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# Physicochemical Properties and Heavy Metals in Groundwater and Streams at Essene, Ikot Abasi Local Government Area, Akwa Ibom State, Nigeria

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**ABSTRACT:** The objective of this paper is to evaluate some physicochemical properties and Heavy Metals in groundwater and streams at Essene, Ikot Abasi Local Government Area, Akwa Ibom State, Nigeria using appropriate standard techniques. The physicochemical analysis showed that the average chemical oxygen demand, biological oxygen demand, and dissolved oxygen levels in groundwater were 1.48±0.39 mg/l, 1.364±0.21 mg/l, and 4.26±0.22 mg/l, respectively. For streams, these values were 1.12±0.44 mg/l, 1.46±0.36 mg/l, and 6.04±0.43 mg/l, respectively. Although these parameters were within WHO recommended limits, though they did not meet the WHO standards for drinking water. The heavy metal analysis revealed higher concentrations in stream water (Fe: 0.721 mg/l; Cu: 0.42 mg/l; Pb: 0.0146 mg/l; Cd: 0.22 mg/l) compared to groundwater (Fe: 0.451 mg/l; Cu: 0.12 mg/l; Pb: 0.004 mg/l; Cd: 0.155 mg/l). Iron (Fe) levels exceeded WHO limits in both groundwater and stream water. However, a paired sample t-test indicated no significant difference ($P<0.05$) between the heavy metal concentrations in groundwater and streams. The study highlighted the elevated levels of certain heavy metals (Fe and Cd), emphasizing the need for regular monitoring to mitigate the impact of human activities on water quality in the Essene community.

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Water is identified as one of the most important natural resources because it is viewed as a key to prosperity and wealth (Arubes *et. al.,* 2003). Throughout history, water has been crucial for sustaining life, both of humans and other organisms, making it a significant part of the world. Safe drinking water is essential to sustain life. It is the basis for human health, survival, growth and development. Therefore, access to safe drinking water is a basic human right. Recognition of this right contributes to the survival of human beings and disease prevention, because water is used not only for drinking, but also for many other purposes such as drinking, recreation, food production, agriculture, cooking and industry. Unsafe water, in combination with inadequate sanitation and hygiene, still contributes to the deaths of some 842,000 people every year, representing 58% of deaths caused by diarrhea in the world. About 361, 000 of these deaths occur in children aged under 5years (WHO, 2014). Safe water supplies are essential not only for health, but also for people's livelihoods, economic growth and development. Therefore, the provision of potable water to the rural and urban population is necessary

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to prevent health hazards (UNESCO, 2004). Careful selection and protection of water sources can be particularly effective in reducing the risks to raw water for drinking water supplies, resulting in water that is of high quality microbiologically and chemically (WHO, 2006). Groundwater is the water contained beneath the surface in rocks and soil and is the water that accumulates underground in aquifers. Groundwater constitutes 97% of global freshwater and is an important source of drinking water in many regions of the world (WHO, 2006). Throughout the world, there is evidence of contaminated ground water leading to outbreaks of diseases. Industrial discharges, urban activities, agriculture, groundwater plumage and disposal of waste can affect groundwater quality. Pesticides and fertilizers applied to lawns and crops can accumulate and migrate to the water tables thus affecting both the physical, chemical and microbial quality of water (Lobina and Akoth, 2015).

In rural Africa where the most common type of sanitation is the pit latrine, this poses great risk on the microbial quality of groundwater. Poor sanitary completion of boreholes may lead to contamination of groundwater. Proximity of some ground water to solid waste dumpsites and animal droppings being littered around them could also contaminate the quality of groundwater (Bello *et al.* 2013). Surface water bodies may also be contaminated by a variety of chemical, microbial and sometimes even physical hazards from human activities. Agricultural wastes such as pesticides, fungicides and fertilizers, human and animal faeces, seepage from pit latrines and septic tanks, refuse dump, industrial, domestic and municipal wastes released into water bodies are often responsible for surface water contamination (Adejuwon and Adelakun, 2012). These characteristics are not the only yardstick for judging the quality of water. Polluted water is not just dirty, it is deadly. Therefore, the key to sustainable water resources is to ensure that the quality of water is suitable for the intended uses, whole at the same time allowing them to be used and developed to a certain level without affecting the health of the people. Hence, the objective of this paper is to evaluate some physicochemical properties and Heavy Metals in groundwater and streams at Essene, Ikot Abasi Local Government Area, Akwa Ibom State, Nigeria

## MATERIALS AND METHODS

*Study Area:* Essene originally named Nnung Assang is a rural community in Ikot Abasi Local Government Area. Akwa Ibom State, Nigeria. It received its name from the nearby Essene creek which was known to 6 the Opobo people as Essene Obio River in Ikot Abasi Local Government Area. It is located at Latitudes 4°36ˈN Longitudes 7°48ˈE and Latitudes 4°29ˈN and Longitudes 7°54ˈE. Essene is the home of the first secondary school in Opobo Division, the Regina Coeli College which was established in 1956. Indigenes are involved in subsistence farming and trading.

