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Full Length Research Article

EFFECT OF DUMPSITE WASTE ON SOIL, DRINKING WATER SOURCES, AND ANTIBIOTIC SUSCEPTIBILITY OF ISOLATES, IN A SUB-URBAN COMMUNITY, BENIN CITY, NIGERIA

[1*]Obueh H.O., [2]Maduka N., [1]Egharevba-Ojo P.A., [3]Enerijiofi K.E., [4]Ikhazuangbe-Benson C.

[1]Department of Biological Sciences, College of Science and Computing, Wellspring University, Benin City, Edo State
[2]Department of Microbiology, Faculty of Science, Federal University Otuoke, Bayelsa State
[3]Department of Biological Sciences, College of Basic, Applied and Health Sciences, Glorious Vision University, Ogwa, Edo State
[4]National Open University of Nigeria, Benin City Study Centre, Benin City

*Corresponding Author Email Address: hettywallz@gmail.com

ABSTRACT
Poor management of dumpsite waste in semi-urban communities could impact the soil and underground source of drinking water, thereby posing a health risk to residents. In this study, the effect of dumpsite waste, Evbotubu Quarters, Benin City, on the physicochemical properties, heavy metals, and minerals content of soil, well water and borehole water, antibiotic susceptibility of isolates from the samples were determined. The frequency of occurrence of organisms isolated include *Bacillus cereus* (22.4%), *Escherichia coli* (12.2%), *Enterococcus* spp. (12.2%), *Staphylococcus aureus* (10.2%), *Pseudomonas aeruginosa* (8.2 %), *Streptococcus* spp. (8.2 %), *Corynebacterium* spp. (8.2 %), *Aspergillus* spp. (8.2 %), *Fusarium* spp. (6.2 %), and *Mucor* spp. (4 %). Although, the Ca, Mg, Na, Zn, Cu, Cr, Pb, Mn, and Fe content of the dumpsite soil were higher than other samples, there are some exceptions with regards to the physicochemical parameters. The borehole water had the lowest values for all the parameters, except pH (6.87±0.03). The results reported were within the World Health Organization (WHO) permissible limits, with few exceptions. Antibiotic susceptibility test showed that ciprofloxacin was the most effective antibiotic. Going by the level of contamination, relevant government agencies should strictly monitor waste disposal, ensure that boreholes, and wells are situated very far from dumpsites.

Keywords: Antibiotic resistance, bioaccumulation, heavy metals, waste management, waterborne diseases.

INTRODUCTION
In developing countries, suburban communities are responsible for solving their water needs with little or no assistance from the government. The communities rely on ground water as the safest source of drinking water (Ishaku *et al.,* 2011). The contamination of various water sources could render it unsafe for drinking, unless it undergoes adequate treatment (Nwiniyi *et al*., 2020). Going by the economic reality in Nigeria today, proper treatment of water before drinking is expensive for many inhabitants of suburban communities. Majority of the people are left with no choice than to drink untreated water that predisposes them to high risk of waterborne diseases such as cholera, typhoid, salmonellosis, *Escherichia coli* diarrhea, among others (Forstintus *et al.,* 2016; Manetu and Karanja, 2021).

Waste generated by households, markets, schools, small scale industries, etc. in suburban communities are usually transported using garbage trucks to landfill or open dumpsites. Waste scavengers visit the dumpsites to sort waste, and sell the ones that could be recycled. Wastes dumped at landfills are subject to either groundwater infiltration from precipitations or erosion which usually contaminates surface water (Amano *et al*., 2021). Improper waste disposal practices especially improper management of dumpsites in sub-urban communities generate leachate that often contaminate the soil surface and underground water (Olukanni *et al*., 2017; Yahaya *et al*., 2022a). Toxic leachates from the dumpsite wastes are capable of impacting the environment. Leachates are most likely to migrate to the water bodies, underground water, soils, and other biophysical components of the environment, resulting in adverse effect on humans, aquatic organisms, plants, and animals (Agbeshiea *et al.,* 2020). According to Bhalla *et al.* (2012), leachates can permeate the soil and ground water close to landfill sites. The resulting effect is pollution of subsoil and ground water through a combination of chemical, physical, and microbial processes in the dumpsite (Kjeldsen *et al*., 2010). The exposure of groundwater to leachate is further increased by excess rainwater (Nagarajan *et al*., 2012).

