Isolation and Characterization of Bacteria from Municipal Solid for Production of Enzymes for Waste Degradation

Dr. Chime Emmanuel Uchenna[1], Godwin Umoren Akpan (Professor)[2], Ibeh Chukwuebuka Ugochukwu[3]

[1,2]Soil Science and Land Resources Management, University of Uyo, Uyo, Nigeria

[3]Department of soil science, Nnamdi Azikiwe University, Awka Anambra State, Nigeria.

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ABSTRACT

Microorganisms involved in the biodegradation of municipal solid waste (MSW) in Uyo dumps were isolated and characterized using standard microbiology technique. Three municipal solid waste (Uyo Village Road, Calabar Itu Road and Eka Street) dumpsites along with control soil from University farm land, all located within Uyo metropolis, Akwa Ibom State, Nigeria were used for this study. The Research was carried out between July 2023 – August, 2024. The soil samples were collected in triplicate at a depth of 2cm-20cm with the aid of a soil auger. Physicochemical analysis of the dumpsite soils revealed elevated levels of nutrients as compared to the control soil sample. The pH of the dumpsite soils was all alkaline amylase, lipase, pectinase, xylanase, and phytase, highlighting the significant biodegradation potential of the microbial isolates. Cellulase activity peaked at Uyo Village dumpsite (66.56 U/mL), while protease activity was highest at Eka Street dumpsite (62.35 U/mL). Amylase activity was most prominent at Calabar Itu dumpsite (45.38 U/mL). Lipase and pectinase activities were highest at Eka Street (42.19 U/mL and 43.17 U/mL, respectively), whereas Uyo Village demonstrated with a pH value ranging from 7.04-7.42. Heavy metal analysis revealed permissible levels of lead (7.99±0.00mg/kg–8.72 ±0.04 mg/kg), cadmium (11.99±0.01–12.41±0.05 mg/kg), Cr (4.01±0.03–4.08±0.03 mg/kg) in the dumpsites, although these values were higher than the control. Enzymatic activities were assessed for cellulase, protease, the highest activities for xylanase (28.38 U/mL) and phytase (30.07 U/mL). The dumpsites exhibited higher microbial count as compared to the control sample. Highest total heterotrophic bacterial count was recorded at Uyo village dumpsite soil with a value of $1.97 \times 10^7 \pm 0.47$ CFU/g.The microbial isolates predominantly included *Pseudomonas aeruginosa*, *Bacillus subtilis*, *Micrococcus sp, Chromatium sp and Bacillus megaterium* which are known for their enzymatic capabilities with *Bacillus s*pp exhibiting highest degradation ability as compared to the other isolates in the study area. However, in this study, 14 bacterial were identified and 4 bacterial strains were subjected qualitative analysis for production of seven different enzymes. In this study 4 of the isolates showed greater production of cellulase, protase, amylase, lipase, pectinase, oxylanase and phytase enzymes which has high market values. The study demonstrates that MSW dumpsites are reservoirs of microbial communities capable of producing industrially significant enzymes, essential for organic waste degradation.

Keywords: Bacterial isolates, Dumpsites, Enzyme activity, Waste degradation, Heavy metals, Uyo, Nigeria

INTRODUCTION

Rapid population growth, urbanization, and changing consumption patterns have led to a substantial increase in the generation of municipal solid waste (MSW) across developing countries, including Nigeria. Poor waste management practices particularly indiscriminate dumping—have resulted in numerous open dumpsites within urban centers, which pose significant environmental and public health hazards. These sites are sources of leachate pollution, greenhouse gas emissions, and soil degradation, but they also harbor rich microbial communities capable of transforming organic waste through enzymatic degradation (Saibu *et al*., 2023; Janeeshma, 2024).

Microorganisms in dumpsite soils have evolved diverse enzymatic systems to metabolize the heterogeneous organic substrates found in waste materials. Bacteria such as *Pseudomonas aeruginosa* and *Bacillus subtilis*, along with fungi including *Aspergillus niger* and *Candida* species, are commonly reported in municipal dumpsites and are known producers of extracellular enzymes such as cellulases, proteases, amylases, lipases, xylanases, pectinases, and phytases (Okoth *et al*., 2025; Rosas-Vega, *et al*., 2025). These enzymes play critical roles in breaking down complex polymers into simpler molecules, thereby facilitating organic matter turnover, nutrient cycling, and carbon dioxide (CO_2) release during microbial respiration (Hussain, *et al*., 2025; Salinas, *et al*., 2025).

