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Physicochemical Profile and Evaluation of Microbial Load in Soil Around Open Waste Dumpsites in Owerri, Southeastern Nigeria

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Abstract

The indiscriminate dumping of solid waste and the lack of proper waste management systems have been an issue threatening environmental and health conditions in most developing countries. This study assessed the physicochemical parameters and microbial load of selected open dumpsite soils in Owerri Imo State. The physicochemical and microbiological qualities were determined using established methods. Results obtained showed that EC values ranged from 103.10±5.48 to 128.88±19.09 µS/cm. The pH value ranged from 5.45±2.10 to 6.78±1.00. At Nekede dumpsite, the phosphate value varied from 33.10±11.01 - 46.50±6.09 mg/kg, Nitrate, 8.30±4.01-10.70±5.09 mg/kg and Sulphate, 12.10±6.03 - 20.70±13.10 mg/kg, compared to Chukwuma Nwaoha dump site with Phosphate 44.00±11.7- 90.01±9.44 mg/kg, Nitrate, 10.80±5.50 - 20.00±8.03c mg/kg and Sulphate, 17.00±5.81 - 40.55±10.33 mg/kg. In both dumpsites, the Phosphate, Nitrate, and Sulphate levels were significantly ($P < 0.05$) higher in the soils from the different sampled locations compared to the control sites. The exchangeable cations: calcium, sodium, magnesium, and potassium across the sample areas also varied from 35.160±11.2 - 37.620±11.9 mg/kg; 8.720±3.91- 12.770±8.22 mg/kg; 10.340±5.01- 17.860±6.10 mg/kg and 0.660±0.01- 1.940±0.88mg/kg for Nekede while Chukwuma Nwaoha recorded 40.90±17.08- 44.560±19.02 mg/kg; 10.500±5.02- 13.018±6.91 mg/kg; 12.140±4.99- 16.040±3.09 mg/kg and 32.600±11.59- 43.640±14.80mg/kg respectively. The most dominant microbial isolate was *Staphyloccocus sp*., (14%) while the least isolate was *Acinetobacter sp*. (3%). For the THB and THF, the average was 3.77±1.48 and 2.61±2.06; 4.97±2.174 and 2.13±0.914 CFU/mL for Nekede Area. The THB and THF average value for Chukwuma Nwaoha Area was 3.01±1.17 and 3.85±2.81; 2.55±1.814 and 1.79±1.884 CFU/mL respectively. The presence of potentially pathogenic microorganisms identified in the dumpsite soils is a major source of public health risk. The study underscores the need for proper waste management systems to forestall environmental pollution.

Keywords: Dumpsites, Physicochemical properties, Microbial load, Imo State

1 Introduction

Virtually every activity by man generates waste of some kind [1]. These wastes are viewed as substances produced in our daily (consumption, recreational, production, and living) activities, which are unwanted and are no longer useful [2]. Solid wastes are described as unwanted or unusable materials which could also be known as trash refuse garbage or junk [3]. They are those materials, which are generated as a result of normal operations over which we have control in terms of their production, disposal, or discharge. The challenge of poor waste management systems is rapidly assuming enormous proportions in most developing countries like Nigeria. Some of the common waste disposal techniques in some countries such as waste dumps, landfills, and incinerators have proved inadequate [4], and this has adversely contributed to the pollution of the environment. As a result of Population growth, economic development, and urbanization, there have been an increase and the complexity of waste generated by urban areas dwellers [5]. Solid waste pollutants are known to serve as an external force that may have an impact on the physicochemical characteristics of soil, and as such can contribute to the poor production of vegetation [6-8]. In most developing countries of the world, the propensity of residents to generate waste seems to have increased in recent times [2];[9-11]. This has been attributed to accelerated industrialization, urbanization, and population growth; which have elicited strong international and national concerns about the possible environmental, health, and safety effects of living in the vicinity of these wastes [12]. However, landfilling and or open dumping of wastes is the prevalent method of managing these wastes [13]. This is because it is the cheapest and most convenient way of disposing of municipal solid wastes [14]; however, all efforts in a bid to get rid of waste also pollute the environment to some extent [15]. When waste is dumped on land, microorganisms such as bacteria and fungi proliferate using the components of the waste materials as a source of nutrients for growth as well as degrading the organic materials in the waste [16-19].