The indiscriminate disposal of waste, burning or decay of dumpsite wastes accumulates obnoxious materials that contain toxic heavy metals (Abdus-Salam, 2009). Pb, Hg, and Cd found in the dumpsites, and its underlying soils could easily be absorbed by plants and other soil microorganisms. Consequently, these heavy metals could enter the food chain, and pose a health risk to humans (Akanchise *et al.,* 2020; Nkwunonwo *et al.,* 2020). Waste dumpsites with a high level of heavy metals are most likely to affect the chemical properties of soil and its nutrients, which ultimately affect crop production, and diversity of soil microorganisms (Fosu-Mensah *et al.,* 2017).

In the last few years, Nigerian urban population has witnessed a remarkable growth due to rural-urban migration (Oyeleye, 2013). High population density in urban and semi-urban areas, especially in developing countries like Nigeria, are associated with poor handling of waste materials of all kinds generated by the inhabitants and few industries (Adekola and Ogundipe, 2017; Enerijiofi and Ekhaise, 2019; Ogbu and Ezeodili, 2021). This problem is compounded by inadequate modern waste disposal facilities, poor physical planning of semi-urban areas, and bad habit of individuals who litter the environment with waste. Consequently, the environment becomes highly polluted, with its attendant health risk to the residents (Adejobi and Olorunnimbe, 2012).

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According to Atikpo *et al*. (2022), the average generation rate of solid waste in Evbotubu community, Edo State, Nigeria is 0.45 kg/p/d. The highest waste generation rate was recorded within the period of December to April. Although the result is within the range of 0.4-0.6 kg/p/d recommended by the United Nations Environmental Program for sub-urban communities in developing countries (Joarder, 2000), a lot of houses in Evbotubu community are barely completed with underground boreholes. Most of the boreholes have no overhead tanks. What is commonly seen in the locality are hand-dug wells close to open dumpsites. Indiscriminate disposal of solid and semi-solid waste in open dumpsites close to water sources has created serious environmental degradation problems translating into economic, social, and health issues (Ukpong *et al.*, 2015). All kinds of waste in the dumpsites are usually left for several days and weeks before waste collectors arrive to evacuate it. Unlawful dumping of municipal solid waste in unapproved sites comes with grave health consequences (Tukura *et al.,* 2018; Ichipi and Senekane, 2023). Waste that accumulate in the dumpsites promote the proliferation of pathogenic microorganisms, vectors, flies, insects, and rodents of public health importance (Ahmed, 2011; Nor Faiza *et al*., 2019). Oyekan and Sulyman (2013) reported that the insects and vectors that transmit diseases of public health importance are usually found in the dumpsites. Vegetation grown in contaminated soil has the ability to bioaccumulate toxic heavy metals in their tissues that pose potential health risks, as they could biomagnify in the consumer's tissues (Onwughara *et al.,* 2010).

Although several studies have been carried out to evaluate the quality of water obtained from boreholes and wells located near dumpsites (Olukanni *et al*., 2017; Ugbebor and Ntesat, 2019; Didia and Weje, 2020; Yahaya *et al.,* 2022a, Yahaya *et a*l., 2022b; Ugwoha *et al*., 2023), there is limited information on the microbial species detected in the water samples collected from different dumpsites and antibiotic susceptibility pattern of the isolates. Therefore, this study is aimed at evaluating the effect of dumpsite waste, Evbotubu quarters, Benin City, on selected physicochemical parameters, heavy metals, minerals content, and antibiotic susceptibility of isolates from dumpsite soil, well water, and borehole water.

MATERIALS AND METHODS

Study area

The study was conducted at the Evbotubu, in Egor Local Government Area of Edo State, Nigeria. Evbotubu is a sub-urban area in Benin City, located geographically at latitude 6° 20' 3.3'' N and longitude 5° 36' 50.724'' E.

Sample collection

Soil and water samples were collected in triplicates from the waste dumpsites. Soil samples were collected from the soil beneath the waste dump at depth 0-5 cm (Sample A); soil leachate (Sample B) using a hand trowel cleaned with 70% alcohol. Both samples were poured inside polyethylene bags. Water (Sample C) from a well close to the dumpsite, and sample D (borehole water in the vicinity of the dumpsite) were collected using a plastic screw capped sterilized bottles (2 litre capacity). All the samples were quickly taken to the laboratory within 2 hours of collection for analysis (Oviasogie *et al.,* 2010; Obire *et al*., 2002).

Serial dilution

One millilitre (1 mL) of water and one gram (1 g) soil sample each was weighed and mixed properly in 9 mL distilled water. Then, 1 mL of the dilution was transferred aseptically into another test tube containing 9 mL distilled water, and diluted serially into other test tubes till a 10^{-5} dilution was achieved using a sterile pipette for each transfer.

