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Groundwater Quality Around Active and Non-Active Dumpsites in Benin City, Nigeria

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Abstract

Groundwater is a source of water for different processes in the environment. The quality of groundwater is a factor that affects many aspects of the plant, animal, human and environmental health. This study is aimed at determining and comparing the quality of groundwater water collected from an active and a non-active dumpsite. Water samples were prepared and analyzed using standard methods. The physicochemical properties, microbiological composition, and heavy metal content of the samples were determined. Results obtained were subjected to statistical analyses using Microsoft Excel 2017 and SPSS Version 21. The results showed that the pH values of samples which ranged from 4.1 - 6.6 do not fall within WHO permissible limits for human consumption. The values of other parameters had ranges as follows: electrical conductivity (10 - 370µS/cm), chloride (7.1 - 56.90mg/L), dissolved oxygen (2.2 - 5.0mg/L), biochemical oxygen demand (0.9 - 2.30mg/L), turbidity (0 - 15.0mg/L), total hardness (8 - 75.0mg/L), total dissolved solids (5.3 - 197.0mg/L) and nitrate (0.31 - 3.12mg/L) all fall within WHO limits. The results of the heavy metal analysis showed that Pb concentration from LC (after 2mins) is above the EPA limits. The highest values for heterotrophic plate count was observed for LB (44cfu/ml) (after 2mins) and LB (3.50cfu/ml) for coliform bacteria. These results also are within the WHO permissible limits for safe drinking water. It can be concluded that the quality of the groundwater in the areas of interest is within safe limits for human consumption although it can be improved through the treatment of water.

Keywords: *Groundwater pollution, water quality, dumping, Benin city.*

1. Introduction

The World Health Organization (WHO) recommends a minimum daily per capita water consumption of 27 liters/person/day. However, a large percentage of the world's population especially in developing countries manages far less than 27 liters as approximately 70% of the renewable water resources are unavailable for human use or are under-developed or unevenly distributed (Minh *et al*., 2011). Drought, desertification, and other phenomena that contribute to water scarcity are estimated to affect as many as one-third of the world's population (Talafre and Knabe, 2009). The increasing human population and rising demand for food and other services have increased the demand for water (Rodak *et al*, 2011). As a result, reliance on groundwater resources has increased, creating challenges, among which is the provision of adequate quantities of good-quality water (WWDR, 2011). It is not clear how much water is available per capita in Benin City; however, many residents manage far less than 27 liters a day. Benin City had a population of 49,143 in 1950 and it has grown to an estimated 1,781,999 in 2021 with a 3.17% annual change (Akpoveta *et al.,* 2011).

Groundwater is easily the most important component of the hydrological cycle and constitutes about two-thirds of the freshwater resources of the world including Nigeria. Groundwater provides a reasonably constant supply for domestic use, livestock, and irrigation, which is not likely to dry up under natural conditions (Calow *et al*., 2011). In arid and semi-arid areas where rainfall is scarce or highly seasonal and surface water is extremely limited, groundwater is a means of coping with water deficiencies (David, 2011). Due to the financial benefits arising from borehole development projects, numerous non-environmental and non-hydrogeological experts are into borehole and hand-dug well development. Some of these projects are sited close to waste dump sites, pit toilets, soak-away pits, and septic tanks.

Contamination of groundwater is an issue of serious environmental concern (Silderberge, 2003; Akpoveta *et al*., 2011) because groundwater is vulnerable to pollution due to the water table being near the soil surface, the permeability of overlying layers and sources of pollution being numerous (Singh *et al.,* 2012). Contamination of groundwater may be due to the leaching of pollutants (Bekhit *et al.,* 2009), contaminant transport in the soil (Andricevic *et al.,* 2011) and human activities such as indiscriminate waste disposal, poor agricultural practices and construction of septic tanks, pit latrines and graves near boreholes, contribute to borehole water contamination (Lu, 2004; Kelly *et al*., 2011). Some of these activities account for the presence of coliform bacteria in groundwater which makes it unsuitable for domestic use as a resource due to contamination (Holmes, 2007). Contamination of groundwater water by microorganisms occurs because of their ability to survive in the short travel time from the pollution site to the groundwater source (Enyinna and Nkemdirim, 2018). Other contaminants of groundwater include heavy metals, agrochemicals, nutrients, colloids, organic matter, etc. (Hillel and Rabideau, 2000;

