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Assessment of the Pollution Threat of Boreholes Located Around an Abandoned Dumpsite in Uyo Metropolis, Akwa Ibom State, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aim: The study was aimed at assessing the heavy metal and microbial contamination levels of ground water located in an abandoned municipal dumpsite in Uyo metropolis.
Study Design and Duration: The study was carried-out over a period of 3 months (September to November, 2017). Water samples were collected aseptically and preserved in an ice chest immediately after collection.
Methodology: Water samples were collected from 4 boreholes; 3 boreholes around the Uyo abandoned dumpsite and from 1 control borehole. The collected samples were analysed for Pb, Cd, Cr and Hg using Atomic Absorbtion Spectrophotometer (AAS), while the microbial contents were analysed in microbiology laboratory according to the methods of Gerhardt.
Results: The mean concentrations of Pb, Cd and Cr in the borehole water were 0.015 ± 0.011, 0.058 ± 0.067 and 0.083 ± 0.139 mg/L respectively. The Pb and Cd concentration varied

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significantly between the boreholes ($p<0.05$), while Cr varied insignificantly between the boreholes ($p>0.05$). The total coliform count (TCC) and yeast count (YC) varied significantly between the borehole ($p<0.05$), while total plate count (TPC) of bacteria varied insignificantly between the boreholes ($p>0.05$). *Eschericha coli* was not detected in the 4 borehole water samples, but TPC and TCC were observed in boreholes 2, 3, and 4. The TPC, TCC, *E. coli*, and YC in borehole 1 (control) were all within the Nigerian standard for drinking water quality (NSDWQ), and was deemed healthy for drinking. In general, borehole 2, 3, and 4 are unhealthy for consumption since majority of the microbial parameters and heavy metals studied were above the NSDWQ acceptable limit.

Conclusion: Despite recently moving the dumpsite far from residential areas, the boreholes around the abandoned dumpsite are still contaminated and unsafe for drinking. Thorough treatment and regular monitoring of the boreholes is recommended as a strategy, to prevent outbreak of water borne diseases.

Keywords: Pollution; threats; boreholes; municipal; abandoned and dump site.

1. INTRODUCTION

Water contributes immensely to proper earth eco-system functioning [1]. Water is of diverse importance to man, which includes drinking, industrial, waste disposal, agricultural land irrigation, fishing, transportation, domestic use and so on [1,2]. In developing countries, the population increase of man has caused enormous pressure on safe water availability for drinking [3]. Drinking of unclean water worldwide generates health threat, and increases the risk of contracting diarrheal and intoxication by chemical [4]. The portability of water bodies worldwide are consistently jeopardised by pollution [5].

Dumpsites are areas where waste are disposed by man in a way harmful to the environment [6]. They cause various disease, alter environment value, cause nuisance and generate leachates which leaches into the aquifer [6]. The concentration of heavy metals in dumpsites are increased when used batteries, garbage, paints, spoiled foodstuff and electronic goods are dumped in municipal dumpsites [5]. Surface and ground water consistently receives toxic compounds from dumpsites through runoffs [6], which causes pollution of water bodies due to leachate percolation [7,8]. Poor water pipe management, non-maintenance of treatment plants, release of untreated effluents into water bodies reduces the quality of drinking water.

Water receives its bacterial spores from air, sewage, organic waste, dead plants, and animals [9]. Bacteria are the main pollutants of water, even though nearly every microorganisms exist in water [10]. Even rain water are impure, because it receives suspended microbial dust and other dissolved materials, and so Water wells, boreholes, streams and rivers are chemically not pure [11].