As opined by [20], the environment can be polluted by leachates from dumpsites which occur at the end of the decay of solid waste, mixed with precipitates of surface water. As a

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result, surface water collection systems (rivers, creeks, and lakes), subsurface collection systems (groundwater reservoirs), and solid systems (different soil layers) become vulnerable to pollution from the dump site. Several incidences have been reported in the past where leachates have contaminated the surrounding soil and polluted the underlying groundwater aquifer or nearby surface water [16]; [18-22]. Imo State does not have a well-organized waste disposal system [5]. Nekede and Chukwuma Nwaoha are among the areas within Owerri where wastes are dumped by inhabitants. These waste materials are deposited in certain “open” dump sites and allowed to be compiled until they are taken away or incinerated. Improper disposal of untreated municipal solid waste is not only harmful to human health but also a threat to the environment [23]. Pathogenic microorganisms and harmful chemicals in solid waste can be introduced into the environment when the waste is not properly managed [24-27]. Waste can contaminate surface water, groundwater, soil, and air which poses more problems for humans, other species, and ecosystems [28]. Thus, this study aims to evaluate the physicochemical and microbial load of surface soils collected in the vicinity of these makeshift open waste dumpsites located within Owerri, Imo State. The data obtained in this study can help to prioritize sustainable waste management practices in the State and also reduce the potential risks associated with these landfills in the environment.

2 Materials and methods

2.1 Place and Sources of samples for the study

This study was conducted in Owerri Metropolis, geographically located between Latitude 5.4166° N, and Longitude 6.9853° E. Soil samples were aseptically collected from two (Nekede and Chukwu Nwaoha axis) dump sites located in Owerri, Imo State. Twenty grams (20 g) of soil from dump sites were collected in sterilized cellophane or polythene bags in line with the method [18]. Contamination observed from the soil samples was therefore ascribed to waste disposal [20].

Figure 1: An Open dumpsite at Chukwuma Nwaoha axis

All samples were properly labeled and transported to the laboratory for analysis immediately after collection. The samples used as control were collected from areas with no history of waste disposal. The dump sites are situated around residential areas, shops, and markets. The constituents of the wastes included: paper, wood, plastic paper bags, straws, buckets, tin cans, sacks, clothes, glass bottles, cotton wool, food wastes, leaves, fruit wastes, medicine bottles, foams, ashes, water sachets, dry leaves, cardboard and human excreta (urine and feces), etc.

2.2 Method of sample collection

The soil was sampled at a total of 6 sampling points, made up of 3 each, around Nekede (Nekede soil samples 1, 2, and 3 coded NKSS1, NKSS2, NKSSC respectively) and Chukwuma Nwaoha (Chukwuma Nwaoha soil sample 1, 2 and 3 coded CNWSS1, CNWSS2 and CNWSSC respectively) dumpsite under stringent controls. A hand augur was employed to take the soil samples after decontamination using distilled water at each point of sampling. Sampling depth was at 0-15cm per point with 2m space between sampling points [28]; and then all combined for homogeneity, to make a composite sample per location/site (ISO, 11074-2, 1998); after which the samples were transported to the laboratory [29]. The samples were thereafter treated within 2 h after collection. The soil samples were sieved through a 0.2 mm wire mesh, which was previously swabbed with 95% ethanol, to obtain fine soil particles [3].

2.3 Physicochemical analyses

The physicochemical parameters of soil samples were determined using the Association of Official Analytical Chemists [29] method. The pH of the soil was determined using the Jenway pH meter (3015 model).