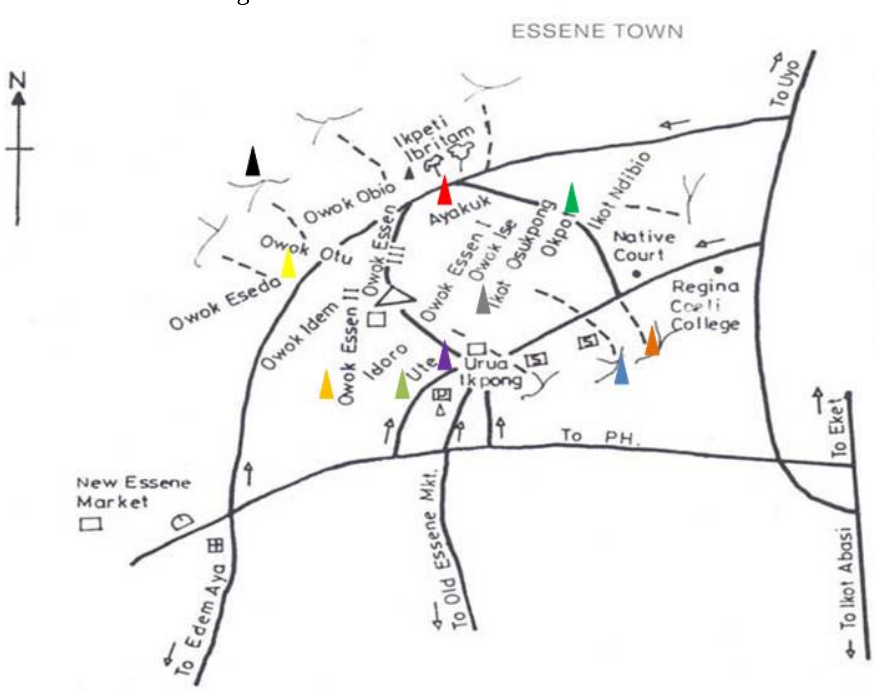


**Fig. 1:** Map of Study Area

Five groundwater sources and five streams in the community were randomly selected for the study using a table of random numbers. The groundwater was labeled as BH1-BH5 and the stream water was labeled as SWA-SWE

**Table 1:** Groundwater samples and their location

| Groundwater samples | Location |
|---|---|
| BH 1 | Ikot Osukpong |
| BH 2 | Owok Out |
| BH 3 | Okpot |
| BH 4 | Ute |
| BH 5 | Owok Essen |

**Table 2:** Stream water samples and their location

| .Stream samples | Location |
|---|---|
| SW A | Ikot Osukpong Stream |
| SW B | Ayakuk Stream |
| SW C | Ofon-Ikang Stream |
| SW D | Okpot Stream |
| SW E | Ute Stream |

*Sample Collection* The water samples were collected using new screw-capped bottles that have been sterilized to avoid contamination. Water was fetched from boreholes by dipping cotton wool in ethanol. The cotton wool was flamed and used to clean the mouth of the tap. The tap was opened and allowed to run before water was fetched. Water was fetched from the stream by rinsing the bottles with the stream water. The water was then fetched and the bottles cocked immediately. All the collected samples were kept in a cooler loaded with ice blocks and then transported to the lab for preservation and analysis. The physicochemical properties of the groundwater and stream water samples were analyzed using standard analytical procedures recommended by APHA (1992 and 1998). Unstable or easily changeable parameters such as pH and temperature of water samples were measured In-situ.


**Fig .1:** represent the ground water (a) gsround water in ikot osupong, (b) ground water in owoke out, (c) ground water in okpot, (d) ground water in ute, (e)) ground water in owok essien

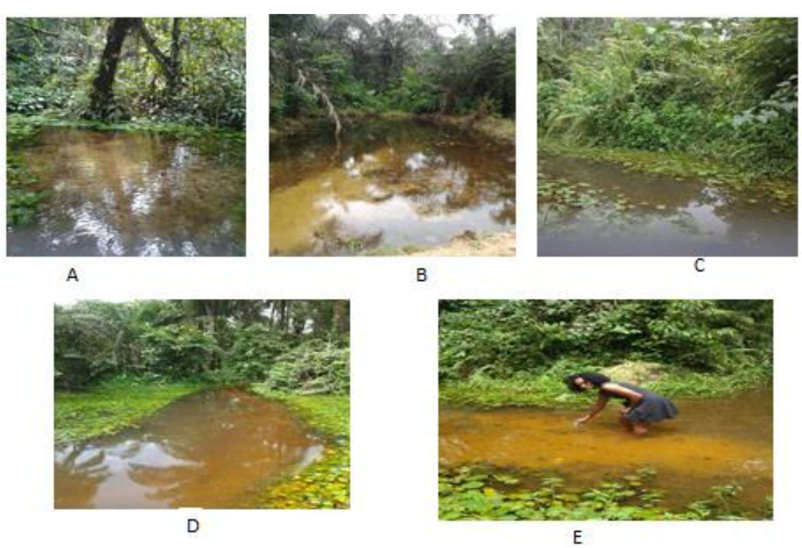


**Fig** .2: represent the streams (a) ikot osukpong stream, *(b) Ayakuk stream, (c) Ofong ikang stream, (d) okpot stream, (e) Ute stream

*Determination of pH:* A portable pH meter (Orion Equipment Model 310) was used for in situ measurement of pH. The pH meter was calibrated using a buffer solution of 4 and 7. Each water sample was poured into a beaker and the electrode was then dipped into each sample. The readings were then taken from the meter and recorded.