Solid waste is any non-flowing substance which has no economic relevance at a particular time, either as a raw material, end products, expired products, containers or after use remnants which must be disposed of [12]. Diverse hospital, industrial, agricultural and domestic activities of man creates solid waste [12]. It may be categorised according to its contents (organic material, glass, metal, plastic paper etc); according to hazard potential (toxic, non-toxin, flammable, radioactive, infectious etc) or its origin (domestic, industrial, commercial, construction or institutional) [12]. In Nigeria, open dumping and landfills is the main means of disposing solid waste [13]. Several biochemical and physical processes takes place in solid waste disposed of in landfills, which causes gaseous emissions and the production of leachate [13]. Municipal waste dumping sites, are not properly constructed or designed, yet waste are deposited in there [13]. Leachates are generated from waste dumped over the years when biodegraded and becomes pollution point sources into soil and groundwater [13]. Runoffs containing numerous organic and inorganic salts are transported to nearby aquifers, resulting in the alteration of quality of water [14,15]. Availability of oxygen, size of particle, decomposition of solid waste, compaction degree, site hydrology landfill age, temperature and moisture are some of the factors that influences the rate of leachate production and characteristics [14,15]. Leachates from dumpsite leaches into the ground, and then moves in according to the flow of groundwater direction, thereby contaminating the groundwater [16]. The dumpsite was moved 2 years ago and the water from the boreholes around the abandoned dumpsite are consumed daily by residents. Hence, there is need to assess the water quality of boreholes located close to the abandoned dumpsite, because it will reveal its health consequences to residents drinking from these boreholes.

This study was aimed at assessing the possible microbial, and some heavy metals contamination of an abandoned dumpsite in Uyo metropolis.

2. MATERIALS AND METHODS

2.1 Study Area

Uyo municipality is the capital territory of the Akwa-Ibom State, South Eastern Nigeria. Apart from being a booming center of business in the state, it serves as the administrative and political headquarters, and links Akwa-Ibom State with Abia, Imo, Cross River, and Rivers States, in South Eastern Nigeria. The abandoned Uyo municipal dumpsite is between latitude 5^o and 5^o17^1 N, and longitude 7^o and 7^o50^1 E (Fig. 1), off Barracks road [17]. It was an open dumpsite, which was located within the upland area, within the east transect in the low land [17]. The area is located in the sub-equatorial belt, characterized by the rainy and dry seasons [17]. The rainy season starts from April and ends in September, with a peak in June and July, while the dry season starts from October and ends in March [17]. It has a plain topography, except for a few areas of sloppy terrain, which end in a ravine [17]. It is consistently flooded whenever it rains heavily, due to poor drainage system.

The vegetation is however, affected by activities like agriculture, construction and urbanization. Apart from the wind, other climatic parameters such as mean annual rainfall, temperature, global radiation reflection coefficient, to mention a few, also influence the study area [17]. The study area vegetation is made up of rainforest, but human activities like cutting down trees for roads, building houses and schools has resulted in the depletion of the rainforest [18].

The soil is composed of coastal plain sand which belongs to tertiary deposits [18]. The alluvial deposits are used for construction, and has light brown and grey colour [18]. The hydrological Province of the study area is grouped into basement and intrusive rocks, sandstone, shale, and alluvial deposits [18]. The lithology is characterized by an underlying aquifer. The surface and ground water bodies are recharged by high precipitation [18]. The aquifer is confined with few aquicludes, which is made up of silt, clay and sandstone [18]. The dump site was over a decade old before it was moved [18].