2.4 Microbiological analyses

The total heterotrophic bacterial count was performed in duplicates on dried nutrient agar plates and incubated at 30°C for 24 h [17]. At the end of the incubation period, isolation for pure culture was carried out. Acidified potato dextrose agar plates containing streptomycin (1 mg/100 ml) were used to obtain fungal isolates as described by Harley and Prescott [30]; and [31]. The plates were incubated at 30°C and observed after 48 h for yeasts and 96 h for mold, thereafter, isolation of pure isolates was done in line with the method of [11].

2.5 Identification and Characterization of isolates

The pure bacterial strains were identified based on their morphological and biochemical tests with descriptive identification schemes as described by [32] and [33]. The pure cultures of the bacterial isolates were subjected to various morphological and biochemical characterization tests such as color, shape, elevation, consistency, margin, catalase test, MRVP (Methyl Red-Voges Proskauer test), fermentation of sugars, Kovacs citrate, indole, hydrolysis of starch and sensitivity tests [34]. To determine the identity of bacteria isolates, results were compared with standard references of Bergey’s Manual of Determinative Bacteriology [35].

2.6 Statistical analysis

Results were subjected to statistical analysis employing the student t-test at 95% probability levels using SPSS (VERSION 20.0) statistical package.

3 Results and discussion

The physicochemical parameters of the soil sample from Nekede and Chukwuma Nwaoha area dumpsites are displayed in Table 1. Results obtained showed that the concentration of EC ranged from 103.10±5.48 to 128.88±19.09 µS/cm. These values were lower than those earlier reported by [36] who reported values from 164.00 to 540.00 µS/cm, but in the same range as the findings of [19] who reported 77.22 ± 6.14 to 259.67 ± 64.34 µS/cm respectively. The EC values were significantly higher at the dumpsite sites than those at the control site. The high EC values obtained in this study are an indication that the soil samples have a high concentration of soluble salts which is a good indicator of plant growth [10]. The pH value ranged from 5.45±2.10 to 6.78±1.00 indicating a generally acidic soil medium. The mean pH values of the soils from most of the locations were significantly higher than that of the control soil. According to earlier reports, this could be attributed to liming materials and the activities of some microorganisms in solid wastes [37]. pH among variables such as soil structure, the organic matter quantity, and the cation exchange potential of the soil could control the circulation and enrichment of heavy metals in soil [38-39]. This could potentially favor the precipitation and bioaccumulation of heavy metals in soil [21];31], such as Mn, Zn, and Ni [31]. The percentage of TOC and TOM obtained for the respective soils ranged from 3.92±1.80 to 9.50±3.00 and 2.16±1.89 to 5.18±1.90. These percentages were higher than those of [40] who reported 0.028-0.409 and 0.048-0.707%. The carbon content and organic matter in the various dumpsite soils were significantly higher than those of the control soil samples respectively. The higher percentage of the concentration of organic matter in the examined soils could be attributed to the presence of organic waste residues which add more organic matter when decomposed. The elevated amount of organic carbon in the vicinity of dumpsites could be suggestive of possible degradation or the presence of degradable and compostable wastes [41].