*Determination of Turbidity*: Turbidity was determined using the HANNA HI Equipment (Model 93703) microprocessor turbidity meter. Water sample was poured into the cuvette and the cuvette was inserted into the measuring cell of the meter. The read key was pressed and the result was displayed on the screen and recorded in Nephelometric Turbidity Unit (NTU).

*Determination of Dissolved Oxygen*: Dissolved oxygen was determined using the HANNA HI Equipment (Model 9146) meter. The meter was calibrated. The cell probe was rinsed with a portion of the sample. The probe was inserted into the beaker which contained the water sample. The result was displayed on the screen and the reading was recorded.

*Determination of Electric Conductivity* (EC): EC is a numerical value or expression of the water's ability to conduct electric current. This was taken using HANNA HI Equipment (Model 99300). The power key and the conductivity key of the conductivity meter were switched on. The temperature of the meter was adjusted and the meter was calibrated with 1000µS/cm, conductivity standard. The cell-probe was rinsed with a portion of the sample. The probe was dipped into the water samples until a stable reading was obtained and recorded.

*Determination of Temperature*: A portable meter HANNA HI Equipment (Model 99300) was used to measure the temperature In situ. The probe was immersed directly into the water until a stable reading was obtained and recorded. Values were recorded in degree Celsius.

*Determination of Total Dissolved Solids (TDS)*: Dissolved solids are solids that are in dissolved state in a solution. TDS was determined using HANNA HI Equipment (Model 99300). The values were expressed as mg/L of water. Water was collected in a beaker. The electronic probe of the meter was immersed directly into the beaker until a stable reading was obtained and recorded.

*Determination of Biological Oxygen Demand (BOD)*: Samples were incubated for five days at 20oC in BOD bottles. Dissolved oxygen (DO) was measured before and after the incubation. Initial DO was determined shortly after dilutions were added: 1ml of MgSO4, CaCl2, phosphate buffer, FeCl3 was added to one liter of water. The solution was shaken thoroughly to saturate the dissolved oxygen. The diluted sample solution was then poured into BOD bottles and subsequently incubated at 20 o C in the dark for 5 days. BOD was determined in Equation 1.

$$\text{BOD mg/l} = \frac{DO5-DO1}{percent\ dilution} \quad (1)$$

Where $DO_5$ = final dissolved oxygen (day 5), $DO_1$ = initial dissolved oxygen (day 1).

*Determination of Chemical Oxygen Demand (COD):* According to APHA (2005), COD is the measure of total oxygen required for the complete oxidation of organic matter present in the water body using a strong chemical oxidant such as dichromate. COD was determined by Open reflux method using potassium dichromate (APHA, 1998).

*Determination of Total Suspended Solid (TSS):* TSS was determined by drying a 0.45mm filter paper in an oven at 105°C for 1 hour. The filter paper was then removed, cooled in a desiccator for 30 minutes weighed and recorded. 50ml of the water sample was measured and filtered through the Millipore filtration apparatus. The filter paper was then put in the oven again to dry for 1 hour at 105°C, removed and cooled in a desiccator for 30 minutes too. It was then weighed and recorded. The TSS was determined in Equation 2

$$\text{TSS} = \frac{W2-W1}{V} \times 1000 \quad (2)$$

Where $W_2$ = weight of filter paper and residue, $W_1$ = weight of filter paper before filtration,
V = volume of the sample.

*Determination of Chloride:* Chloride was determined as done according to the method described in Udo *et al.* (2009). Exactly 1ml of 5% potassium chromate ($K_2CrO_4$) indicator was added to 50ml of distilled water. It was titrated by constantly stirring it with 0.0282M silver nitrate ($AgNO_3$) to a brick red colour precipitate end point. This was the blank. Then to a 50ml of each water sample, 1ml of 5% $K_2CrO_4$ indicator was added and titrated by constantly stirring it with 0.028M $AgNO_3$, the colour at the end point being compared with that of the blank. Chloride was determined in Equation 3.

$$\text{Cl (mg/l)} = \frac{(A-B)\times M\times 70900}{Volume of sample\ (ml)} \quad (3)$$

Where A= volume of $AgNO_3$ used for titrating the sample, B = volume of $AgNO_3$ used for titrating the blank, M = molarity of $AgNO_3$ used.

*Determination of nitrate by Brucine Method*: Nitrate was determined by preparing a suitable volume of unknown sample in a 25ml standard flask. 10ml of each sample was transferretd into 25ml standard flask and 0.5ml of brucinesulphanilic acid was added, then 10ml of concentrated hydrogen tetraoxosulphate (VI) acid ($H_2SO_4$) was added. It was mixed for 30 seconds and allowed to stand for about 5 minutes. The flasks and the contents were set in cold water bath for some minutes and then marked up to volume with deionized water. The absorbance was read at wavelength 420nm with Jenway 7200 spectrophotometer.

*Determination of nitrite by Photometric Method*: The water sample was poured into a 100ml volumetric flask and filled to 80ml. 2ml of sodium-EDTA solution, 5ml sulphanilamide solution and 2ml of hydrochloric acid were added. After 3 minutes, 1ml N-(1-Naphtyl) ethylenediamine-dihydrochloric solution was added. The solution was thoroughly mixed. A blank sample was also prepared. The absorbance was read at wavelength 542nm with Jenway 7200 spectrophotometer.