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Adekunle *et al.,* 2007)

The consumption of contaminated water poses the risk of water-borne diseases as evidenced by rampant water-borne diseases such as typhoid and diarrhea. These diseases are further worsened by the lack of access to basic water treatment methods and the ignorance of users to hazards associated with the consumption of these waters. For these reasons, the provision of good quality L4.2 is a necessity.

This study aimed to comparatively assess the quality of groundwater around active and non-active dumpsites around Benin City.

2. Materials and Methods

2.1 Study Area

The study was carried out in Benin City, the capital of Edo state in the humid tropical rainforest belt of southern Nigeria. Benin City is underlain by the Benin Formation which is of the Oligocene-Pleistocene type, characterized by a reddish top layer composed of ferruginized or literalized clay sand and subsequent layers made of sands, sandy clays, and ferriginized sandstone (Ikhile, 2016).

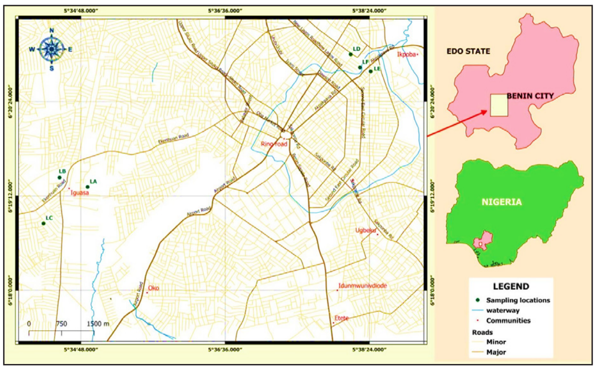

Figure 1. A map of the study area showing the sampling locations.

2.2 Sample Collection

Three (3) samples of groundwater were collected from boreholes of three residences in two major locations; one each around an active (Iguasa) and a non-active dumpsite (Ikpoba). The samples collected from Iguasa were designated LA, LB, and LC, while those from Ikpoba were designated LD, LE, and LF. Locations LA and LB, and LD and LE were 10 meters away from their respective dumpsites; however, LC and LF were 40 meters away from the respective dumpsites and serve as control samples. The boreholes were of the shallow well type and their depths ranged between 140 and 180 feet. The samples were an initial sample, then another taken after two minutes to know if there would be a change in concentration of contaminants during the analysis, and a control sample. The samples were collected using water sampling bottles after which they were kept at 4°C and taken to the laboratory for analysis.

2.3 Physicochemical Analyses

The physicochemical parameters of the groundwater samples were determined as described. The pH was determined using a pH meter. Conductivity was determined using a conductivity meter. Turbidity was determined using a nephelometer. Total total dissolved solids (TDS) were determined using the weight difference method. Alkalinity was determined by acid-base titration with H_2SO_4 using phenolphthalein as an indicator. The concentrations of nitrate and ammonia in the samples were determined by analysis using ultraviolet-visible spectrometry. Total hardness was determined by titration with EDTA using Eriochrome Black-T as an indicator. The concentration of chlorides was determined using a spectrofluorometer. The dissolved oxygen levels of the samples were determined using BOD bottles and titration with sodium thiosulphate. Biochemical oxygen demand was determined by the 5-day BOD test using Winkler A and B solutions. All physicochemical analyses were done in triplicates and the mean results were recorded.

2.4 Heavy Metal Analyses

Heavy metal analysis was carried out after the method used by Oko *et al.* (2017). Three (3) liters of each water sample were first concentrated in a sandy oven at 80°C until the volume reached 50ml. 4ml of concentrated sulfuric acid (Merck, 98%) was added to each sample which was then digested using the digesdahl apparatus for 3 minutes. After that, 10ml of hydrogen peroxide (Merck, 30%) was added and the mixture was heated until oxidation was completed. After cooling, each sample was filtered using Whatman No. 44 filter paper. The filtrate was diluted to a final volume of 50ml using deionized water. The prepared samples were analyzed using a flame atomic absorption spectrophotometer (FAAS) to determine the concentrations of heavy metals. The detection limit of the FAAS instrument was 0.01mg/L. The heavy metal analyses were all carried out in triplicates to ensure the quality of the results. The means of values obtained were recorded in mg/L.