At the Nekede dump site; the phosphate value varied from 33.10±11.01 - 46.50±6.09 mg/kg, Nitrate, 8.30±4.01-10.70±5.09 mg/kg, and Sulphate, 12.10±6.03 - 20.70±13.10 mg/kg, compared to Chukwuma Nwaoha dump site with Phosphate 44.00±11.7- 90.01±9.44 mg/kg, Nitrate, 10.80±5.50 - 20.00±8.03c mg/kg and Sulphate, 17.00±5.81 - 40.55±10.33 mg/kg. In both dumpsites, the Phosphate, Nitrate, and Sulphate levels were significantly ($P < 0.05$) higher in the soils from the different sampled locations compared to the control sites. This corroborates the findings of [33]. The mean values of the nutrient content of the soil, phosphate, nitrate, and sulfate followed the trend Phosphate >Sulphate> Nitrate. A study by [37] slightly differed in trend as follows- Phosphate >Nitrate >Sulphate, but conformed to the concentration of the nutrients of the prevailing study. The active dumpsite contained more nutrients than the control. This could be an indication of dumpsite-aided contamination [19]. So there is a tendency to produce a low-grade chronic metabolic acidosis and then hypercalciuria, calcium release from the bone with setting in of osteoclast [39]. Application of fertilizers for soil enhancement for farming purposes could exceed the absorption capacity of the crops on the farm and accumulate in the soil. Hence there is the possibility of leaching soluble phosphate, as well as nitrate into the surface and groundwater where they could pollute surface and groundwater aquifers (Galoo and Ventresca, n.d). Nitrate (NO^3) compound is important for fertilizing plants, but a dangerous contaminant of groundwater. Phosphate is one of the key nutrients found in fertilizers and is also necessary for plant growth (Gallo and Ventrescan.d). Discharge of substances containing nitrate or phosphate into aquatic ecosystems could induce eutrophication, which is an excess enrichment of a body of water with minerals and nutrients, causing an extreme increase in plants and algae [42]. This could deplete available oxygen in the aquatic ecosystem [43] with consequent adverse impacts on the aquatic ecosystem such as the creation of a 'dead zone' (Gallo and Ventrescan.d). Hence oxygen available to the organism is highly reduced and may cause death. With increased nitrate load in a biological system, there could be biotransformation which may cause the formation of metabolites such as nitrosamine resulting in carcinogenesis, teratogenesis, and juvenile methemoglobinemia [43]. In school children, their thyroid gland state as regards size and functionality has been reported as adversely affected by nitrate-contaminated drinking water [44]. The exchangeable cations: calcium, sodium, magnesium, and potassium across the sample areas also varied from 35.160±11.2 - 37.620±11.9 mg/kg; 8.720±3.91- 12.770±8.22 mg/kg; 10.340±5.01- 17.860±6.10 mg/kg and 0.660±0.01-1.940±0.88mg/kg for Nekede while in the same vain, Chukwuma Nwaoha recorded 40.90±17.08- 44.560±19.02 mg/kg; 10.500±5.02- 13.018±6.91 mg/kg; 12.140±4.99-16.040±3.09 mg/kg and 32.600±11.59- 43.640±14.80 mg/kg.

Figure 2 shows soil particle size characteristics in the two locations where the dumpsites are located. While the Nekede dumpsite vicinity has more sandy soil with a mean value of about 53%, clay formed the foremost part of the soil structure at the Chukwuma Nwaoha axis with 58.50%. In both sites, silt was the lowest with about 10.6% and 7% recorded at Nekede and Chukwuma Nwaoha axis respectively. The high proportion of sand in the soil samples for the operational dumpsite bared the sandy loamy texture class of the dumpsite waste [4]. Hence there could be poor metal retention capacity at the Nekede dumpsite. According to [4], there is a decrease in the retention potential of soil as clay content decreases.

Table 1: Mean Physicochemical features of soil at Nekede and Chukwuma Nwaoha dumpsite vicinity