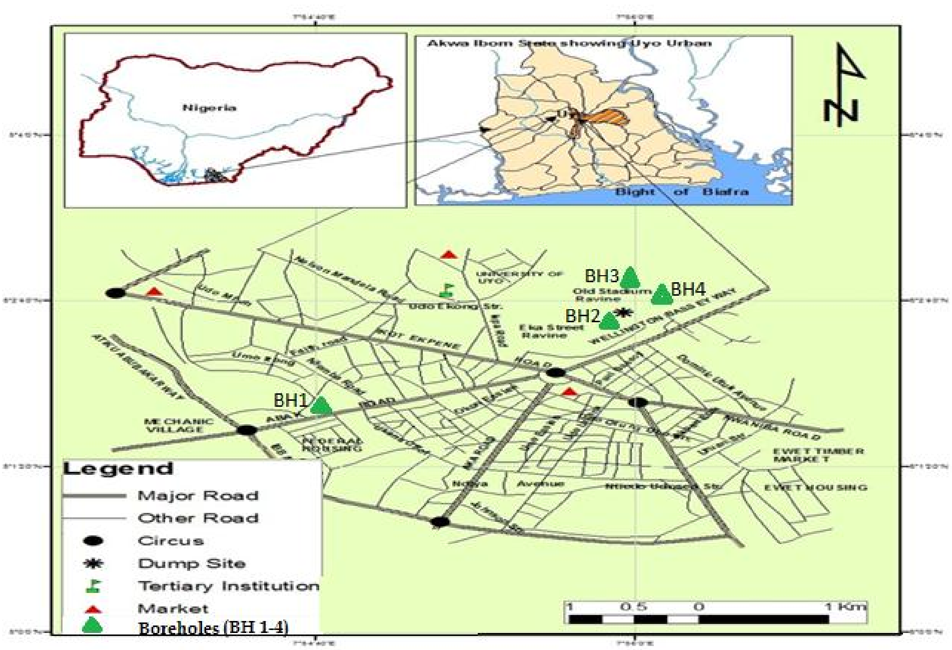

Fig. 1. Map of the Uyo metropolis showing the abandoned Uyo municipal dumpsite
Map source: [17]

2.2 Collection of Water Samples for Microbial and Heavy Metal Analysis

Water samples for the study were collected from 4 selected boreholes over a period of 3 months; from September to November, 2017. Three boreholes were located around the abandoned Uyo dump site and 1 borehole (control) was located at Abak Federal Housing, Uyo, which is approximately 8 kilometers from the abandoned dumpsite. Four water samples were collected from the 4 boreholes during each sampling occurrence, combining to 12 water samples throughout the study. The samples were aseptically collected. A cotton wool was dipped into a methylated spirits and used to clean the tap mouth and flushed for 3 minutes, before the collection of the samples. The water samples were collected into 1 liter sampling bottles, which were sterilized with 99% ethanol and covered tightly. The water samples were immediately put in an ice chest after collection, before transporting to the microbiology laboratory, University of Calabar, within 6 hours of collection, for microbial analysis [19].

The water samples for heavy metal analysis were preserved in an ice chest immediately after collection, before transporting them to the Ministry of Science and Technology Laboratory, Uyo for spectrophotometric analysis, using a Perkin Elmer, 480 model atomic absorption spectrophotometer, for levels of lead (Pb), cadmium (Cd), chromium (Cr) and mercury (Hg).

2.3 Microbiological Analyses

The presence of specific bacteria was confirmed by preparing and cultivating of water samples using selective, differential, and non-selective, which involves the use of sterile tips, spread plates on MacConkey agar as a presumptive medium. These were used due to the fact that they are both differential and selective for members of the selected enteric pathogenic bacteria [20]. The MacConkey medium has bile salt, which inhibits all other microbes, except those found in human intestines [20]. Lactose fermenting organisms like *E. coli* was detected using lactose and pH indicator (bromocresoi purple). A yellow coloration of the broth is an indication that the coliforms had fermented the lactose to produce acid [20]. Coliform presence were confirmed by brilliant green medium, because it reduces the growth of anaerobic lactose fermenters like *Clostrieium, perfrienges*, thereby causing false positive MacConkeys broth [20]. Bacteria capable of fermenting lactose like *E. coli* and Enterobacter were identified using Eosin methyllene agar, by acidification of the medium, which was indicated by the appearance of a black colony with a greenish sheen [20]. The differential medium for verification of *E. coli* was koser's citrate medium, from *Entrobacter areogen*, based on the standard method for their examination of water [20].

About 40 uL of undiluted water were spread in 5 plates, so as to allow the development of colonies, and then the colony counter enumeration. The morphology and colours of the developed colony was noted. The culture was then gram-stained as a confirmatory test [21].