Dumpsite microbial activity is strongly influenced by the physicochemical characteristics of the waste and soil environment particularly pH, moisture content, organic carbon, total nitrogen, and heavy metal concentrations. These environmental factors determine microbial abundance, enzyme expression, and waste degradation efficiency (Adhikari *et al*., 2022; Chukwu *et al*., 2021).

However, limited information exists on how these parameters interact in Nigerian dumpsites, especially in Akwa Ibom State, where varying waste composition and climatic conditions may shape microbial functionality differently from other regions. Furthermore, there is a scarcity of studies integrating enzyme quantification, degradation potential (measured through CO_2 evolution and weight loss), and multivariate statistical analysis such as Principal Component Analysis (PCA) to explain the relationships between microbial activity and environmental factors.

This research was therefore designed to assess the bacterial communities in selected municipal dumpsites within Uyo, Akwa Ibom State namely Uyo Village Road, Calabar-Itu Highway, and Eka Street with a control site from the University of Uyo research farm. The study aimed to characterize dominant bacterial isolates, determine their enzyme production potential, and evaluate their waste degradation efficiency under controlled laboratory conditions. The findings provide insights into the functional capacity of bacterial populations in municipal dumpsite soils and their possible application in biotechnological and environmental waste management interventions.

MATERIALS AND METHODS

Study Area

The study was conducted in Uyo, Akwa Ibom State, Nigeria (latitude 5°01′N and longitude 7°56′E), which lies within the humid tropical rainforest zone of southern Nigeria. The area experiences a bimodal rainfall pattern, with an annual precipitation range of 2,000–3,000 mm and a mean temperature of 26–30 °C. Three municipal solid waste dumpsites Uyo Village Road (5.035°N, 7.927°E), Calabar-Itu Highway (5.080°N, 7.937°E), and Eka Street (5.050°N, 7.925°E) were selected for sampling, along with a control soil sample collected from the University of Uyo research farm (5.042°N, 7.920°E), an area not directly impacted by waste deposition.

Soil Sample Collection

Soil samples were collected from the surface layer (0–20 cm) of each dumpsite using a sterile soil auger. Five subsamples were taken from each location and homogenized to form a composite sample. The samples were placed in sterile polyethylene bags, labeled accordingly, transported on ice to the Microbiology Laboratory of the University of Uyo, and stored at 4 °C prior to analysis.

Determination of Physicochemical Properties

The physicochemical properties of the soil including pH, electrical conductivity (EC), organic carbon, total nitrogen, and organic matter were determined following standard methods. Soil pH was measured in a 1:2.5 soil-to-water suspension using a calibrated pH meter (Model HI2210, Hanna Instruments, USA). Electrical conductivity was determined using a conductivity meter. Organic carbon was determined by the Walkley Black dichromate oxidation method, and total nitrogen was analyzed using the Kjeldahl digestion technique (Bremner, 2019). Organic matter was estimated by multiplying the organic carbon value by a factor of 1.724.

Heavy Metal Analysis

Heavy metals including iron (Fe), zinc (Zn), lead (Pb), nickel (Ni), cadmium (Cd), and chromium (Cr) were analyzed using Atomic Absorption Spectrophotometry (AAS, Model AA-7000, Shimadzu, Japan). One gram of air-dried soil sample was digested with a mixture of HNO_3, $HClO_4$, and H_2SO_4 (5:2:1 v/v/v) following standard protocols (APHA, 2017). The digested samples were filtered and diluted to 50 mL with deionized water prior to reading. The metal concentrations were expressed in mg/kg and compared against international permissible limits recommended by the World Health Organization (WHO, 2021) and the Food and Agriculture Organization (FAO, 2020).

Isolation and Identification of Bacterial Isolates

Serial dilution and pour plate techniques were used for bacterial isolation. One gram of soil was serially diluted up to 10^{-6} in sterile saline solution. Aliquots of 0.1 mL from appropriate dilutions were inoculated onto nutrient agar plates and incubated at 37 °C for 24–48 hours. Distinct colonies were sub-cultured to obtain pure cultures. Identification was carried out based on colonial morphology, Gram staining, and biochemical characterization following the schemes of Cowan (1974) and Buchanan and Gibbons (1974). The dominant bacterial isolates identified were *Pseudomonas aeruginosa* and *Bacillus subtilis*, while the predominant fungi were *Aspergillus niger* and *Candida* spp.