*Determination of sulphate by Turbid Metric Method*: Sulphate was determined by measuring 50ml of the sample into a conical flask. 20ml 5% hydrochloric acid was added. 5ml 10% of barium chloride was also added and stirred. The mixture was allowed to stand for an hour for colour change. A blank solution was also prepared. Standard solution of sodium tetraoxosulphate (VI) acid was prepared by dissolving 0.1479g anhydrous $Na_2SO_4$ in distilled water and diluted to 1liter. The absorbance was read at wavelength 425nm with Jenway 7200 spectrophotometer.

*Determination of phosphate by Colorimetric Method*: A volume of 25ml of each water sample was measured into 50ml volumetric flask. 10ml of vanadate molybdate reagent was added and diluted to volume with distilled water. A blank was prepared by adding 10ml of vandate molybdate reagent to 2ml of distilled water. The solutions were stirred and allowed to stand for 10 minutes. The absorbance at 470nm was taken with a Jenway 7200 spectrophotometer.

*Heavy Metals Analysis of Groundwater and Stream Water Samples:* According to Chinedu *et al*., (2011), digestion of sample is necessary before analysis of metals concentrations in order to reduce the interference of organic matter and also to convert metal to a form that can be analyzed by AAS. In this study, water samples were digested as follows: 100ml of the water was pipette into a beaker and 5mls of concentrated nitric acid ($HNO_3$) was added. The concentrations of copper, cadmium, lead, arsenic, and iron in the sample were determined using flame Atomic Absorption Spectrophotometer as described in the manufacturer's instruction manual (Ukpong and Okon, 2013).

*Statistical Analysis:* SPSS package (version 10) was used for analyzing the data obtained. Paired t-test was used to analyze the heavy metals variations between the stream and groundwater. Correlation between selected physicochemical parameters ($p<0.05$) in the stream and groundwater was carried out using Pearson's correlation (r).

## RESULTS AND DISCUSSION

The physicochemical analysis results obtained in the study of the groundwater and stream water in Essene, Akwa Ibom state, Nigeria are presented in Tables 3 and 4.

**Table 3:** Physicochemical properties of groundwater samples

| Parameters | Groundwater samples | | | | | Mean ± SD | WHO Limit |
|---|---|---|---|---|---|---|---|
| | BH1 | BH2 | BH3 | BH4 | BH5 | | |
| pH | 7.1 | 7.6 | 7.7 | 7.5 | 7.9 | 7.56±0.30 | 6.5-8.5 |
| Temperature | 24 | 24 | 23 | 24 | 23 | 23.6±0.55 | 30°C-32°C |
| Turbidity | 2.64 | 2.62 | 2.8 | 2.8 | 3.2 | 2.812±0.23 | 5NTU |
| Electric conductivity | 15.33 | 16.2 | 15 | 16.3 | 15.1 | 15.586±0.62 | 50-1000 μhos/cm |
| Dissolved Oxygen | 4.3 | 4.6 | 4.2 | 4 | 4.2 | 4.26±0.22 | 7.5mg/l |
| BOD | 1.6 | 1.52 | 1.4 | 1.1 | 1.2 | 1.364±0.21 | 6-9mg/l |
| COD | 1.6 | 0.8 | 1.6 | 1.8 | 1.6 | 1.48±0.39 | 7.5mg/l |
| Chloride | 37.99 | 17.99 | 17.99 | 7.99 | 7.99 | 17.99±12.25 | 250mg/l |
| TDS | 23.11 | 23.11 | 24.12 | 30.06 | 30.1 | 26.1±3.66 | 1000mg/l |
| TSS | 0.3 | 0.05 | 0.4 | 0.41 | 0.305 | 0.293±0.15 | 500mg/l |
| Nitrate | 0.2 | 0.4 | 0.4 | 0.3 | 0.4 | 0.34±0.09 | 50mg/ |
| Nitrite | 0.3 | 2 | 2 | 3 | 1.5 | 1.76±0.98 | 3.0mg/l |
| Sulphate | 0.37 | 0.7 | 0.47 | 0.1 | 0.17 | 0.362±0.24 | 500mg/l |
| Phosphate | 0.11 | 0.41 | 0.16 | 0.16 | 0.17 | 0.202±0.12 | 400mg/l |