Microbiological analyses

Determination of heterotrophic bacterial count and total fungal count

An aliquot of 0.1 mL of each dilution was aseptically plated out using pour plate method on tryptone soy blood agar (Lab M Ltd UK), deoxycholate citrate agar (Lab M Ltd, UK), and nutrient agar (Lab M Ltd UK) for bacteria isolation, while potato dextrose agar (Lab M, UK) supplanted with 0.5% chloramphenicol is for fungi. Isolation and enumeration of the total heterotrophic bacterial count (THBC), and total fungal count (TFC) was done in triplicates. All culture plates were incubated at 37 °C for 24 to 48 hour to obtain bacterial counts; at 25 °C for 72 hours for fungal counts. The discrete colonies on the different agar media were observed, and counted in a Techmel and Techmel counter model TT 201. The results were expressed accordingly as colony forming units per gram (CFU/g) and colony forming units per millilitre (CFU/mL).

Determination of pure isolates

Different bacterial colonies that appeared on the culture plates were subcultured onto freshly prepared nutrient agar plates, and incubated at 28 °C for 24 hours. This procedure was repeated until discrete colonies were obtained in the culture plates. The discrete colonies were transferred aseptically onto nutrient agar slants, and incubated at 28 °C for 24 hours.

Characterization of bacterial and fungal isolates

Representatives of the pure bacterial colonies were subjected to various cultural, morphological, and biochemical tests. Identification of the isolates was based on Bergey's Manual of Determinative Bacteriology (Holt *et al*., 2000). For the fungal isolates, wet mount method was used to determine their macroscopic and microscopic characteristics (Tsuneo, 2010).

Heavy metals, minerals and physicochemical analyses

The minerals content and physicochemical parameters of the soil and water samples were determined using the standard methods. Quantitative analysis of minerals (calcium, magnesium, and manganese), and heavy metals (copper, zinc, chromium, iron, and lead) in the dumpsite soil, dumpsite leachate, well water, and borehole water samples were determined using atomic absorption spectrophotometer (AAS), and the procedure described by the Association of Official Analytical Chemists (AOAC, 2000). The potassium and sodium contents of the samples were determined using flame emission spectrophotometer (AOAC, 2000). The pH of soil and water samples was determined using a Hach pH meter, in line with the procedure described by the American Public Health Association (APHA, 2005). The conductivity test was carried out using a Hach Conductivity meter (APHA, 2005). The total organic carbon in the samples was determined by the method of ASTM (2003). The alkalinity, sulphate, nitrate, phosphate, biochemical oxygen demand (BOD), total suspended solids (TSS), total dissolved solids (TDS), and chloride concentrations in the soil and water samples were determined using the method of APHA (2005). The concentration of soil in the suspension that determines the level of organic matter, silt, clay, and sand in the samples were carried out using a simplified hydrometer procedure described by Moorberg and Crouse (2021).

Antimicrobial susceptibility test

The Kirby-Bauer disk diffusion method described by Jorgensen and Turnidge (2007), was used to evaluate the antimicrobial susceptibility of the bacterial isolates from the dumpsite soil, dumpsite leachate, well water, and borehole water samples. The commercially prepared antibiotics used include Amoxycillin (10 µg), Cotrimoxazole (30 µg), Peflacin (30 µg), Oflaxacin (5 µg), Augmentin (30 µg), Nirofurantoin (300 µg), Tetracycline (30 µg), Gentamicin (10 µg), Erythromycin (30 µg), Streptomycin (30 µg), Ceftazidime (30 µg), and Ciprofloxacin (5 µg). Overnight broth cultures of pure bacterial and fungal isolates were suspended in sterile peptone water. Using a sterile swab stick, each isolate was inoculated into the surface of dried plates of Mueller-Hinton agar, and rotated carefully to ensure even distribution (Salaimon *et al*., 2015). The surface of the inoculated plates was allowed to dry for few minutes. Thereafter, a sterile forceps was used to lift antibiotic discs from the manufacturer's pack and placed on the inoculated plates. The plates were incubated at 37 °C for 24 hours. The diameter of the zone of inhibition of each antibiotic in the disk was measured to the nearest whole number, and interpreted using the guidelines of the Clinical and Laboratory Standard Institute (CLSI, 2005).