Incubation: Incubation was done at 37°C for at least 24 hours. Plates were inverted during incubation.

Numerical estimation of bacterial growth: The numerical estimation of bacterial load was obtained from the primary cultures. Each plate was counted physically, and the number expressed as colony forming units (CFU) per mL.

2.4 Isolation and Characterization

Distinctive colonies were sub-cultured into relevant media to differentiate them, and this was performed on all isolates to characterize them as gram positive, or gram negative.

Gram Stain: On a grease free slide, a heat fixed smear of test organisms was prepared, and then placed on a staining rack [21]. Crystal violet was used to flood the slide for a period of one minute, then the excess dye was poured off, and the slide briefly rinsed in tap water. The slide was then flooded with grams iodine and allowed to react for one minute, then tap water was used to wash it off. The smear was then flooded within 70% alcohol for about twenty seconds once the coloration disappeared and tap water was used to rinse the slide. The slide was then flooded with sefranin for 20 seconds, which was washed off and allowed to dry, and then observed.

2.5 Coliforms Test (Multiple-tube Technique/Most Probable Number)

Presumptive, confirmed and completed test were the methods used to test for coliform in the water samples. The test was carried-out according to the methods described by Cheesboough [19].

2.6 Identification of Isolates

Presumptive test was carried-out from positive tubes sub-cultured using the Eosin methylene blue agar, and MacConkey agar, to count the Enterobacteriaceae. All the incubated media was incubated aerobically at 37°C for 24 hours. Morphological and colonial characterization on solid media were carried-out in order to identify the isolates [20].

2.7 Analysis of Water for Heavy Metals

Heavy metal concentration in water was determined using an atomic absorption spectrophotometer (AAS) (Perkin Elmer, 2280 model). The samples were prepared and analysed for cadmium, lead, chromium and mercury. Sulphuric acid was added (0.51 mL) to 50 mL of an unfiltered water sample in a 500 mL Taylor flask. This was boiled until white fumes were seen, then allowed to cool. Afterwards, 1.0 mL of 60% $HClO_3$ and 5.0 mL of concentrated HNO_3 were then added. The obtained mixture was then digested, so as to obtain a clear solution. This digest was allowed to cool, before being filtered, using No 44 Whatman paper in a 500 mL volumetric flask, and the digest was analyzed spectrophotometrically for heavy metals in mg/L [22].

3.8 Statistical Analysis

All data collected were subjected to descriptive statistics (mean, standard deviation, and range). Analysis of variance (ANOVA) was used to test for the level of significance of the difference in bacterial abundance and heavy metal concentration, between the different bore-hole water samples collected ($p<0.05$), and at their relevant degrees of freedom. All statistical analysis was carried-out using Predictive Analytical Software (PASW) version 20.

3. RESULTS

3.1 Microbial Counts in Borehole Water

The microbial counts in boreholes around the abandoned Uyo Municipal dumpsite is shown in Table 1. In borehole 1 (control), the total plate count of bacteria (TPC), total coliform count (TCC), *E. coli* count, and yeast count (YC) was 0 colony forming units per mL (CFUs/mL). In borehole 2, a total plate count, and total coliform count of 92 and 14 CFU/mL respectively were observed, but *E. coli* and yeast were totally absent. In borehole 3, a total plate count and total coliform count of 12 and 8 CFU/mL respectively were observed, but *E. coli* and yeast were totally absent. In borehole 4, a total plate count, total coliform count and yeast count of 25, 16 and 2 CFU/mL respectively were observed, but *E. coli* was totally absent (Table 1).

The TPC, TCC, and YC varied between the four boreholes. Statistically, the TCC and YC varied significantly between the 4 boreholes at $p<0.05$, while the TPC of bacteria did not vary significantly between the different boreholes at $p>0.05$. The TPC, TCC, *E. coli*, and YC in borehole 1 (control) were all within the NSDWQ acceptable limit. The TPC and TCC were above the NSDWQ acceptable limit for borehole 2 and 3. The TPC, TCC and YC were above the NSDWQ acceptable limit for borehole 4 (Table 1).