*Source: Field data (2017)*

**Table 4:** Physicochemical properties of stream water samples

| Parameters | Stream water samples | | | | | Mean±SD | WHO Limit |
|---|---|---|---|---|---|---|---|
| | **SWA** | **SWB** | **SWC** | **SWD** | **SWE** | | |
| Ph | 7.0 | 7.9 | 7.7 | 6.8 | 7.8 | 7.44±0.50 | 6.5-8.5 |
| Temperature | 25 | 24 | 24 | 23 | 25 | 24.2±0.84 | 30°C-32°C |
| Turbidity | 4.7 | 5.57 | 3.81 | 5.55 | 4.53 | 4.832±0.74 | 5NTU |
| Electric conductivity | 19.1 | 21.5 | 19.04 | 19.04 | 19.02 | 19.54±1.10 | 50-1000μhos/cm |
| Dissolved Oxygen | 6.4 | 6.2 | 5.3 | 6.2 | 6.1 | 6.04±0.43 | 7.5mg/l |
| BOD | 1.9 | 1.8 | 1.1 | 1.2 | 1.3 | 1.46±0.36 | 6-9mg/l |
| COD | 0.8 | 1.6 | 0.8 | 1.6 | 0.8 | 1.12±0.44 | 7.5mg/l |
| Chloride | 17.99 | 17.99 | 7.99 | 7.99 | 17.99 | 13.99±5.48 | 250mg/l |
| TDS | 23.24 | 25.22 | 30.26 | 27.21 | 33.16 | 27.818±3.96 | 1000mg/l |
| TSS | 0.015 | 0.335 | 0.25 | 0.05 | 0.49 | 0.228±0.20 | 500mg/l |
| Nitrate | 0.6 | 3 | 1.4 | 1.3 | 0.3 | 1.32±1.05 | 50mg/ |
| Nitrite | 1.5 | 1.9 | 2.5 | 1.8 | 1.3 | 1.8±0.46 | 3.0mg/l |
| Sulphate | 0.94 | 0.75 | 0.69 | 0.78 | 0.53 | 0.738±0.15 | 500mg/l |
| Phosphate | 0.14 | 0.15 | 0.16 | 0.21 | 0.16 | 0.164±0.027 | 400mg/l |

*Source: Field data (2017)*

The pH of the groundwater samples ranged from7.1 to 7.9 with a mean value of 7.56±0.30 while that of the stream water ranged from 6.8 to 7.9 with a mean value of 7.44±0.50. pH values of all the water samples met WHO standard for drinking water (6.5-8.5). There was no significant difference in the groundwater samples and the streams (p=0.212).

The temperature of the groundwater samples ranged between 23°C to 24°C with a mean value of 23.6±0.55 while that of the stream water ranged between 23°C to 25°C with a mean value of 24.2±0.84. Temperature values of all the water samples were below the WHO standard for drinking water (30°C-32°C). There was no significant difference in the groundwater samples and the streams (p=0.305).

Turbidity values of the groundwater samples ranged from 2.62 to 3.2 with a mean value of 2.812±0.23 while that of the stream water ranged from 3.81 to 5.57 with a mean value of 4.832±0.74. Turbidity values of all the water samples met the WHO standard of drinking water (5NTU) except SWB and SWD. There was significant difference in the groundwater samples and the streams (p=0.910).

Electric conductivity (EC) values of the groundwater samples ranged from 15.0 to 16.3 with a mean value of 15.586±0.62 while that of the stream ranged from 19.10 to 21.5 with a mean value of 19.54±1.10. EC values of all the water samples met the WHO standard for drinking water (50-1000μmhos/cm). There was no significant difference in the groundwater samples and the streams (p=0.001).

Dissolved Oxygen (DO) values of the groundwater samples ranged from 4.0 to 4.6 with a mean value of 4.26±0.22 while that of the streams ranged from 6.1 to 6.4 with a mean value of 6.04±0.43. DO values of all the water samples met the WHO standard for drinking water (7.5mg/l). There was no significant difference in the groundwater samples and the streams (p=0.001).

Biological Oxygen Demand (BOD) values of the groundwater samples ranged from 1.1 to 1.6 with a mean value of 1.364±0.21 while that of the stream water ranged from 1.1 to 1.9 with a mean value of 1.46±0.36. BOD values of all the water samples met the WHO standard for drinking water (6-9mg/l). There was no significant difference in the groundwater samples and the streams (p=0.423).

Chemical Oxygen Demand (COD) values of the groundwater samples ranged from 0.8 to 1.8 with a mean value of 1.48±0.39 while that of the streams ranged from 0.8 to 1.6 with a mean value of 1.12±0.44. All the water samples met the WHO standard for drinking water (7.5mg/l). There was no significant difference in the groundwater samples and the streams (p=0.313).

Chloride values of groundwater samples ranged from 7.99 to 37.99 with a mean value of 17.99±12.25 while that of the stream water ranged from 7.9 to 17.99 with a mean value of 13.99±5.48. All the water samples met the WHO standard for drinking water (250mg/l).

Total dissolved solids (TDS) values of groundwater samples ranged from 23.11 to 30.1 with a mean value of 26.1±3.66 while that of the stream ranged from 23.24 to 33.16 with a mean value of 27.81826.1±3.663.96. All the water samples met WHO standard for drinking water (1000mg/l). There was no significant difference in the groundwater samples and the streams (p=0.315). Total suspended solids (TSS) values of the groundwater samples ranged from 0.05 to 0.41 with a mean value of