Locations	**NEKEDE AREA**			**CHUKWUMA NWAOHA AREA**		
	NKSS1	NKSS2	NKSSC	CNSS1	CNSS2	CNSSC
GPS Location	N05.46405 E07.03067	N5.46896 E07.04138	N5.47168 E07.04167	N5.46527 E07.02983	N5.46549 E07.02989	N5.46304 E07.02871
Parameters						
EC (µS/cm)	103.10±5.48^{a}	127.47±9.02^{ab}	99.01±28.91^{c}	126.90±11.09^{ab}	128.88±19.09^{b}	87.95±6.91^{cb}
pH	5.86±1.06^{a}	5.73±1.01^{a}	4.17±1.10^{b}	6.78±1.00^{a}	5.45±2.10^{ab}	4.11±2.40^{b}
TOC (%)	7.30±2.03^{a}	3.92±1.80^{b}	0.70±0.12^{c}	9.50±3.00^{d}	5.40±2.10^{ab}	1.52±0.30^{c}
TOM (%)	5.18±1.90^{a}	4.31±1.20^{b}	1.69±0.36^{c}	2.16±1.89^{ac}	3.52±2.15^{b}	1.10±0.41^{c}
Phosphate (mg/kg)	46.50±6.09^{a}	45.04±7.21^{b}	33.10±11.01^{a}	90.01±9.44^{c}	60.20±7.20^{d}	44.00±11.7^{a}
Nitrate (mg/kg)	10.70±5.09^{a}	8.30±4.01^{a}	9.10±5.01^{a}	20.00±8.03^{c}	17.55±11.29^{b}	10.80±5.50^{a}
Sulfate (mg/kg)	20.70±13.10^{c}	12.70±6.01^{a}	12.10±6.03^{a}	40.55±10.33^{c}	35.01±14.88^{c}	17.00±5.81^{b}
Calcium (mg/kg)	35.160±11.2^{a}	36.580±15.33^{a}	37.620±11.9^{a}	43.800±20.04^{b}	40.90±17.08^{b}	44.560±19.02^{b}
Sodium (mg/kg)	12.770±8.22^{b}	9.650±11.60^{a}	8.720±3.91^{a}	10.500±5.02^{a}	11.17±6.90^{b}	13.018±6.91^{b}
Potassium (mg/kg)	17.860±6.10^{c}	15.040±3.09^{c}	10.340±5.01^{a}	16.040±3.09^{c}	17.380±5.12^{c}	12.140±4.99^{a}
Magnesium (mg/kg)	1.940±0.88^{a}	1.520±1.00^{a}	0.660±0.01^{a}	32.600±11.59^{b}	35.580±12.10^{b}	43.640±14.80^{a}

Values are Mean ± SD of three replicates. Different superscripts in the same column indicate significant differences at $p < 0.05$ according to Duncan Multiple Range Test (DMRT).

The implication could be the infiltration of large amounts of leachate due to waste degradation into groundwater as time goes on due to weakly buffered soil. The soil particle size relative abundance as observed for the Chukwuma Nwaoha dumpsite was silt < sand< clay while for the Nekede dumpsite, it was silt < clay< sand as displayed in Figure 3. The Chukwuma Nwaoha dumpsite result differs from the work of [44] who observed clay < silt < sand, which is in tandem with works by [45]; [23]; and [46] who reported high sand constitution of soil in Southeast Nigeria. The difference in the observed trend for the two dumpsites could be attributed to anthropogenic activities taking place at the sites.

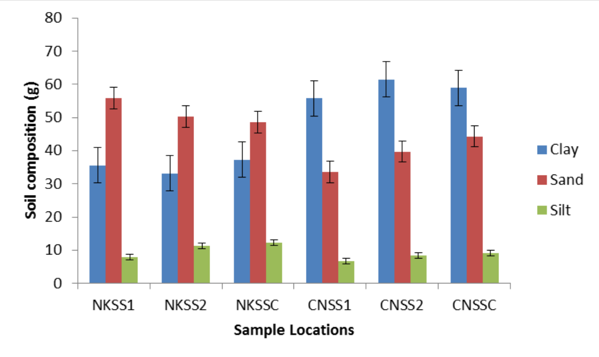

Figure 2: Soil Textural composition around dumpsite in Nekede and Chukwuma Nwaoha Dumpsites. *Values are Mean ± SD of three replicates.*

Table 2 summarizes the microbial status of soil around the Nekede and Chukwuma Nwaoha Area dumpsites. There is a detectable amount of microbial activity in the soil of both dumpsites. As displayed in Table 2, a THB bioload average of 3.77±1.48^4 and 2.61±2.06^4 CFU/mL for Nekede Area and 3.01±1.17 and 3.85±2.81 CFU/mL for Chukwuma Nwaoha Area respectively were recorded. The bacterial counts in soils from the dumpsites were significantly higher than those of the control soil (2.91±0.51^4). For the THF, the average was 4.97±2.17^4 and 2.13±0.91^4 CFU/mL for Nekede Area. THF average value for the Chukwuma Nwaoha area was 2.55±1.81^4 and 1.79±1.88^4 CFU/mL, with a corresponding 2.10±0.41^4 value for the control area.