Statistical analysis

The results were presented as mean standard values of triplicate analysis. A one-way analysis of variance (ANOVA) and student t-test was performed using the data generated from the analyses as described by Ogbeibu (2005). Duncan's Multiple Range Test (DMRT) was carried out to test for significant difference at $P < 0.05$ between treatment combinations. Statistical Package for the Social Sciences (SPSS) version 16 software was used for easy analysis of data.

RESULTS AND DISCUSSION

The result of biochemical and physicochemical properties of dumpsite soil (sample A), dumpsite leachate (sample B), well water (sample C), and borehole water (sample D) are presented in Table 1. The pH values range from 5.26±0.03 to 6.87±0.04. The pH permissible limit stipulated by the World Health Organization (WHO, 2010) is 6.5-8.5. Among all the four samples analyzed for pH, sample C and sample D were within the WHO permissible limit. The distance both water sources maintained from the dumpsite could be one of the reasons the water samples was slightly acidic (6.45-6.87). The pH of dumpsite soil (sample A) and dumpsite leachate (sample B) was moderately acidic (5.26-5.71), but failed to meet the WHO requirement. This could be attributed to the nature of waste materials dumped on the ground, chemical processes, breakdown, and bioaccumulation of organic waste that infiltrate underground water, and acidic rainwater. According to Ano and Okwunodudu (2008), the acidic nature of soil samples in the waste sites could leach to the underground water and affect its taste.

The pH of a sample is positively correlated with electrical conductivity and total alkalinity (Gupta and Shukla, 2006). The electrical conductivity (EC) values of dumpsite soil, dumpsite leachate, well water, and borehole water samples range from 15.00±0.08 to 132.00±1.52 µS/cm. The dumpsite leachate sample B had the highest EC (132.00±1.52 µS/cm). The presence of ionic contaminants, chemicals, and salts from all kinds of wastes dumped on the ground could be responsible for high EC of dumpsite leachate. The electrical conductivity (EC) values of all the samples were below the WHO permissible limit.

The total suspended solids (TSS) and total dissolved solids (TDS) in the water samples range from 0.06±0.00-23.24±0.30 mg/L and 7.00±0.01-55.50±0.01 mg/L, respectively. Higher values of TSS and TDS in the well water sample, compare to the dumpsite soil, dumpsite leachate, and borehole water could be attributed to its liquid state that dissolve or suspend solids, and exposure of the well water to contamination by foreign materials. For example, the runoff from the dumpsite wastes can enter a nearby well, and contaminate the water. According to Adejuwon and Mbuk (2011), high level of dissolved and suspended solids in water is caused by pollution, especially the presence of chemicals in the water sources. The biochemical oxygen demand (BOD) estimates the level of organic pollution of water. In the dumpsite soil and dumpsite leachate, BOD was not detected. However, the BOD values of water samples C and D was 4.35±0.41 and 1.67±0.10 mg/L, respectively. According to the classification of surface water quality, BOD > 2.0 mg/L is indicative of pollution of the water source, and regarded as unfit for human consumption (Afolabi *et al.,* 2012). However, the BOD of the water samples was below the WHO permissible limit (6.0 mg/L).

The chloride, sulphate, and nitrate content of the dumpsite soil, dumpsite leachate, well water, and borehole water samples were within the WHO permissible limits. A similar result was reported for the phosphate content of all the samples, with exception of the well water sample. The excess quantity of phosphate in the well water, could promote the growth of algae and production of slime, which compromises the quality of water (Ibiam *et al.,* 2024). Although, the WHO Standard for alkalinity of drinking water is yet to be ascertained, the Indian authority recommend that the water for domestic use, and drinking water should have values below 200 ppm (Akhtar *et al.,* 2013). According to George *et al.* (2010), alkalinity influences the chemical and biochemical reactions in water. The total organic carbon (TOC), clay, silt, sand, and organic matter, were not detected in the well water and borehole water samples. However, different values were reported for each of the parameters in the dumpsite soil, and dumpsite leachate samples. The total organic carbon (TOC) reported in both samples were below the WHO permissible limit. The results obtained from this study substantially agrees with the findings by Olukanni *et al.* (2017), that determined the effect of dumpsite leachates from a tertiary institution on the quality of groundwater.