0.293±0.15 while that of the streams ranged from 0.05 to 0.335 with a mean value of 0.228±0.20. The WHO standard for drinking water (500mg/l) was met by all the water samples. There was significant difference in the groundwater samples and the streams (p=0.638). Pearson's correlation coefficient analysis of relation between BOD, COD, DO, TSS and TDS on the groundwater samples revealed a high positive significant relationship between COD and TSS at 0.05 level of probability (r = 0.962), however there was also a high negative correlation between BOD and TDS (r = -0.955), COD and DO (r = -0.948), DO and TSS (-0.942) at 0.05 level of probability. The result also revealed moderate positive correlation between BOD and DO (r = 0.686), TDS and TSS (r = 0.719) content of the stream water at 0.05 level of probability. Nitrate values of the groundwater samples ranged from 0.2 to 0.4 with a mean value of 0.34±0.09 while that of the stream ranged from 0.3 to 3.0. All the water samples met the WHO standard for drinking water (500mg/l). There was no significant difference in the groundwater samples and the streams (p=0.097). Nitrite values of the groundwater samples ranged from 0.3 to 3.0 with a mean value of 1.76±0.98 while that of the stream ranged from 1.3 to 2.5 with a mean value of 1.8±0.46. The water samples all met WHO standard for drinking water (3.0mg/l). There was no significant difference in the groundwater samples and the streams (p=0.460). Sulphate values of the groundwater samples ranged from 0.1 to 0.7 with a mean value of 0.36±0.24 while that of the streams ranged from 0.53 to 0.94 with a mean value of 0.738±0.15. All the water samples met the WHO standard for drinking water (500mg/l). There was no significant difference in the groundwater samples and the streams (p=0.30). Phosphate values of the groundwater samples ranged from 0.11 to 0.41 with a mean value of 0.20. ± 0.12 while that of the streams ranged from 0.14 to 0.21 with a mean value of 0.164±0.027. All the water samples met the WHO standard for drinking water (400mg/l). There was no significant difference in the groundwater samples and the streams (p=0.538).

However statistical analysis (at 95 % confidence limit, p = 0.05) showed moderate positive relationship between nitrate and phosphate (r = 0.533) while a high positive correlation was established between phosphate and sulphate (r = 0.720) in groundwater.

*Heavy metal load of groundwater and stream water samples:* The concentrations of the heavy metals in the groundwater samples and stream water are presented in Tables 5 and 6 respectively.

**Table 5:** Heavy metal loads (mg/l) of groundwater

| **Borehole** | **Fe** | **Cu** | **Pb** | **As** | **Cd** |
|---|---|---|---|---|---|
| BH1 | 0.31 | 0.20 | 0.001 | <0.001 | 0.034 |
| BH2 | 0.316 | 0.121 | 0.010 | <0.001 | 0.104 |
| BH3 | 0.32 | 0.326 | 0.001 | <0.001 | 0.403 |
| BH4 | 0.031 | 0.012 | 0.001 | <0.001 | 0.052 |
| BH5 | 1.14 | 0.05 | 0.004 | <0.001 | 0.063 |
| Mean | 0.45175 | 0.12725 | 0.004 | - | 0.1555 |
| WHO Limit | 0.3 | 2 | 0.001 | 0.01 | 0.003 |

*Source: Field data (2017)*

**Table 6:** Heavy metal loads (mg/l) of stream water

| **Stream** | **Fe** | **Cu** | **Pb** | **As** | **Cd** |
|---|---|---|---|---|---|
| SWA | 0.73 | 0.149 | 0.021 | <0.001 | 0.463 |
| SWB | 0.14 | 0.402 | 0.010 | <0.001 | 0.237 |
| SWC | 1.132 | 0.343 | 0.020 | <0.001 | 0.361 |
| SWD | 1.033 | 0.854 | 0.002 | <0.001 | 0.028 |
| SWE | 0.57 | 0.361 | 0.020 | <0.001 | 0.037 |
| Mean | 0.721 | 0.4218 | 0.0146 | - | 0.2252 |
| WHO Limit | 0.3 | 2 | 0.001 | 0.01 | 0.003 |

*Source: Field data (2017)*

The values for iron ranged from 0.31 to 1.14 with a mean value of 0.45175 in the groundwater samples while the value of iron in the streams ranged from 0.14 to 1.132 with a mean value of 0.721. None of the water samples met the WHO standard of iron for drinking water (0.3mg/l) except BH4 and SWB.