Enzyme Assay Procedures

The activities of cellulase, protease, amylase, lipase, xylanase, and pectinase were determined using culture supernatants obtained after centrifugation of microbial broth cultures at 10,000 rpm for 15 minutes.

- **Cellulase Activity:** Determined using the dinitrosalicylic acid (DNS) method with carboxymethyl cellulose as substrate (Bernfeld, 1955).
- **Protease Activity:** Determined using casein as substrate, and tyrosine liberated was measured at 280 nm (Hagerman and Austin, 1986).
- **Amylase Activity:** Determined using soluble starch as substrate, and reducing sugars released were measured with DNS reagent (Ladd and Butler, 2016).
- **Lipase Activity:** Measured using p-nitrophenyl palmitate (pNPP) as substrate (Bailey, Biely, and Poutanen, 1992).
- **Pectinase Activity:** Determined using pectin substrate and galacturonic acid standard curve (Grenier, Antier, and Wicker-Planquart, 2001).
- **Xylanase Activity:** Determined using birchwood xylan as substrate, and reducing sugars were measured by the DNS method.

All enzyme activities were expressed in international units (IU/mL), where one unit of enzyme activity was defined as the amount of enzyme required to release 1 μmol of product per minute under assay conditions.

Statistical and Multivariate Analysis

All data were subjected to one-way analysis of variance (ANOVA) using SPSS version 20.0, and means were compared using Duncan's Multiple Range Test at $p < 0.05$. Correlation analysis was performed to examine the relationships among physicochemical and microbial parameters. Principal Component Analysis (PCA) was used to identify the most influential variables contributing to enzymatic activity and waste degradation potential.

RESULTS AND DISCUSSIONS

Total Heterotrophic Bacterial Count (THBC)

The Total Heterotrophic Bacteria count is higher at the dumpsites (Uyo village, Calabar Itu, and Eka street) than at the control site. The Uyo village dumpsite had the highest THB count ($1.97 \times 10^7 \pm 0.47$ CFU/g). This can be attributed to the large volume of waste generated in the area, especially due to its proximity to urban centers and industries. The THB count at the Calabar Itu dumpsite was slightly lower than that at the Uyo village dumpsite, with a value of $1.94 \times 10^7 \pm 0.49$ CFU/g. The Eka street dumpsite had the lowest THB count among the dumpsites, at $1.58 \times 10^7 \pm 0.38$ CFU/g. The control sample, which represents an area less affected by municipal waste, showed a THB count of $1.47 \times 10^7 \pm 1.91$ CFU/g (Tables 4.5 and 4.8). The Total Heterotrophic bacterial count (THBC) content of the soils of the study area significantly vary at ($P<0.05$) level of significance. The bacterial strains isolated from the dumpsites were: *Bacillus cercus*, *Bacillus sublilis*, *Eschericha coli*, *Micrococcus* sp, *Serrati* asp, *Pseudomonas aeruginosa*, *Staphylococus albus*, *Klebsiella* sp, *Vibriohaemolyticus*, *Chromatium* sp, *Vibrio cholera*, *Clostridum* sp, *Citrobacter* sp, *Pseudomonas putida* and *Bacillus megaterium*.

The significantly higher Total Heterotrophic Bacterial Count (THBC) recorded at the municipal dumpsites compared to the control soil clearly reflects the strong influence of solid waste accumulation on microbial proliferation. Dumpsite soils are typically enriched with readily degradable organic substrates, including food residues, paper, plant materials, and other biodegradable wastes, which provide energy and nutrient sources that stimulate heterotrophic bacterial growth. The elevated THBC observed at the Uyo village dumpsite suggests that this site experiences more intense anthropogenic input, likely due to higher waste volume and diversity associated with its proximity to densely populated and commercial areas. Similar trends have been reported in dumpsite soils across southern Nigeria, where increased waste loading consistently resulted in higher bacterial densities relative to uncontaminated control soils (Adeleke and Ogunseitan, 2021; Adebayo and Ojo, 2022).

The comparatively lower THBC observed at the Eka Street dumpsite, although still significantly higher than the control, may be linked to differences in waste composition, moisture regime, waste age, and frequency of waste deposition. These factors are known to influence microbial colonization and metabolic activity in dumpsite environments. Studies conducted in urban dumpsites in Uyo and other parts of the Niger Delta have demonstrated that sites receiving heterogeneous and frequently replenished waste tend to support higher heterotrophic bacterial populations than sites with older or less diverse waste materials (Chukwu and Nwankwo, 2022; Komolafe and Adegunloye, 2021).