Table 1. Biochemical and physicochemical compositions of dumpsite soil, dumpsite leachate, well water, and borehole water

Parameter	Unit	Samples					
		A	B	C	D	WHO Permissible Limits	References for the WHO Standard
pH		5.71 ± 0.05^{b}	5.26 ± 0.03^{a}	6.45 ± 0.02^{c}	6.87 ± 0.03^{d}	6.5-8.5	Sargar *et al.* (2024)
EC	µS/cm	95.00 ± 0.13^{c}	132.00 ± 1.47^{d}	41.00 ± 1.90^{b}	15.00 ± 0.26^{a}	500	Odu *et al.* (2021)
Chloride	mg/L	16.87 ± 0.39^{c}	23.76 ± 0.79^{d}	9.98 ± 0.14^{b}	8.59 ± 0.17^{a}	200 mg/L	Sargar *et al.* (2024)
Sulphates	mg/L	4.25 ± 0.02^{c}	5.98 ± 0.06^{d}	2.03 ± 0.05^{b}	0.18 ± 0.04^{a}	250-500 mg/L	Odu *et al.* (2020)
Phosphates	mg/L	2.81 ± 0.06^{c}	3.96 ± 0.07^{d}	1.33 ± 0.03^{b}	0.00 ± 0.00^{a}	0.5 mg/L	Odu *et al.* (2020)
Nitrates	mg/L	7.59 ± 0.08^{c}	8.99 ± 0.07^{d}	1.72 ± 0.07^{b}	0.78 ± 0.02^{a}	10 mg/L	Odu et al. (2020)
Alkalinity	mg/L	ND	ND	21.87 ± 0.05^{b}	9.40 ± 0.02^{a}	-	Sargar *et al.* (2024)
BOD	mg/L	ND	ND	4.35 ± 0.41^{b}	1.67 ± 0.10^{a}	6.0 mg/L	Olukosi *et al.* (2016)
TDS	mg/L	ND	ND	55.50 ± 0.01^{b}	7.00 ± 0.01^{a}	1000	Akhtar *et al.* (2014)
TSS	mg/L	ND	ND	23.24 ± 0.30^{b}	0.06 ± 0.00^{a}	1000	Odu *et al.* (2020)
TOC	mg/L	3.32 ± 0.01^{b}	0.53 ± 0.01^{a}	ND	ND	50 mg/L	Pandey *et al.* (2021)
Organic matter	%	0.65 ± 0.02^{a}	0.65 ± 0.02^{a}	ND	ND		
Sand	%	71.98 ± 0.04^{b}	63.24 ± 0.05^{a}	ND	ND		
Silt	%	17.81 ± 0.03^{a}	19.76 ± 0.03^{b}	ND	ND		
Clay	%	17.00 ± 0.04^{b}	10.21 ± 0.02^{a}	ND	ND		

Values represent a triplicate mean $\pm$ standard error. The means with different superscripts in the same row are significantly different at $p \leq 0.05$.
Key: Sample A - dumpsite soil; Sample B - dumpsite leachate; Sample C - well water close to dumpsite; Sample D - borehole water in the vicinity of dumpsite; EC - Electrical conductivity; BOD - Biochemical oxygen demand; TDS - Total dissolved solids; TSS - Total suspended solids; TOC - Total organic carbon; ND - Not detected

Presented in Table 2 is the minerals and heavy metals content of dumpsite soil, dumpsite leachate, well water, and borehole water. The quantity of each of the minerals or heavy metals in the four samples is significantly different ($p<0.05$). It is worthy to note that the quantity of each mineral (Ca, Mg, Na, K, and Mn), and heavy metal (Cu, Cr, Fe, Zn, and Pb) in the dumpsite soil followed by dumpsite leachate was higher than the result reported in other samples. This observation could be attributed to human activities in the area, that generate a large quantity of household wastes, plumbing, gasoline, iron, industrial waste products etc. (Afolabi *et al*., 2012). On the contrary, borehole water in the vicinity of the dumpsite had the lowest quantity of the minerals and heavy metals. Calcium, potassium, sodium, magnesium, and zinc contents of all the samples were below the WHO permissible limits.