2.5 Microbiological Analysis

Microbiological analysis of water samples was carried out to determine the heterotrophic plate count and the coliform counts for all samples. The heterotrophic plate count was done using the spread plate method and the coliform count was done using the membrane filter count method. All results were expressed as colony-forming units per milliliter of water (cfu/ml). All isolated microorganisms were subcultured onto nutrient agar made for purification. They were then transferred onto nutrient agar slants for storage and further analysis, after which they were identified using Bergey's Manual of Systematic Determinative Bacteriology (Buchanan and Gibbons, 1974).

2.6 Statistical Analysis

The mean and standard deviations of all values were calculated using Microsoft Excel 2017. Analysis of variance (ANOVA), correlation analysis, and t-tests waswere carried out using the Statistical Package for the Social Sciences (SPSS) Version 21.

3. Results and Discussion

3.1 Physicochemical analysis of water

The results of the physicochemical analysis of the water samples are were displayed in figures 2 to 12. The pH values of the samples ranged from 4.1 (LE) to 6.6 (LA). Electrical conductivity values ranged from 10µS/cm (LB) to 370µS/cm (LE). The turbidity values ranged from 0mg/L (LB, LC and LD) to 15mg/L (LA). The TDS values ranged from 5.3mg/L (LB) to 196.13mg/L (LE). Values for alkalinity ranged from 0mg/L (LD, LE, and LF) to 126mg/L (LA). The range for nitrate concentrations was 0.31mg/L (LA) to 3.10mg/L (LD). The concentrations of ammonia ranged from 0.09mg/L () to 0.85mg/L (LD and LF). Total hardness ranged from 8mg/L (LB) to 72mg/L (LE). Concentrations of chlorides ranged from 7.1mg/L (LC) to 56.5mg/L (LD and LE). The concentration of dissolved oxygen was highest in LB at 5.0mg/L and lowest in LA at 2.2mg/L. The biochemical oxygen demand was highest in LE at 2.3mg/L and lowest in LA at 0.9mg/L.

The pH values from the active dumpsite range from 5.3 - 6.6 and those from the non-active dumpsite range from 4.1 - 4.4. From these results, the values are not within the World Health Organization's acceptable pH range (6.5 - 8.5) for water quality (WHO, 2006). Organic waste such as food waste, green waste, and pruning waste was found in the assessed dumpsites. The low pH values recorded from the water samples are attributed to the early acidogenic phase of organic waste decomposition as described by Wdowczyk and Szymanska-Pulikowska (2020). The electrical conductivity of all collected water samples falls within the limits (1300mS/cm) set by the World Health Organization (WHO, 2006). The total dissolved solids values of all groundwater samples fall within the limits (500mg/L) set by the World Health Organization (WHO, 2006). The turbidity of groundwater samples collected from LA is above WHO standards (WHO, 2006). The presence of high concentrations of dissolved solids is responsible for this phenomenon. Nitrate concentrations for all the samples are within the WHO standard limits for nitrate in groundwater (10mg/L) (WHO, 2006). Groundwater nitrate contamination may be due to wastewater discharge, effluent from on-site sanitation, and leachate from solid waste dump sites (Kuppusamy *et al.,* 2015). The values of total hardness for all the samples fall within the WHO standards (500mg/L) (WHO, 2006). The chloride concentrations in the groundwater samples all fall within the limits set by the World Health Organization standards for chloride (250mg/L) (WHO, 2006). The WHO (2006) set no standards for alkalinity and ammonia in groundwater. The dissolved oxygen (DO) and biochemical oxygen demand (BOD) levels of the samples are all within the WHO limits of each parameter (WHO, 2006). The low DO and BOD levels of the groundwater samples indicate the near absence of organic matter in the samples. This agrees with the results of a study by Kuppusamy *et al.* (2015).

