA, 2005). The conductivity values recorded in this study ranged from 7.2 to 196.0 μScm^{-1} across the study stations, and was similar to the findings by Adejuwon and Adelakun (2012) on the physico-chemical and bacteriological analysis of surface water in Ewekoro Local Government Area of Ogun State, Nigeria. The turbidity values were generally very low and were within acceptable limits of 5 NTU for drinking water. Freshwater water bodies with high coliform count would have a high BOD (Agbabiaka and Sule, 2010). This statement agreed with the BOD values in this study. Water samples with BOD less than 6 mgL^{-1} are considered clean. The BOD concentrations from this study depicts a high level of organic matter contamination; an indication of microbial contamination. The concentration of dissolved oxygen (DO) differed from the DO concentration obtained by Olomukoro and Oviojie (2014) on the physico-chemical characteristics and bacteriological studies in hand dug wells in Udu Community of Delta State, Nigeria. The total dissolved solids (TDS) values were in contrast to the findings by Adefemi (2013) on the physico-chemical and microbiological assessment of groundwater from Ijan-Ekiti, south western Nigeria. The salinity value was highest (192.6 mgL^{-1}) in the borehole water at Igarra town. The concentration of DO, TDS, turbidity and salinity were within the WHO and SON acceptable limits for drinking water.

Chloride is a widely distributed element in all rock types in one form or the other (Braide *et al*., 2004). Chloride concentration (10.23 - 106.36 mgL^{-1}) differed from the results obtained by Ojo and Agbede (2014) on Ikogosi Warm Spring Water in Ekiti State, south western Nigeria. The concentration of magnesium was above the permissible limit of 0.2 $mgL^{-1}$and conferred hardness on the water. This corresponded to the results obtained by Abdullahi *et al.* (2013). The high magnesium concentration could be as a result of weathering of rocks and as such result in the hardness of water (USGS, 2015). The calcium values recorded in the study area were within the acceptable limits, and differed from the findings obtained by Adefemi (2013).

Nitrate concentrations were within the WHO acceptable limit for drinking water and corroborate the findings by Odeyemi *et al.* (2013). The concentration of phosphate was highest in the spring water (7.32 mgL^{-1}) and may be attributable to weathering of rocks rich in phosphate compounds around the spring; however, this also agreed with the findings of Onweluzo and Akaugbazie (2010) on the quality of bottled and sachet water sold in Nsukka town in Nigeria. The concentrations differed from the findings by Okonkwo *et al*. (2011) on the study of the Public Health Risk Status of the Water Supply Framework in Nsukka town and environs.

The concentration of chloride, nitrate, phosphate, sulphate and calcium were within the WHO permissible limits. Concentrations of trace metals were low in water samples compared to WHO and SON limits. The sources of zinc and other heavy metals in natural waters may be from geological rock weathering or from human activities such as industrial and domestic waste water discharges and animals where it forms constituent functions in maintaining cytoplasmic integrity (Kori-Siakpere and Ubogu, 2008; Dirisu *et al.*, 2017). The mean concentration of iron, zinc and copper in water were below the permissible limits of both the WHO and Nigerian standard for drinking water. The concentrations of Zn, Fe and Cu agree with the findings of Denise *et al.* (2014) on concentration heavy metals in some water bodies in Eket and Nsit Ubium Local Government Area of Akwa Ibom State, Nigeria. The mean values of Pb were beyond permissible limit of 0.01 mgL^{-1} in all stations and differed from the findings of Eze and Okeke (2012) on the analysis of heavy metal characteristics of tap and borehole water in Owerri, Nigeria. The concentrations of the heavy metal were significantly high throughout the study and are attributed to the rocky geology rich in the elemental mineral composition.

The water samples had mean bacterial and fungal counts that exceeded the WHO standards for drinking water (Table 3). This level of microbial contamination is in agreement with the results obtained by Nwachuckwu and Ume (2013) on the bacteriological and physicochemical qualities of drinking water sources in eastern Nigeria. The spring water, pond and rock-pond are surface water bodies that are exposed to intense anthropogenic contamination. In one of the sites, the hand-dug well is located less than 20 meters to a pit toilet. The higher number of bacterial count recorded in spring water, pond and rock pond samples could probably be as a result of the increased surface area which exposes the water to contaminants as well as other human activities (Manjula *et al*., 2011). Peak microbial counts were obtained during the rainy season which is strongly attributed to the deposition from eroded matter.

The application of water quality index (WQI) in this study has been profoundly useful in the assessment of the overall quality of the water sources. The WQI of the water samples (349.59, 571.04, 1185.39, 788.40 and 537.85) from the various water sources, and the overall water quality index (686.456) were not within the permissible limits for the entire samples taken in this study. This was an indication that the water from the selected sources in the study area could be categorized as unsuitable for human consumption.

CONCLUSION

In conclusion, the physicochemical analyses of ground and surface waters in the study area revealed high levels of, BOD, DO, acidic pH, iron and lead, which were beyond the WHO permissible limits for drinking water. Microbiological analysis of the samples showed microbial contamination beyond acceptable standards for drinking water in Nigeria. The overall water quality index (WQI) revealed that the water analysed were unfit for human consumption. Ground water sources should be located at least 30 meters away from septic tanks/pits to reduce microbial contamination, and natural surface water sources should be protected against uncontrolled anthropogenic activities. There's an urgent need for the provision of safe drinking water sources for rural communities and towns in Akoko-Edo to maintain good public health.

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