All the samples also contain copper and iron below the WHO permissible limit, with exception of dumpsite soil and dumpsite leachate. However, the chromium and lead content of all the samples were above the WHO permissible limit, with the exception of borehole water. According to Bhalla *et al.* (2012), heavy metals contamination of boreholes and hand dug wells could be attributed to infiltration or permeation of the landfill leachate through the water. High toxicity, mutagenic, and carcinogenic properties of hexavalent chromium could be harmful to health. According to Odu *et al.* (2020), drinking water that contains excess quantity of chromium could cause allergic dermatitis and cancer. Severe damage to reproductive, peripheral and central nervous system, poor functioning of the kidney, cardiovascular system and joints, hampering the synthesis of hemoglobin could be attributed to lead poisoning. It causes mutagenic, teratogenic, and carcinogenic effect in the human body (Nwinyi *et al*., 2020). According to Udofia *et al*. (2016), lead poisoning could impair brain development and learning ability in children. Among all the samples, only the dumpsite soil contains manganese that was above the WHO permissible limit. The water from the well close to the waste dumpsite (Sample C) contain Cr (0.28 ± 0.01 mg/L) and Pb (0.08 ± 0.0 1mg/L), that exceeded the WHO (2010) permissible limit. The implication is that the well water is unfit for human consumption. Drinking water that contains chromium above 0.05 mg/L can lead to cancer or allergic dermatitis. High concentration of lead in a water source is of public health significance because drinking the water might cause anaemia, kidney diseases, cancer, and affect vitamin D metabolism, and mental development in infants (NIS, 2007).

Table 2. Minerals and heavy metals content (mg/L) of dumpsite soil, dumpsite leachate, well water, and borehole water

Parameters	Samples					
	A	B	C	D	WHO Permissible Limit	References for the WHO Standard
Calcium	6.86 ± 0.05^{d}	5.77 ± 0.04^{c}	1.87 ± 0.04^{b}	0.36 ± 0.04^{a}	75 mg/L	Hossin *et al.* (2016)
Magnesium	9.33 ± 0.08^{d}	7.84 ± 0.04^{c}	6.62 ± 0.04^{b}	1.02 ± 0.03^{a}	50 mg/L	Hossin *et al.* (2016)
Sodium	17.16 ± 0.10^{d}	12.18 ± 0.10^{c}	4.10 ± 0.10^{b}	0.43 ± 0.05^{a}	200 mg/L	Hossin *et al.* (2016)
Potassium	9.11 ± 0.05^{d}	6.47 ± 0.03^{c}	2.66 ± 0.03^{b}	0.67 ± 0.01^{a}	55 mg/L	Hossin *et al.* (2016)
Zinc	2.24 ± 0.03^{d}	1.59 ± 0.03^{c}	1.09 ± 0.03^{b}	0.81 ± 0.04^{a}	3.0 mg/L	Mahugija (2018)
Copper	6.19 ± 0.04^{d}	2.35 ± 0.03^{c}	0.84 ± 0.01^{b}	0.00 ± 0.00^{a}	2.0 mg/L	Manne *et al.* (2022)
Chromium	7.40 ± 0.05	0.33 ± 0.01	0.28 ± 0.01	0.00 ± 0.00^{a}	0.05 mg/L	Khan *et al.* (2011)
Lead	3.11 ± 0.02^{d}	0.21 ± 0.01^{c}	0.08 ± 0.01^{b}	0.00 ± 0.00^{a}	0.01mg/L	Mahugija (2018)
Manganese	8.33 ± 0.06^{d}	0.28 ± 0.02^{c}	0.18 ± 0.02^{b}	0.12 ± 0.01^{a}	0.4 mg/L	Obasi and Akudinobi (2020)
Iron	28.86 ± 0.15^{d}	3.45 ± 0.09^{c}	0.29 ± 0.05^{b}	0.07 ± 0.03^{a}	0.3 mg/L	Mahugija (2018)

Values represent a triplicate mean $\pm$ standard error. The means with different superscripts in the same row are significantly different at $p \leq 0.05$.
Sample A - dumpsite soil; Sample B - dumpsite leachate; Sample C - well water close to dumpsite; Sample D - borehole water in the vicinity of dumpsite

Presented in Table 3 is the total heterotrophic bacterial and fungal count of dumpsite soil, dumpsite leachate, well water, and borehole water. The result shows that the Sample B (dumpsite leachate) had the highest bacterial and fungal counts of $5.4 \times 10^5 \pm 0.1$ CFU/mL and $2.1 \times 10^5 \pm 0.1$ CFU/mL, respectively. On the contrary, the borehole water in the vicinity of the dumpsite had the lowest heterotrophic bacterial and fungal count. In a related study, Ugbebor and Ntesat (2019) reported that the THBC (6.0×10^3 CFU/mL) of borehole water samples at Igwuruta solid waste dumpsite is the highest among all the samples. However, Yahaya *et al.* (2022a) and Yahaya *et al.* (2022b) reported that the total fungi/yeast in the water samples obtained from boreholes located near Olusosun dumpsite, and Simpson Transfer Loading Station in Lagos state is below the detection level. This result is not in agreement with the findings from this study.