The analysis of the correlation between the physicochemical parameters showed the following significant ($p > 0.05$) correlations: pH had strong positive correlations with turbidity and alkalinity, and negative correlations with nitrate and ammonia; electrical conductivity was strongly positively correlated with total dissolved solids, nitrate, ammonia, hardness and chloride, and a negative correlation with dissolved oxygen; turbidity had a positive correlation with alkalinity, however, it was negatively correlated with nitrate, ammonia, and biochemical oxygen demand; total dissolved solids showed a strong positive correlation with nitrate, ammonia, hardness, chloride and dissolved oxygen. Other significant correlations were alkalinity negatively correlated with nitrate and ammonia, nitrate positively correlated with ammonia and chloride, hardness positively correlated with chloride and negatively with dissolved oxygen, and dissolved oxygen positively correlated with biochemical oxygen demand.

Positive correlations indicate that as the concentration of one parameter increased, so did the other. However, the negative correlations indicate that as the concentration of one parameter increased, the other decreased.

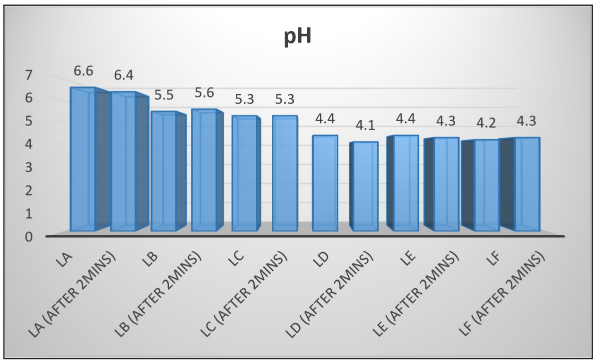

Figure 2. Concentrations of pH in all samples.

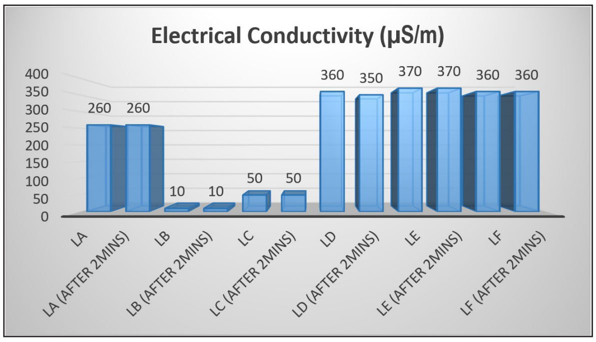

Figure 3. Concentrations of electrical conductivity in all samples.

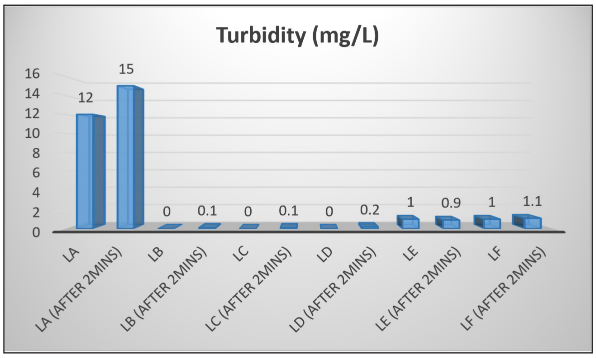

Figure 4. Concentrations of turbidity in all samples.

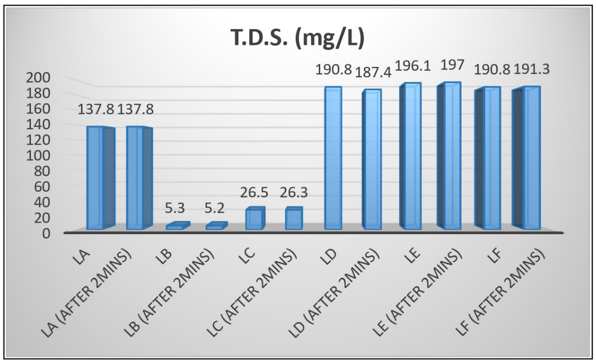

Figure 5. Concentrations of total dissolved solids in all samples.