Values are Mean ± SD of three replicates. Different superscript in the same column indicates significant differences at p < 0.05 according to Duncan Multiple Range Test (DMRT). THB and THF Total Bacterial and Fungal counts. The isolation and identification of microbes such as *Acinetobacter sp., Pseudomonas sp., Micrococcus sp. Bacillus sp., Klebsiella sp., Enterobacter sp. Aspergillus sp., Penicillium sp., Mucor sp*., and *Fusarium sp*. in the two dumpsite soils corroborates the report by [20] who isolated similar microorganisms from a municipal waste dumpsite in Benin City. All the microbial isolates identified from the soil samples have been previously reported to be associated with waste biodegradation [31]. There were noteworthy variations in the Percentage frequency of occurrence of the microbial isolates for the two dumpsites as shown in Figure 3. The percentage frequency of the bacterial isolates from the two waste dumpsite soils fluctuated as follows: Klebsiella sp. (13%), Staphylococcus sp. (14%), Pseudomonas sp. (10%), Bacillus sp. (8%), Micrococcus sp. (5%), Acinetobacter sp. (3%), Enterobacter sp. (10%), while fungi species encountered were: Pennicilium sp. (12%), Fusarium sp. (7%), Aspergillus niger (5%), and Mucor sp. (13%) respectively. This is in line with the report of [46] who identified similar microbes at Orji and Naze Dumpsite in Owerri Imo State. The observation in this study was also in line with that of [44] who identified the presence of *Bacillus* and *Staphyloccocus* from a waste dumpsite located at Eagle Island, River State. A study by [31] also recorded similar observations at Electronic Waste Dumpsite in Port Harcourt Metropolis, River state. Most of the bacterial species encountered at the dumpsites have been implicated as opportunistic human pathogens [22]. As reported by [47], though positive species such as Staphylococcus aureus have high pathogenic effects in recent times Staphylococcus epidermidis has emerged as a nosocomial pathogen in individuals with compromised immune systems. According to [48-50], the open dumping of wastes could function as a breeding ground for disease vectors such as flies, mosquitoes, cockroaches, rats, and other pests. The microorganisms found in these dumpsites get their nutritional requirement from the wastes, hence the high bacterial growth profile in the waste dumpsites [19]. The microbial isolates identified from the soil samples have been reported to be associated with waste and waste biodegradation [23]. Also, *Aspergillus, Fusarium, Mucor, Penicillium, and Rhizopus* have been reported to participate in waste biodegradation [44]. This should be the case in this study which further suggests the participation of these bacteria and fungi in waste biodegradation.

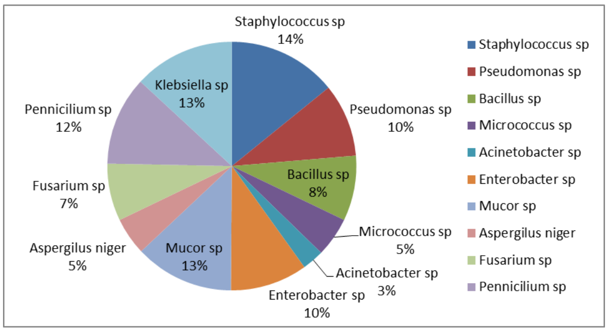

Figure 3: Percentage frequency of occurrence of the microbial isolates from the dumpsites

Correlation analysis was carried out in other to understand the strength of the relationship between THB and THF with the soil properties and the result is displayed in Table 4.