The significantly lower THBC recorded in the control soil is consistent with its relatively undisturbed nature and limited organic inputs. Natural soils without continuous organic waste amendment generally support lower heterotrophic bacterial populations due to reduced substrate availability. This observation aligns with findings from previous studies in southeastern Nigeria, which reported that background soils away from waste disposal sites exhibit comparatively lower microbial biomass and activity (Okoro and Nwachukwu, 2020; Nnadi and Udeh, 2019).

The diverse array of bacterial species isolated from the dumpsites further underscores the role of municipal solid waste as a reservoir for metabolically versatile microorganisms. The dominance of genera such as *Bacillus*, *Pseudomonas*, *Micrococcus*, *Serratia*, and *Clostridium* is particularly significant, as these groups are well known for their ability to degrade a wide range of organic compounds through the production of extracellular enzymes. *Bacillus* species, including *Bacillus subtilis* and *Bacillus megaterium*, are frequently reported in dumpsite soils due to their spore-forming ability and resilience under fluctuating environmental conditions, as well as their strong enzymatic capabilities in degrading cellulose, proteins, and lipids (Akinmoladun and Ojo, 2021; Kong and Singh, 2022).

The presence of *Pseudomonas aeruginosa* and *Pseudomonas putida* is also noteworthy, as these organisms are recognized for their metabolic flexibility and efficiency in decomposing complex organic substrates in waste-impacted soils. Their occurrence has been widely documented in municipal dumpsites in Nigeria and other developing countries, where they contribute significantly to organic matter turnover and waste stabilization processes (Ogugbue and Sawidis, 2020; Gao and Zhang, 2019). Similarly, the isolation of *Clostridium* species indicates active anaerobic micro-zones within the dumpsite soils, which are typical of compacted waste environments with limited oxygen diffusion (Akinola and Eze, 2020).

However, the detection of potentially pathogenic bacteria such as *Escherichia coli*, *Vibrio cholerae*, *Vibrio haemolyticus*, *Klebsiella* species, and *Staphylococcus albus* raises important public health concerns. These organisms are commonly associated with fecal contamination and improperly managed waste and have been reported in several Nigerian dumpsite studies. Their presence highlights the risks associated with open dumping practices, including the potential contamination of nearby soil, water resources, and food crops (Ejidike and Okonkwo, 2020; Obiri and Yeboah, 2019).

Overall, the significantly higher THBC and broad bacterial diversity observed in the dumpsite soils demonstrate that municipal solid waste disposal strongly enhances microbial abundance and diversity, thereby creating biologically active environments capable of substantial organic waste degradation. These findings support the suitability of dumpsite soils as sources of indigenous bacteria with potential applications in waste biodegradation and bioremediation, while simultaneously emphasizing the need for improved waste management strategies to mitigate associated environmental and health risks.

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Table Biochemical Characterization and Identification of Bacterial Strains Isolated from Municipal Waste Samples.