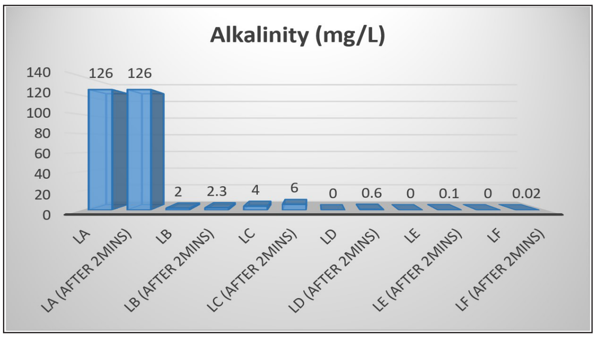

Figure 6. Concentrations of alkalinity in all samples.

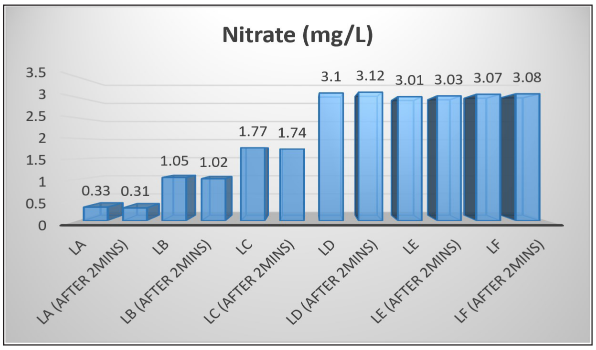

Figure 7. Concentrations of nitrate in all samples.

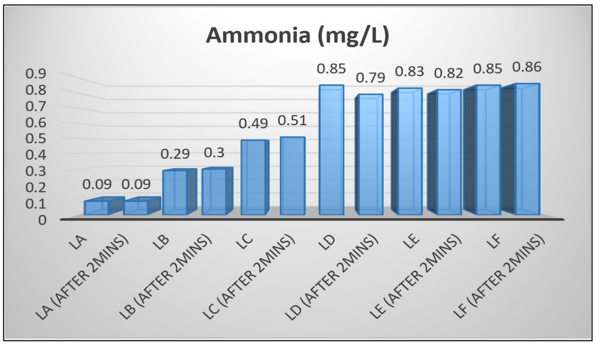

Figure 8. Concentrations of ammonia in all samples.

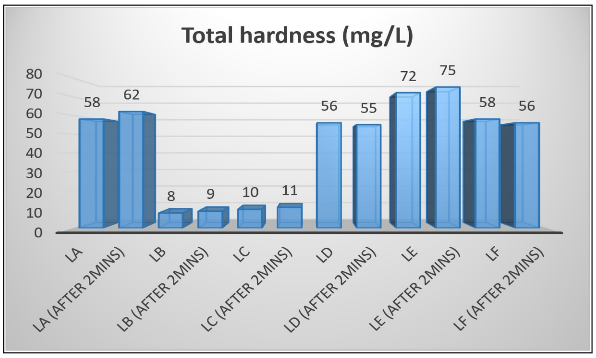

Figure 9. Concentrations of total hardness in all samples.

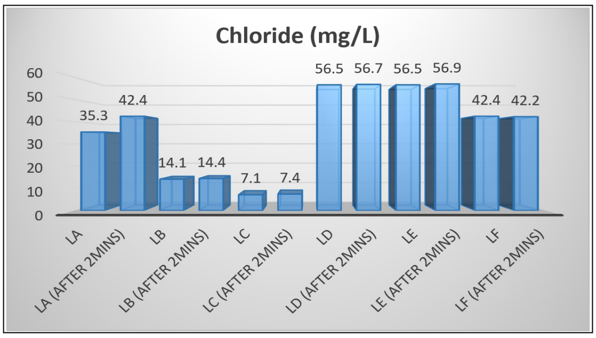

Figure 10. Concentrations of turbidity in all samples.