Table 4 shows the distribution, frequency, and percentage occurrence of the bacterial isolates from the dumpsite soil, dumpsite leachate, well water, and borehole water. A total of seven bacterial species (*Bacillus cereus, Enterococcus* spp., *Streptococcus* spp., *Escherichia coli, Corynebacterium* spp., *Pseudomonas aeruginosa,* and *Staphylococcus aureus*), and three fungal species (*Fusarium* spp., *Aspergillus* spp., and *Mucor* spp.) were isolated from the samples. Among the isolates, *Bacillus cereus* and *Mucor* spp. had the highest and least percentage occurrence of 22.4 and 4.0%, respectively. This result is partly in agreement with a related research finding by Enerijiofi and Ekhaise (2019). The highest frequency of occurrence of *Bacillus cereus* in the samples could be attributed to its ability to form spores, well-known to be resistant to adverse environmental conditions, and ubiquitous nature of the bacterium (Ahaotu *et al.,* 2021).

Table 3. Total heterotrophic bacterial and fungal count of dumpsite soil, dumpsite leachate, well water, and borehole water samples

Samples	Microbial Counts	
	Bacterial counts	Fungal counts
A (CFU/g)	$3.6 \times 10^5 \pm 0.1$	$0.2 \times 10^5 \pm 0.1$
B (CFU/g)	$5.4 \times 10^5 \pm 0.1$	$2.1 \times 10^5 \pm 0.1$
C (CFU/mL)	$7.9 \times 10^3 \pm 0.2$	$4.5 \times 10^2 \pm 0.2$
D (CFU/mL)	$1.2 \times 10^1 \pm 0.1$	$0.9 \times 10^1 \pm 0.1$

Key: Sample A - dumpsite soil; Sample B - dumpsite leachate; Sample C - well water close to dumpsite; Sample D - borehole water in the vicinity of dumpsite.

Table 4. Distribution, frequency, and percentage occurrence of bacterial and fungal isolates from the dumpsite soil, dumpsite leachate, well water, and borehole water samples

Bacterial Isolates	Sample				Frequency	Mean percentage occurrence
	A	B	C	D		
Bacillus cereus	4 (26.7)	4 (21.1)	2 (22.2)	1 (16.7)	11	22.4
Enterococcus spp.	3 (20.0)	2 (10.5)	1 (11.1)	-(0.0)	6	12.2
Streptococcus spp.	1 (6.7)	2 (10.5)	1 (11.1)	-(0.0)	4	8.2
Escherichia coli	2 (13.3)	3 (15.8)	1 (11.1)	-(0.0)	6	12.2
Corynebacterium spp.	1 (6.7)	2 (10.5)	1 (11.1)	-(0.0)	4	8.2
Pseudomonas aeruginosa	1 (6.7)	2 (10.5)	1 (11.1)	- (0.0)	4	8.2
Staphyloccus aureus	1 (6.7)	1 (5.3)	1 (11.1)	2 (33.3)	5	10.2
Fusarium spp.	1 (6.7)	1 (5.3)	1 (11.1)	- (0.0)	3	6.2
Aspergillus spp.	- (0.0)	1 (5.3)	- (0.0)	3 (0.50)	4	8.2
Mucor spp.	1 (6.7)	1 (5.3)	-(0.0)	-(0.0)	2	4.0
Total number of isolates	15 (30.6)	19 (38.8)	09 (18.4)	06 (12.2)	49	100.0

Key: Sample A = dumpsite soil; Sample B = dumpsite leachate; Sample C = well water close to dumpsite; Sample D = borehole water in the vicinity of dumpsite

The waste accumulated in the dumpsite is a reservoir of pathogenic infectious agents poses a great danger to public health. The high prevalence of *Escherichia coli* and *Enterococcus* spp., 12.2% each, in all the soil and water samples, except the sample D representing borehole water in the vicinity of the dumpsite, is an indication that the human and animal excreta is part of the waste in the refuse dumpsite. This is capable of causing outbreak of food and waterborne diseases (Adeyeba and Akinbo, 2002). The presence of these organisms in the well water, sample C indicates that the water is polluted and is unfit for human drinking. Infectious microorganisms may be present in human or animal waste. Wells and other drinking water sources can be contaminated by storm, water run-off from waste dump sites, landfills, roadways, farms and livestock operations, discharges from sewage treatment plants, or septic system discharges. In sub-urban areas like Evbotubu, access to clean, safe, and treated water is a major public health problem. In developing countries, access to both clean water and sanitation is limited. According to Fenwick (2006), two and a half billion people globally have no access to improved sanitation, and more than 1.5 million children die each year from diarrheal diseases. The isolation of *Bacillus* and *Staphylococcus* species from the dumpsites is in agreement with the studies by Williams and Hakam (2016). According to the researchers, both microorganisms produce enzymes known as Dnase and staphylokinase that could degrade wastes at dumpsites, and convert it to useful materials.