Gram Reactions	Shape	Catalase	Coagulase		Motility	Starch hydrolysis	Citrate	Urease	MR	VP	Spore formation	H2S	Oxidase	Indole	Glucose	Maltose	Xylose	Lactose	Fructose	Sucrose	Mannitol	Galactose	Probable organisms
+ve	rod	+	-		+	+	-	-	-	+	+	-	-	-	AG	A	-	-	A	A	-	A	Bacillus cercus
+ve	rod	+	-		+	+	+	-	-	+	+	-	-	-	AG	A	A	-	A	-	-	A	Bacillus sublilis
-ve	rod	+	-		+	-	-	-	+	-	-	-	-	+	AG	AG	A	-	-	-	AG	-	Escherichia coli
+ve	Cocci in chains	+	-		-	+	-	-	+	-	-	-	-	-	A	A	-	A	A	-	-	A	Streptococcus sp
+ve	Coccin pairs	+	-		-	+	+	+	+	-	-	-	+	-	-	A	A	-	A	-	A	A	Micrococcus sp
+ve _	rod	+	-		+	+	+	_-	-	+	-	-	-	-	-	-	AG	-	-	-	AG	A	Serratia sp
-ve	rod	+	-		+	-	+	-	-	+	-	+	-	+	A	-	-	AG	AG	AG	AG	AG	Pseudomonas
+ve	Cocci in clusters	+	-		-	-	+	-	-	+	-	-	-	-	A	A	-	-	A	A	AG	A	Staphylococus albus
-ve	rod	+	-		+	+	-	-	-	+	-	-	-	-	A	AG	AG	AG	-	-	AG	-	Klebsiella sp
-ve	rod	+	-		+	-	-	+	+	-	-	+	-	-	AG	A	-	AG	AG	AG	-	AG	Proteus sp
+ve	Cocci in short chain	-	-		-	+	-	+	-	+	-	+	-	-	A	AG	A	AG	AG	-	AG	AG	Enterococcus sp
+ve	Cocci in clusters	+	+		-	-	+	-	-	+	-	-	-	-	AG	A	AG	-	A	A	AG	A	Staphylococus aureus
-ve	comma	+	-		+	+	+	-	-	+	-	-	+	-	A	A	-	-	A	AG	A	A	Vibrio haemolyticus
+ve	rod	+	+		-	+	+	+	-	+	-	-	-	-	A	A	-	-	A	A	A	AG	Chromatium sp
-ve	comma	+	-		+	+	+	-	-	+	-	-	+	-	A	A	-	-	A	A	-	A	Vibrio cholerae
+ve	Drum stick	-	-		-	+	+	-	-	+	+	+	-	-	AG	A	-	A	A	AG	-	A	Clostridium sp
-ve	Short rod	+	-		+	-	+	-	+	-	-	-	-	-	AG	AG	AG	AG	-	-	A	-	Citrobacter sp
-ve	rod	+	-		+	-	+	-	+	-	-	+	-	-	A	A	A	-	-	-	AG	-	
-ve	rod	+	-		+	-	-	-	+	-	-	+	-	-	A	AG	A	-	-	AG	AG	A	
-ve	rod	+	-		+	-	+	-	-	+	-	-	+	+	A	A	A	-	A	-	-	-	
+ve	rod	-	-		+	+	-	+	-	+	-	-	-	-	AG	AG	A	-	A	AG	-	A	
-ve	rod	+	-		+	+	-	-	+	-	+	-	-	-	A	AG	AG	AG	-	-	A	-	Klebsiella sp
-ve	rod	+	-		+	-	-	-	-	+	-	-	-	+	AG	AG	A	-	-	-	AG	-	Enterobacter sp
Source: Field data (2024)																							

Heavy Metals

Iron

Iron concentrations were significantly higher at the dumpsites than the control (P < 0.05), with Uyo Village 1803.72 ± 5.66 mg/kg, Eka Street 1800.03 ± 9.09 mg/kg, and Calabar Itu 1769.68 ± 69.06 mg/kg. The control soil had 1657.41 ± 46.39 mg/kg. Although Fe is an essential micronutrient for microbial metabolism and enzyme co-factors, excessive accumulation may alter soil structure and reduce bioavailability of other nutrients (Adeleke and Ogunseitan, 2021). However, the Fe levels recorded are below the FAO/WHO guideline of 10,000 mg/kg for agricultural soils, indicating that Fe enrichment, while elevated, is not likely to be ecotoxic (FAO/WHO, 2020).

Zinc (Zn)

Zinc levels were elevated at all dumpsites, with Uyo Village (145.33 ± 6.12 mg/kg) showing the highest concentration, followed by Eka Street (144.03 ± 6.16 mg/kg) and Calabar Itu (142.68 ± 4.77 mg/kg). The control soil recorded 120.40 ± 5.13 mg/kg. Zinc is essential for microbial enzymatic functions but can be toxic at high concentrations. According to FAO/WHO (2020), the permissible limit for Zn in agricultural soils is 300 mg/kg. Therefore, the measured values are within safe limits, and unlikely to cause significant toxicity to soil microbes or plants. Nonetheless, chronic accumulation in waste-affected areas could pose long-term risks if soils are used for cultivation (Obiri and Yeboah, 2019).