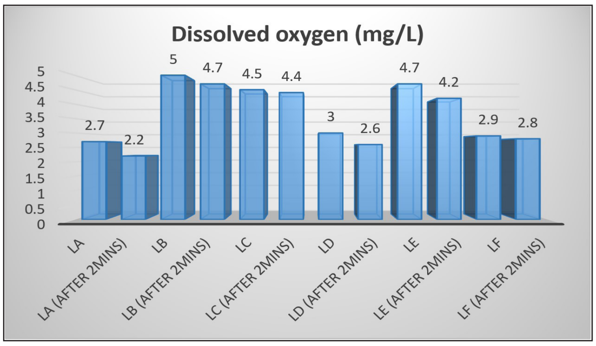

Figure 11. Concentrations of dissolved oxygen in all samples.

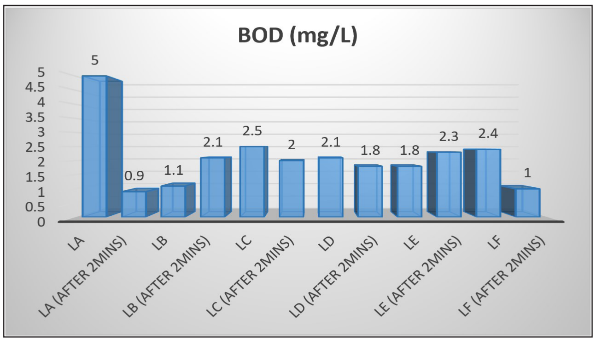

Figure 12. Concentrations of BOD in all samples.

Heavy metal analysis of water

The results of the heavy metal analysis for the water samples are shown in figures 13 and 14. LE had the highest concentration of iron (Fe) at 2.877 mg/L, while the lowest recorded concentration for Fe was 0.411 mg/L in the sample LB. The concentration of lead (Pb) was highest at LC and was 0.508 mg/L and the concentration of Pb at LB was below the detectable level. All concentrations of cadmium (Cd) from all locations were below detectable levels.

The heavy metal analysis of lead (Pb), cadmium (Cd), and iron (Fe) were carried out in all the water samples. The result, however, shows that Cd was not present in any of the samples. The concentration of lead in the samples ranged from below detectable levels (BDL) to 0.508mg/L. The highest concentration of Pb is above the standards set by the EPA (1986). The spike in lead concentrations in LC after 2 minutes is attributed to the entry of lead ions into the water due to the corrosion of plumbing materials that conduct water from the ground to the surface (USEPA, 2022). The low concentration of heavy metals in the groundwater samples is an indication that the waste in the dumpsite is mainly composed of municipal solid and household wastes. This agrees with a study carried out by Wdowczyk and Szymanska-Pulikowska (2020). The statistical analysis shows no significant difference between the mean values of the Pb concentrations in the samples from the active and non-active dumpsite. The concentrations of Fe in the groundwater samples ranged from 0.41 to 2.862mg/L. The high iron content in the water samples is attributed to the presence of ferruginized materials at various depths within the soil profile as described by Ikhile (2016) in combination with metallic ions from sedimentary rocks dissolving in groundwater (Omalu *et al.,* 2012). There is a significant difference between the mean values of Fe concentrations in the groundwater samples collected from the active and non-active dumpsite at p<0.05. The higher concentration of Fe in the groundwater samples from the non-active dumpsites may be due to the low pH of the water as low pH i.e. high acidity increases the solubility of metals (Wuana and Okieimen, 2011).

Correlation analysis for heavy metals and other parameters showed that at $p > 0.05$, iron was positively correlated with electrical conductivity, total dissolved solids, nitrate, hardness, and chloride. This showed that with an increase in the concentrations of these parameters in water, the concentration of iron increased.