Table 5 shows the antibiotic susceptibility pattern of bacterial and fungal isolates from the dumpsite soil, dumpsite leachate, well water, and borehole water samples. The result shows that ciprofloxacin was the most effective antibiotic based on the total percentage of isolates (45.37%) susceptible to the antibiotic. On the contrary, tetracycline was the least effective antibiotic that accounted for 12.04% of the isolates that was susceptible to the antibiotic. Interestingly, ciproflaxacin was most effective against *Staphylococcus aureus,* followed by *Pseudomonas aeruginosa*. It should be a great concern that the antibiotics were least effective against *Corynebacterium* spp. *Bacillus cereus,* and *Enterococcus* spp. The resistance demonstrated by these bacterial isolates against the antibiotics could be attributed to the production of enzymes, which inactivate or modify antibiotics. It is possible that the organisms could change its microbial cell membrane, modify the target site of the antibiotics, and metabolic pathways such that the antibiotics will have little effect on them (Odeyemi *et al*., 2011). Therefore, continuous discharge of wastes in the dumpsites, and eventual infiltration into underground water present a high risk of spreading antibiotic resistant genes in the pathogens. Consequently, treatment of infections in humans caused by the pathogens harbouring antibiotic resistant genes becomes very difficult.

Table 5. Antibiotic susceptibility pattern of bacterial and fungal isolates from dumpsite soil, dumpsite leachate, well water and borehole water samples

Microbial Isolates	Number of Isolates	Percentage (%) of each bacterial isolate susceptible to antibiotics											
		STR	CIP	ERY	GEN	OFL	AMX	COT	PEF	AUG	NIT	CAZ	TET
Bacillus cereus	11	0.00	25.00	-	25.00	20.00	25.00	25.00	33.33	0.00	50.00	-	0.00
Enterococcus spp.	6	-	33..33	25.00	33.33	0.00	0.00	-	-	0.00	25.00	33.33	25.00
Streptococcus spp.	4	-	-	-	10.00	0.00	0.00	33.33	60.00	25.00	40.00	40.00	0.00
Escherichia coli	6	-	40.00	0.00	0.00	25.00	33.33	0.00	33.33	66.67	0.00	-	0.00
Corynebacterium spp.	4	25.00	10.00	0.00	0.00	33.33	0.00	-	-	25.00	-	40.00	-
Pseudomonas aeruginosa	4	33.33	60.00	60.00	0.00	0.00	-	40.00	-	-	0.00	25.00	0.00
Staphylococcus aureus	5	25.00	100.00	0.00	-	60.00	-	25.00	0.00	33.33	0.00	0.00	0.00
Fusarium spp.	3	50.00	40.00	-	0.00	-	100.00	0.00	25.00	0.00	33.33	25.00	25.00
Aspergillus spp.	4	0.00	60.00	25.00	25.00	0.00	33.33	25.00	66.67	-	25.00	0.00	33.33
Mucor spp.	2	25.00	40.00	-	25.00	-	0.00	33.33	25.00	-	-	60.00	25.00
Total	49	22.61	45.37	18.33	13.14	17.29	23.96	22.71	34.76	21.43	21.67	27.91	12.04

Key:- Represent culture plates that yielded no growth; 0.00 = Not susceptible; STR=Streptomycin; CIP=Ciprofloxacin; ERY= Erythromycin; GEN= Gentamicin; OFL=Ofloxacin; AMX= Amoxycillin; COT= Cotrimoxazole; PEF= Peflaxin; AUG= Augmentin; NIT=Nitrofurantoin;CAZ=Ceftazidimine; TET=Tetracycline

Conclusion

The accumulation of waste in the dumpsite affected the physicochemical parameters, heavy metals, and minerals content of the dumpsite soil, well water, and borehole water to the extent that some of the results obtained were above the WHO permissible limits. Despite being located near a waste dumpsite, the quality parameters of borehole water is preferable than the well water. The isolation of pathogenic microorganisms from the soil and water sources, antibiotic resistance demonstrated by the isolates, calls for intensified efforts by the general public, and authorities to effectively manage open dumpsites in semi-urban communities to avoid outbreak of diseases.

Conflicting Interests

Authors have declared that no competing interests exist

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