3.2 Heavy Metals Concentration in Borehole Waters

The summary of the concentration of heavy metals in borehole water around the abandoned Uyo Municipal dumpsite is shown in Table 2. In borehole 1 (control), lead and mercury were not detected throughout the study. Cadmium concentration in the borehole water ranged from 0.001 – 0.003 mg/L, having a mean and standard deviation of 0.002 ± 0.001 mg/L, while the chromium concentration ranged from 0.032 – 0.043 mg/L and with a mean and standard deviation of 0.037 ± 0.005 mg/L (Table 2).

For borehole 2, the lead concentration ranged from 0.020 – 0.034 mg/L, with a mean and standard deviation of 0.027 ± 0.007 mg/L. The cadmium concentration ranged from 0.105 – 0.203 mg/L, with a mean and standard deviation of 0.137 ± 0.054 mg/L, while the chromium concentration ranged from 0.060 – 0.519 mg/L, with a mean and standard deviation of 0.222 ± 0.257 mg/L. Mercury was not detected throughout the study in borehole 2 (Table 2).

In borehole 3, the lead concentration ranged from 0.012 – 0.016 mg/L, with a mean and standard deviation of 0.014 ± 0.002 mg/L. The cadmium concentration ranged from 0.014 – 0.151 mg/L, with a mean and standard deviation of 0.060 ± 0.078 mg/L, while the chromium concentration ranged from 0.031 – 0.047 mg/L, with a mean and standard deviation of 0.039 ± 0.008 mg/L. Mercury was not detected throughout the study in borehole 3 (Table 2).

Table 1. Microbial counts in borehole water around abandoned Uyo Municipal dumpsite

Microbial parameters (Cfu)	BH 1 (control)	BH 2	BH 3	BH 4	NSDWQ
Total plate count (bacteria) (TPC)	0[a]	92[a]	12[a]	25[a]	0
Total coliform count (TCC)	0[a]	14[b]	8[c]	16[d]	0
E. coli count	0	0	0	0	0
Yeast count (YC)	0[a]	0[b]	0[c]	2[d]	0

Values are significant at $p<0.05$; Values with different superscript are significantly different
BH – Borehole water; NSDWQ – Nigeria standard for drinking water quality

In borehole 4, the lead concentration ranged from 0.001 – 0.010 mg/L, with a mean and standard deviation of 0.005 ± 0.004 mg/L. The cadmium concentration ranged from 0.019 – 0.029 mg/L, with a mean and standard deviation of 0.023 ± 0.005 mg/L, while the chromium concentration ranged from 0.022 – 0.031 mg/L, with a mean and standard deviation of 0.026 ± 0.004 mg/L. Mercury was not detected throughout the study in borehole 4 (Table 2).

The distribution of heavy metals in the borehole waters around the abandoned Uyo Municipal dumpsite is shown in Fig. 2. The heavy metal concentration in borehole water varied for the different boreholes. Throughout the study, the lead concentration ranged from BDL – 0.035 mg/L, having a mean and standard deviation of 0.015 ± 0.011 mg/L. Cadmium ranged from 0.001 – 0.201 mg/L, having a mean and standard deviation of 0.058 ± 0.067 mg/L, while chromium ranged from 0.022 – 0.521 mg/L having a mean and standard deviation of 0.083 ± 0.139 mg/L. Mercury was not detected at all in all the boreholes throughout the study (Table 2). The lead concentration in borehole 2 and 3 were all above the Nigeria standard for drinking water quality (NSDWQ) acceptable limit. The cadmium concentration in borehole 2, 3 and 4 were all above the NSDWQ acceptable limit. The chromium concentration in borehole 2 was above the NSDWQ acceptable limit. From the statistical point of view, the lead and cadmium concentration varied significantly between the four boreholes at $p<0.05$, while the concentration of chromium did not vary significantly between the four boreholes at $p>0.05$ (Table 2).