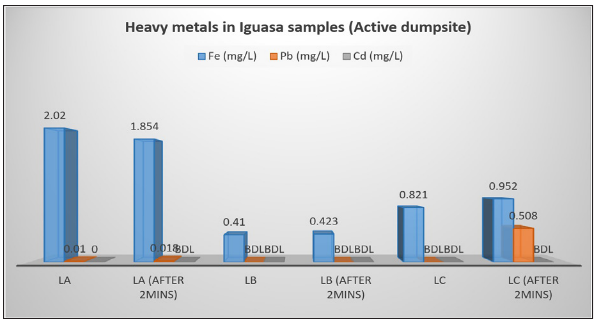

Figure 13. Heavy metal concentrations in samples from the active dumpsite.

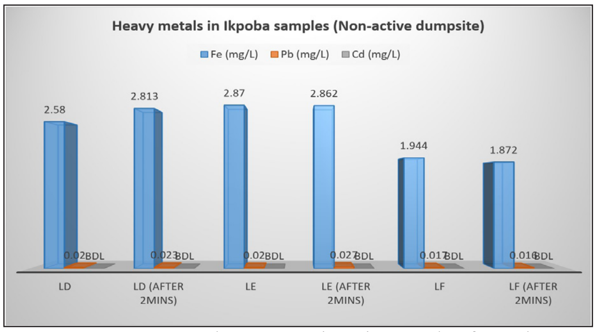

Figure 14. Heavy metal concentrations in samples from the non-active dumpsite.

Microbiological analysis of water samples

For the heterotrophic plate count (Table 1), the highest mean heterotrophic plate count was 27.5cfu/ml from LB, which increased to 44cfu/ml (the highest) after two (2) minutes. The lowest mean heterotrophic plate count was 4cfu/ml from LE and it increased to 4.5cfu/ml after two (2) minutes. The lowest mean count after two minutes was 3cfu/ml from LD. The repeat coliform count (Table 2) showed that the highest mean coliform count was 3.5cfu/ml for LB, which decreased to 3cfu/ml (highest) after two (2) minutes. The lowest mean coliform count was 1.5cfu/ml for LD, LE, and LF, while the lowest mean coliform count was 1cfu/ml for LE after two (2) minutes.

The highest heterotrophic plate count value among all the samples was 44cfu/ml, obtained from LB after 2 minutes. This high count is attributed to the presence of microbial biofilms within the water-conducting systems at the sampling location. This is as described by Gavriel *et al.* (1998). There was no significant difference between the heterotrophic plate count values initially and after 2 minutes for all groundwater samples except LB, at p<0.05. The coliform count reveals a maximum count of 3.5cfu/ml. According to studies by Sebiawu *et al.* (2014) and Mishra *et al.* (2016), coliform count values below 16cfu/ml are not threatening to human health. This means that the samples used in the study are within safe limits for human consumption. The statistical analysis revealed that there was no significant difference between the coliform counts for all samples initially and after 2 minutes, at p<0.05.

Table 1. Heterotrophic plate count (HPC).

Sample location	HPC		HPC after 2 minutes		Log_{10} of HPC		Log_{10} of HPC after 2 minutes	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
LA	15.50	0.71	18.00	0.00	2.19	0.02	2.26	0.02
LB	27.50	0.71	44.00	1.41	2.44	0.01	2.64	0.01
LC	15.50	4.95	35.00	7.07	2.18	0.14	2.54	0.14
LD	6.00	1.41	3.00	1.41	1.77	0.10	1.45	0.10
LE	4.00	0.00	4.50	0.71	1.60	0.00	1.65	0.00
LF	5.50	0.71	6.50	0.71	1.73	0.06	1.81	0.06

Table 2. Tabular representation of the repeat coliform count.

Sample location	Coliform count (cfu/ml)		Coliform count after 2 minutes (cfu/ml)		Log_{10} of coliform count		Log_{10} of coliform after 2 minutes	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
LA	2.50	0.71	1.50	0.71	1.39	0.12	1.15	0.21
LB	3.50	0.71	3.00	1.41	1.54	0.09	1.45	0.21
LC	2.50	0.71	4.50	0.71	1.39	0.12	1.65	0.07
LD	1.50	0.71	1.50	0.71	1.15	0.21	1.15	0.21
LE	1.50	0.71	1.00	0.00	1.15	0.21	1.00	0.00
LF	1.50	0.71	1.50	0.71	1.15	0.21	1.15	0.21

The bacteria isolated and identified from the water samples are displayed in Table 3. A total of ten (10) species of microorganisms were identified. They are *Enterobacter aerogenes*, *Escherichia coli*, *Bacillus pumilus*, *Morganella morganii, Klebsiella oxytoca*, *Pseudomonas aeruginosa*, *Alcaligenes faecalis, Bacillus subtilis, Proteus vulgaris* and *Serratia marcescens.*

Table 3. Bacteria identity and distribution.