Table 2: Total Bacterial and Fungal counts of the surface soil samples from the dumpsites

	NEKEDE AREA			CHUKWUMA NWAOHA AREA		
	NKSS 1	NKSS 2	NKSSC	CNSS1	CNSS2	CNSSC
Parameter						
THB (×10^{4}cfu/g)	3.77±1.48	2.61±2.06	1.33±0.49	3.01±1.17	3.85±2.81	3.36±1.43
THF (×10^{4}cfu/g)	4.97±2.17	2.13±0.91	1.85±3.30	2.55±1.81	1.79±1.88	2.51±1.06
Control	**2.91±0.51**			**2.10±0.41**		

Table 3: Pearson Correlation Coefficient between physicochemical properties and mean microbial counts of the soil samples at the dumpsites

	THB ($\times10^4$cfu/g)	THF($\times10^4$cfu/g)
EC (µS/cm)	-0.337*	0.153
pH	0.031	0.281**
TOC (%)	0.017	0.002
TOM (%)	-0.441	0.071
Phosphate (mg/kg)	0.183	0.309
Nitrate (mg/kg)	-0.273**	0.401**
Sulphate (mg/kg)	0.588*	-0.341*
Calcium (mg/kg)	0.141	0.620
Sodium (mg/kg)	0.161	0.304
Potassium (mg/kg)	0.382*	0.381*
Magnesium (mg/kg)	-0.331	0.276**

***NOTE**: ** = Correlation is significant at the 0.01 level (2-tailed). *=Correlation is significant at the 0.05 level (2-tailed).*

Results obtained revealed that EC, Nitrate, Sulphate, Potassium, and Magnesium correlated negatively but weakly with the total bacterial count (r = -0.337), (r = -0.273), (r = 0.588), (r = 0.382) and (r = -0.331) respectively at a $p < 0.01$ significant level. This inverse relationship may be attributed to the high level of EC, sulfate, Potassium, Magnesium, and nitrates which may become toxic to the bacterial populations. pH correlated positively but weakly with the total fungal count (r = 0.281; at $p < 0.05$). The weak positive association could be attributed to the moderate acidic pH level of the soil due to anthropogenic activities around the areas. Nitrate, Sulphate, Potassium, and Magnesium correlated positively with THF (r =0.401), (r =-0.341), (r = 0.381), and (r = 0.276) at $p < 0.01$. The high soil fungal counts could be attributed to the greater availability of nitrates nutrients which could be a result of the increased accumulation of biodegradable wastes at the dumpsites [13].

4 Conclusion

The crux of this study was to appraise the physicochemical and microbial load in the soil in the vicinity of Open Waste Dumpsites in Owerri, South-Eastern Nigeria. This study revealed the presence of a high microbial load which could be associated with the increased nitrate, phosphate, and organic matter levels established in the examined dumpsite soils. These waste sites could be a potential source of infections to the inhabitants living around the open waste dumpsites which in turn could lead to public health problems arising from the spread of communicable diseases carried by potentially pathogenic bacteria and fungi occurring in the waste dumpsite soils. Hence, the government should collaborate with relevant agencies or public-private partnerships on large-scale investment in the proper management of municipal waste using sustainable alternatives such as recycling and energy generation from municipal waste.

5 Recommendations

- We recommend continuous monitoring at major dumpsites within the city.
- Stricter environmental policies should be implemented as a matter of urgency.
- There is therefore an urgent need for remediation technology and management of the contaminated soils in this study sites to render them fit for ecosystem health.
- Again, the provision of adequate waste collection facilities can improve the collection and management of municipal solid waste.
- Further studies should be carried out on water bodies around the dumpsites.

Ethical issue

Authors are aware of and comply with, best practices in publication ethics specifically about authorship (avoidance of guest authorship), dual submission, manipulation of figures, competing interests, and compliance with policies on research ethics. Authors adhere to publication requirements that the submitted work is original and has not been published elsewhere in any language. Also, all procedures performed in studies involving human participants were following the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. All procedures performed in this study involving animals were following the ethical standards of the institution or practice at which the studies were conducted.

Competing interests

The authors declare that no conflict of interest would prejudice the impartiality of this scientific work.

Authors' contribution

All authors of this study have a complete contribution to data collection, data analyses, and manuscript writing.

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