4. DISCUSSION

Contamination takes place as leachates move down the soil strata and penetrate even at great depth [16,23,24]. The present study revealed that heavy metals concentration in borehole water is influenced by distance from the dumpsite. Also, it was revealed that the heavy metals concentration in the borehole water varied between boreholes, with the control borehole (borehole 1) having the best water quality due to its distance from the former dumpsite location. The mean concentration of lead observed in the present study is lower, while the cadmium concentration is higher than that reported by Arisi et al. [6]; when evaluating the pollution status of heavy metals in groundwater systems around open dumpsites in Abakaliki, and higher than [18]; while studying the emerging threats of contaminants in boreholes along the Ikot Effanga dumpsite, Calabar Municipality. Also, the mean cadmium concentration in the present study was

Table 2. Mean, standard deviation, ranges of heavy metals in borehole water around abandoned Uyo Municipal dumpsite

Metals (mg/L)	BH 1 (Control)	BH 2	BH 3	BH 4	Mean	NSDWQ
Pb	BDL[a]	0.027 ± 0.007[b] (0.020 – 0.034)	0.014 ± 0.002[c] (0.012 – 0.016)	0.005 ± 0.004[d] (0.001 – 0.010)	0.015 ± 0.011 (BDL – 0.035)	0.001
Cd	0.002 ± 0.001[a] (0.001 – 0.003)	0.137 ± 0.054[b] (0.105 – 0.203)	0.060 ± 0.078[c] (0.014 – 0.151)	0.023 ± 0.005[d] (0.019 – 0.029)	0.058 ± 0.067 (0.001 – 0.201)	0.003
Cr	0.038 ± 0.005[a] (0.032 – 0.043)	0.222 ± 0.257[a] (0.060 – 0.519)	0.039 ± 0.008[a] (0.031 – 0.047)	0.026 ± 0.004[a] (0.022 – 0.031)	0.083 ± 0.139 (0.022 – 0.521)	0.05
Hg	BDL	BDL	BDL	BDL	BDL	0.001

Values are in Mean ± standard deviation; Ranges are in Parenthesis ( )
Values with different superscript across the different boreholes are significantly different at $p<0.05$
Values with the same superscript across the different boreholes are not significantly different at $p>0.05$
BH – Borehole water; BDL – Below detectable limit; NSDWQ – Nigeria standard for drinking water quality

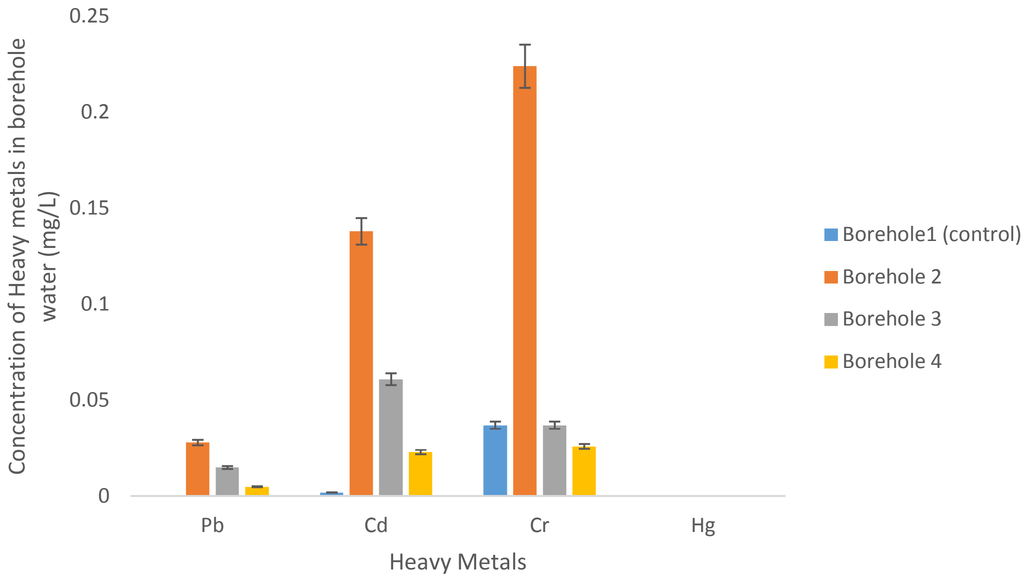

Fig. 2. Distribution of heavy metals in borehole waters around the abandoned Uyo Municipal dumpsite

higher than that reported by Ekpo et al. [25], while mean chromium of this study was also lower than the findings of Adesuyi et al. [26].