Sample location	Bacterial Identity and distribution
LA	*Enterobacter aerogenes*, *E. coli*, *Bacillus pumilus*, *Morganella morganii*.
LB	*Klebsiella oxytoca*, *E. coli*, *Pseudomonas aeruginosa*, *Alcaligenes faecalis*
LC	*E. coli, Enterobacter aerogenes, Bacillus subtilis, Proteus vulgaris.*
LD	*E. coli, Enterobacter aerogenes, Serratia marcescens, Bacillus pumilus.*
LE	*E. coli, Enterobacter aerogenes, Serratia marcescens, Bacillus pumilus.*
LF	*Enterobacter aerogenes, E. coli, Bacillus pumilus, Morganella morganii.*

Keys: Active dumpsite (LA, LB, LC); Non-active dumpsite (LD, LE, LF).

Table 4 shows the percentage occurrence of the bacteria species. *Escherichia coli* had the highest percentage occurrence (25%), while the least occurrence was seen with *Klebsiella oxytoca*, *Pseudomonas aeruginosa*, *Alcaligenes faecalis, Bacillus subtilis* and *Proteus vulgaris* which were 4.17%.

Table 4. Frequency of occurrence of bacteria in samples.

Microorganism	Frequency of occurrence (%)
Enterobacter aerogenes	20.83
Escherichia coli	25
Bacillus pumilus	16.67
Morganella morganii	8.33
Klebsiella oxytoca	4.17
Pseudomonas aeruginosa	4.17
Alcaligenes faecalis	4.17
Bacillus subtilis	4.17
Proteus vulgaris	4.17
Serratia marcescens	8.33

The values of pH, turbidity, alkalinity, and BOD were higher in the samples from the active dumpsite, while the values of electrical conductivity, total dissolved solids, nitrate, ammonia, total hardness, chloride, and dissolved oxygen were higher in the samples from the non-active dumpsite. This can be attributed to the range of different point sources of contaminants as discovered by other researchers (Oyelami *et al.,* 2013; Oko *et al.,* 2017). The concentrations of Fe in the non-active dumpsite samples were higher than those from the samples of the active dumpsite. This may be due to leaching from the dumpsite, reducing conditions in the groundwater aquifer, and rusty pipes and pumps in the borehole system as explained by Kuppusamy *et al.* (2015). Leaching occurs when moisture enters the refuse in a dumpsite. Pb was detected in all samples from the non-active dumpsite but was not found in three of the samples taken from the active dumpsite which may be due to the presence of Fe-oxidizing bacteria (Kuppusamy *et al.,* 2015). The heterotrophic plate count and coliform counts were higher in the samples from the active dumpsite than those from the non-active dumpsite. This agrees with the results of Asibor and Oborakpororo (2019) who stated that microbial diversity increases as more waste accumulates.

4. CONCLUSION

Groundwater contamination is a major issue that affects human and environmental health. Different contaminants from dumpsites can leach or infiltrate through the soil and into groundwater. This study attempted to evaluate the quality of groundwater from an active dumpsite and compare it with that from a non-active dumpsite. From the results of this study, it is concluded that the groundwater from the non-active dumpsite has more inorganic contaminants than the active dumpsite groundwater. It is seen also that the groundwater from the active dumpsite area has more microbial contamination than the non-active dumpsite. While the level of microbial contamination is not hazardous, it can be further reduced by treating the water with boiling or chlorination. Finally, when the physicochemical properties and heavy metal content of the samples are compared, the groundwater of the active dumpsite is less contaminated than that of the non-active dumpsite.

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