Copper values of the groundwater samples ranged from 0.05 to 0.326 with a mean value of 0.12725 while that of the stream water ranged from 0.149 to 0.854 with a mean value of 0.4218. All the water samples met the WHO standard for drinking water (2.0mg/l). Lead values for the groundwater samples ranged from 0.001 to 0.010 with a mean value of 0.001 while that of the stream water ranged from 0.002 to 0.021 with a mean value of 0.001. The groundwater samples met the WHO standard for drinking water (0.001mg/l) except BH2 and BH5while none of the streams met the WHO standard. The value of arsenic for the groundwater samples and the streams were all <0.001 and they all met the WHO standard limit of 0.01mg/l. The value of cadmium for the groundwater samples ranged from 0.034 to 0.403 with a mean value of 0.1555 while that of the stream ranged from 0.028 to 0.463 with a mean value of 0.2252. None of the water samples met the WHO standard of drinking water (0.003mg/l). The distribution of heavy metals in groundwater was in the order: Fe >Cu>Cd>Pb>As (.The distribution of heavy metals in the stream was in the order: Fe>Cu>Pb>Cd>As. Iron concentration was highest in groundwater and stream water recording values above WHO limits, while, Arsenic (As) had the lowest concentration in both water samples. Statistically, paired sample t test showed no significant ($P < 0.05$) difference between heavy metals concentrations in the groundwater and stream. A significant issue in emerging and highly populated nations is ground water pollution and the resulting degradation of hydrologic systems (Dahunsi *et al.,* 2014; Ayandiran *et al.,* 2018). Large volumes of untreated wastewater and solid wastes have been indiscriminately disposed in rivers and streams as a result of increased urban, industrial, and agricultural activity as well as a lack of enforcement of environmental legislation. The pH of the water samples for both groundwater sources and streams ranged from 6.8 to 7.9 with an average of 7. This result was in agreement with the study conducted by Ehiowemwenguan *et al.* (2014) where pH values of 6.8-7.3 were recorded and Bernard (2013) where pH values of 6.89-7.15 were recorded. However, the result obtained in this study differed from previous authors like Josiah *et al.* (2014) where pH values ranged from 4.50-5.39 and the water was found to be acidic. This may be attributed to underground pollution caused by agricultural activities on farm lands. The pH values were within the recommended limit of WHO (6.5-8.5). Therefore, the pH of the groundwater and stream water in this study area could be classified as fit for drinking. The temperatures of the groundwater samples and stream water ranged from $23^oC$-$25^oC$ and were below the WHO limit for drinking water which is 30°C-32°C.This result was in agreement with the study conducted by Dhanaji *et al.* (2016) where temperature ranged from $24^oC$-$26^oC$. Olatunji *et al.* (2011) also recorded 24.3°C to 25.8°C as temperature of water in his study. The observed fluctuation in temperature according could be attributed to the sampling time, climatic conditions and the number of sunshine hours. Water is said to be safe if the concentrations of the undesired substances do not exceed the levels set by the regulatory bodies' (WHO, 2011). Therefore, the temperature of the groundwater and stream water in this study area could be classified as fit for drinking purposes. Electric conductivity EC values recorded in this study 15.0µs/cm -21.5µs/cm was slightly lower than the values recorded in Ezeribe *et al.* (2012) who reported EC range of 30.20µs/cm -38.80µs/cm. However, the values obtained in this study were in conformity with the result obtained by Samie *et al.* (2013) where the value of EC was 22.0µs/cm-31.8µs/cm. This indicates the presence of ions in low levels in the water. The EC values in this study were below 50-1000µs/cm and thus do not pose any threat to consumers. The turbidity values in this study varied between the different stream and groundwater samples. Values ranging from 2.62NTU to 3.2NTU were recorded for the groundwater samples and 3.81NTU to 5.57NTU for stream water samples. The turbidity values obtained for some of the streams were higher than the WHO standard (5 NTU) permissible level. This may be due to the presence of clay, silt, finely divided organic matter, plankton and other microscopic organisms. Ehiowemwenguan *et al.* (2014) recorded turbidity values within the range of 2.50NTU-7.0NTU in their study. However, Lobina and Akoth (2015) recorded turbidity values of 0.5NTU-40.9NTU in their study. In this study, the Dissolved Oxygen DO levels ranged from 5.3 to 6.4 mg/l in groundwater samples while the result of the stream water ranged from 3.05 to 3.17 mg/l. This result suggests that the stream water contains low organic load that supports aquatic life compared to levels obtained in the groundwater. Onwughara *et al.* (2013) reported 30.3 – 33.5mg/l as dissolved oxygen range from selected boreholes in Abia State which were far above the ranges obtained in this research. Adejuwon and Adelakun (2012) recorded 5.94 – 6.65 dissolved oxygen range in surface water in Ogun State which was within the range obtained in this research. Levels of dissolved oxygen were within the WHO standard for drinking water (7.5mg/l) and could be therefore classified as fit for drinking. In this study the Biological Oxygen Demand (BOD)/Chemical Oxygen Demand (COD**)** ranged from 1.1-1.9mg/l. This was in conformity with Oluyemi *et al.* (2010) who reported BOD values of 1.035mg/l for some locations although he also had higher values of 7.24mg/l in other locations of his study at Ogun State. However the range of BOD levels obtained in this study were within the WHO standard for drinking water and therefore below values indicative of pollution (6-9mg/l). This means the water is fit for drinking. Also, the levels of chemical oxygen demand (COD) recorded ranged from 0.8-1.8mg/l. The result gotten was in conformity with Onwughara *et al.* (2013) who recorded COD values within the WHO limit although Oyem *et al.* (2014) recorded