The discrepancy in the mean heavy metal concentration levels in the boreholes water between the compared boreholes could be due to the difference in the study period, the age of the former dumpsite, the distance from the former dumpsite, the relative quantity of contaminants capable of getting to the aquifer, groundwater and contaminants travel time, and geological system contaminant-attenuation capacity [18]. These differences could also be due to the difference in the production rate of leachates, the characteristics of produced leachate, the composition of solid waste, size of particle, compaction degree, the site hydrology, the landfill age, temperature condition, moisture, and the oxygen availability [14,15]. The degree to which attenuation occurs between the boreholes of the different studies could also depend on the soil type and rock, the contaminant type, and the associated activity [27,28]. It was also revealed that despite recently moving the Uyo municipal dumpsite away from its former location to a new area far from residential areas, the boreholes around the former dumpsite were still contaminated and unsafe for drinking [18]. In this study, the control borehole (borehole 1), which is the farthest from the former dumpsite, was the best and was healthy for drinking, because all the metals and microbial parameters were within the Nigerian standard for drinking water quality (NSDWQ) acceptable limit. This was because of its distance from the abandoned dumpsite. The other borehole (borehole 2, 3 and 4) had metal concentrations higher than the acceptable standard in most cases. Borehole 2 was highly unhealthy because the metal levels studied were all higher than the NSDWQ acceptable limit. As a result, borehole 2, 3, and 4 were unhealthy for consumption, and could cause several health challenging issues such as typhoid, liver, and kidney diseases [24].

The microbial counts in borehole water were also influenced by the distance from the former dumpsite and varied between boreholes. The total plate and total coliform count observed in the present study was lower than that reported by many researchers [29,9,30]. This disparity in the microbial counts in the boreholes between the compared boreholes could be due to the difference in the rate of leachates produced, the characteristics of produced leachate, the composition of solid waste, size of particle, compaction degree, the site hydrology, the landfill age, temperature condition, moisture, and the oxygen availability [14,15]. From the microbial point of view, it was also observed that the boreholes around the abandoned dumpsite were contaminated. The control borehole (borehole 1), which is the farthest from the former dumpsite location was healthy for drinking because all microbial parameters analysed were within the Nigeria standard for drinking water quality (NSDWQ) acceptable limit. The other boreholes (borehole 2, 3, and 4), had TPC, TCC or YC higher than the NSDWQ acceptable standard. Borehole 2 was the most unsafe for drinking because the microbial parameters were highest. In general, borehole 2, 3, and 4 are unhealthy for consumption and are capable of causing various health challenges such as liver, typhoid, and kidney diseases [24].

5. CONCLUSION

From this study, heavy metals contamination in borehole water is a characteristics of its location from dumpsite. The microbial counts and levels of heavy metals in borehole water varied from one borehole to the other. Also, the ground water quality was influenced by the location of the abandoned dumpsite. The control borehole (borehole 1) was healthy for consumption, while borehole 2 was the most unsafe for consumption because the levels of heavy metals and microbial counts were highest. Despite the fact that the dumpsite had been recently moved to an area very far from residential areas, the boreholes around the abandoned dumpsite are still contaminated and unsafe for drinking, as a result, it is pertinent that thorough treatments of the boreholes are performed, to avoid further outbreak of deadly diseases. More of similar studies should also be funded, so as to raise awareness levels on the safety (or unsafe nature) of drinking water from these boreholes.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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