Heavy metal content in the study area

Location	Fe (mg/kg)	Zn (mg/kg)	Pb (mg/kg)	Ni (mg/kg)	Cd (mg/kg)	Cr (mg/kg)
Uyo village	1803.72±5.66	145.33±4.66	8.56±0.22	11.31±0.51	12.4±0.05	4.08±0.03
Calabar Itu	1769.68±69.06	144.03±6.16	7.99±0.00	11.28±0.47	11.99±0.01	4.01±0.03
Eka street	1800.03±9.09	146.02±0.21	8.72±0.04	11.91±0.07	12.35±0.05	4.03±0.05
Control	1657±46.39	120.40±5.13	5.11±0.48	5.99±2.20	5.65±1.74	3.00±0.56
LSD (P<0.05)	**0.01**	**0.00**	**0.00**	**0.01**	**0.00**	**0.04**

Source: Field data (2024)

Lead (Pb)

Lead concentrations were elevated in all dumpsites, with Eka Street (8.72 ± 0.04 mg/kg) highest, followed by Uyo Village (8.56 ± 0.22 mg/kg) and Calabar Itu (7.99 ± 0.00 mg/kg). The control soil had 5.11 ± 6.48 mg/kg. The FAO/WHO permissible limit for Pb in agricultural soils is 100 mg/kg, and the NESREA (2020) standard is 85 mg/kg. All measured Pb levels are well below the thresholds, indicating low immediate risk; however, Pb is persistent in soils and can bioaccumulate in crops over time, especially in high-waste areas, potentially impacting food safety and microbial enzyme activity (Ejidike and Okonkwo, 2020; Gao and Zhang, 2019).

Nickel (Ni)

Nickel concentrations ranged from 11.28–11.91 mg/kg in the dumpsites and 5.99 ± 2.20 mg/kg in the control. FAO/WHO recommends a maximum of 50 mg/kg for Ni in agricultural soils. All values are below this limit, indicating that Ni enrichment is not currently toxic, but localized hotspots in waste dumps may influence microbial metabolism and the composition of decomposer communities (Kong and Singh, 2022).

Cadmium (Cd)

Cadmium concentrations were the highest among the measured metals, with Uyo Village 12.4 ± 0.05 mg/kg, Eka Street 12.35 ± 0.05 mg/kg, and Calabar Itu 11.99 ± 0.01 mg/kg, while the control had 5.65 ± 1.74 mg/kg. The FAO/WHO permissible limit for Cd in agricultural soils is 3 mg/kg, and the NESREA limit is 3 mg/kg as well. These results indicate that Cd levels in the dumpsites are significantly above safe thresholds, highlighting a high ecological and health risk. Cd is highly toxic to soil microbes, can inhibit enzymatic activity, and poses a serious risk of bioaccumulation in crops and water sources (Adhikari *et al*., 2022; Obiri and Yeboah, 2019). This finding underscores the urgent need for waste management interventions in these areas.

Chromium (Cr)

Chromium concentrations were elevated in the dumpsites, with Uyo Village 4.08 ± 0.83 mg/kg, Eka Street 4.03 ± 0.04 mg/kg, and Calabar Itu 4.01 ± 0.03 mg/kg, compared to 3.00 ± 0.56 mg/kg in the control. The FAO/WHO maximum permissible limit for Cr is 100 mg/kg. Therefore, the measured concentrations are well below toxic thresholds, and Cr is unlikely to adversely affect microbial enzyme activity. However, continued accumulation in dumpsites could influence long-term soil chemistry and microbial community structure (Akinola and Eze, 2020; Salinas *et al*., 2025).

The heavy metal profile of the dumpsites demonstrates significant anthropogenic enrichment of Fe, Zn, Pb, Ni, Cd, and Cr relative to the control soil. While Fe, Zn, Pb, Ni, and Cr are below internationally recognized toxic thresholds, Cd exceeds safe limits, representing a serious environmental and public health concern. Elevated metal concentrations can influence microbial population dynamics and enzymatic activity, potentially affecting organic waste degradation rates in these soils (Gao and Zhang, 2019; Adeleke and Ogunseitan, 2021). These results highlight the dual role of dumpsite soils: they are enzymatically active and microbial-rich, y*et al*so contaminated with toxic metals requiring careful management.

Enzyme activities in the study area

Location	**Cellulase**	**Protease**	**Amylase**	**Lipase**	**Pectinase**	**Xylanase**	**Phytase**
Uyo village	66.56	58.81	42.69	39.52	31.96	28.38	30.07
Calabar Itu	63.52	58.12	45.38	41.26	39.38	22.75	22.66
Eka street	63.82	62.35	44.78	42.19	43.17	22.81	22.30
Control	21.23	21.45	22.01	26.37	25.84	21.01	18.46
LSD (P<0.05)	**0.01**	**0.00**	**0.00**	**0.01**	**0.00**	**0.04**	**0.02**

Source: Field data (2024)

Enzyme Activities

The assessment of microbial enzyme activities in the dumpsite soils revealed a clear enhancement of hydrolytic and degradative enzymatic functions compared to the control soil, highlighting the stimulatory effect of organic waste on microbial metabolism.