COD values higher than the result obtained in this study (46.80-93.60mg/l). Water with high COD indicate that there is inadequate oxygen available in the water sample which can arise from the use of fertilizers, animal and human waste and decaying plant matter all of which gets to the aquifer through leaching. The total Dissolved Solids (TDS**)** the range of TDS obtained from this study was 23.11-33.16mg/l and was in conformity with the values reported by Mgbemena *et al.* (2014) who recorded values of 5.90-30.53mg/l. This could be due to differences in organic matter that remains as residue in the groundwater. The value reported by Aremu *et al*. (2011) which was 1048.67 mg/l was higher than those reported in this study. Bernard (2013) also recorded relatively higher values than values reported in this study (51.53-418.20mg/l). The concentration of TDS in this research was below WHO standard for drinking water (1000mg/l) and hence does not pose any health threat to consumers. The Total Suspended Solid (TSS) the TSS value ranged from 0.015-0.49mg/l. The range obtained in this study was lower than those reported by Onwughara *et al.,* (2013) where TSS values were 11.4-55.0mg/l. However, Ikeme *et al.* (2014) reported much higher of TSS in his study (98.3-788mg/l).The concentration of TSS in this research was below WHO standard for drinking water (500mg/l) and hence do not pose any health threat to consumers. The Nutrient loads of the water samples and chloride level of the water samples ranged from 7.9-37.99mg/l. Chloride value was higher in the groundwater samples than in the stream water. This could be attributed to the occasional chlorine disinfection by the borehole owners. The result gotten in this study was in conformity with the chloride values of 13.50-42.33 obtained from Bernard (2013). Ezeribe *et al.,* (2012) recorded higher values of chloride in his study (18.40-61.9mg/l). Ehiowemwenguan *et al.* (2014) however recorded higher chloride values too in their study (112-220mg/l). The mean value of chloride for all the water samples is within the WHO standard for drinking water (250mg/l) and therefore do not pose any health threat to consumers. The values of nitrate (0.2-3.0mg/l) and nitrite (0.3-3.0mg/l) for all the water samples were below the WHO guideline values (50mg/l and 3.0mg/l) and therefore pose no health threat to their consumers. The stream water however recorded higher values than the groundwater. This could be due to the streams being located in close proximity to farmlands where fertilizers are used thereby causing surface water pollution. Adejuwon and Adelakun (2012) reported nitrate values (26.00-51.50mg/l) which was higher than that obtained in this study. However, Lobina and Akoth (2015) recorded values of 1.8mg/l-3.2mg/l which was in conformity to the result obtained in this study. Phosphate levels obtained in this study ranged from 0.11-0.41mg/l. However, the groundwater samples recorded slightly higher concentrations than the streams. High levels of phosphate in ground water could indicate the possible pollution from feacal origin or agro products. The mean concentration of phosphate in this study all met the WHO standard for drinking water (400mg/l) and is therefore fit for drinking. Phosphate levels obtained in this study was in conformity with results obtained by Bernard (2013) (0.33-1.66mg/l). The values of sulphate obtained in this study ranged from 0.1-0.94mg/l. These results were within the WHO permissible limits (500mg/l) and therefore are not harmful to the health of man. The levels of sulphate recorded in this research were within the range reported by Ukpong and Okon (2013) but were less than that reported by Bernard (2013). In this study, the value of iron ranged from 0.14-1.14mg/l. The concentration of Fe in most of the water sources was generally higher than the WHO maximum permissible limit. The high concentration of the element in the stream water may be due to direct release of domestic waste from anthropogenic activities. However, the levels of iron in this study differs from authors like Oluyemi *et al*. (2010) who recorded the values of iron as 31.78 ±0.80mg/l and Orosun *et al.* (2016) who recorded iron values of 0.25-0.32mg/l in their study. The ranges of copper obtained in this study ranged from 0.012-0.854mg/l. This result differs from Agnieszka *et al.* (2018) who recorded the range of copper from 0.003-0.05mg/l in their study. The results gotten from this study were within the WHO standard for drinking water (2.0mg/l). The water is therefore fit for drinking. In this study, the level of lead ranged from 0.001mg/ml-0.021mg/l. This result is in agreement with Samuel *et al.* (2015) who recorded lead value of 0.005-0.791mg/l. The result obtained here differs from previous author like Oyekunle *et al*. (2012) who recorded lead values of 0.18±0.04mg/l-2.4±3.3mg/l. Some of the values of Pb in different water sources obtained in this study were higher than WHO standard for drinking water (0.01mg/l). This may be as a result of anthropogenic activities like indiscriminate disposal of used lead-acid batteries, alloys, soldering metals, etc in the study area. Therefore, the water is not fit for drinking purposes. Arsenic (As) can be found in traces in nature. Elevated levels can be found naturally in groundwater which may be as a result of contamination caused by hazardous waste or industries that make use of As. Elevated levels of arsenic in drinking water may cause thickening and discolouration of skin, nausea, vomiting, diarrhoea, numbness in the hand and feet (Farrell-Poe, 2010). In this study, arsenic was below detectable level of WHO (0.01mg/l) in both borehole and stream water samples. This result differed slightly from a study conducted by Samuel *et al.* (2015) who recorded the range of arsenic as 0.001-0.115mg/l. In this study, the values of cadmium ranged from 0.028-0.463mg/l. This high concentration of cadmium could be attributed to high human and industrial activities around the study area. This result was in agreement with Samuel *et al.* (2015) who recorded cadmium values of 0.023-0.534mg/l. None of the water samples met the WHO standard for drinking water (0.003mg/l). Therefore, all the water samples are unfit for drinking purposes.

*Conclusion:* The presence of safe and reliable sources of water is a basic factor in promoting public health and preventing health hazards. The physicochemical parameters analyzed in this study revealed that the water samples were fit for consumption since the tested parameters were within WHO guideline value for drinking water. The levels of iron, lead and cadmium recorded in the water samples were higher than the accepted values of these metals in drinking water as recommended by WHO. This made the water unfit for consumption. The presence of pathogenic organisms in some of the water samples rendered it unfit for drinking due to contamination.

*Declaration of Conflict of Interest:* The authors declare no conflict of interest in this study.

*Data Availability Statement:* Data are available upon request from the first author or corresponding author or any of the other authors

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