Cellulase activity was highest at Uyo Village (66.56 IU/mL), followed by Eka Street (63.82 IU/mL) and Calabar Itu (63.52 IU/mL), whereas the control soil recorded only 21.23 IU/mL. The elevated cellulase levels in the dumpsites can be attributed to the abundance of cellulose-rich substrates such as plant residues, paper, and food waste, which support the proliferation of cellulolytic bacteria and fungi, including *Bacillus subtilis* and *Pseudomonas aeruginosa* (Akinmoladun and Ojo, 2021; Gao and Zhang, 2019). The low activity in the control soil reflects the limited availability of cellulose, demonstrating the critical role of waste enrichment in stimulating microbial cellulolytic potential.

Protease activity was similarly enhanced in dumpsite soils, with the highest activity recorded at Eka Street (62.35 IU/mL), followed by Uyo Village (58.81 IU/mL) and Calabar Itu (58.12 IU/mL). The control soil exhibited the lowest activity (21.45 IU/mL). The high protease activity indicates that protein-rich waste materials provide ample substrates for proteolytic microbes, facilitating amino acid mineralization and supporting microbial growth (Ogugbue and Sawidis, 2020). This is consistent with studies showing that microbial protease production is directly stimulated by the presence of proteinaceous organic matter in waste-impacted soils (Adeleke and Ogunseitan, 2021).

Amylase activity was highest at Calabar Itu (45.38 IU/mL), followed by Eka Street (44.78 IU/mL) and Uyo Village (42.69 IU/mL), while the control recorded 22.01 IU/mL. The enhanced amylolytic activity at the dumpsites reflects the availability of starch-rich substrates in municipal waste, supporting efficient carbohydrate metabolism by microbes (Salinas *et al*., 2025). Low amylase activity in the control indicates limited microbial capacity for starch degradation in soils without organic enrichment.

Lipase activity was highest at Eka Street (42.19 IU/mL), followed by Calabar Itu (41.26 IU/mL) and Uyo Village (39.52 IU/mL), while the control recorded 26.37 IU/mL. Elevated lipase activity indicates active lipid degradation, likely stimulated by fats and oils present in household waste. These findings align with prior reports of lipid-degrading microbial consortia isolated from dumpsites, which play a critical role in organic matter turnover (Ogugbue and Sawidis, 2020; Adeleke and Ogunseitan, 2021).

Pectinase activity was highest at Eka Street (43.17 IU/mL), followed by Calabar Itu (39.38 IU/mL) and Uyo Village (31.96 IU/mL). The control soil exhibited 25.84 IU/mL. Pectinase activity reflects the breakdown of pectic substances in plant-based waste, facilitating microbial access to polysaccharides and enhancing overall organic matter decomposition (Gao and Zhang, 2019). The lower pectinase activity in the control underscores the dependence of microbial pectinolytic activity on substrate availability.

Xylanase activity was highest at Uyo Village (28.38 IU/mL), followed by Eka Street (22.81 IU/mL) and Calabar Itu (22.75 IU/mL), while the control had 21.01 IU/mL. Xylanase production is typically stimulated by hemicellulose-rich plant residues in the waste, and the observed differences reflect site-specific variations in waste composition and microbial community structure (Akinmoladun and Ojo, 2021).

Phytase activity peaked at Uyo Village (30.07 IU/mL), followed by Calabar Itu (22.66 IU/mL) and Eka Street (22.30 IU/mL), while the control soil recorded 18.46 IU/mL. High phytase activity indicates microbial capacity to mineralize organic phosphate compounds from phytate-rich waste, contributing to phosphorus cycling and nutrient availability in the soil (Salinas *et al*., 2025). Minimal activity in the control highlights the role of waste enrichment in stimulating microbial phytate hydrolysis.

Overall, the combined results suggest that dumpsite soils harbor microbial communities with enhanced enzymatic potential**,** capable of degrading diverse organic substrates. The observed enzyme profiles are consistent with the high microbial loads measured in these soils and illustrate the biotechnological potential of indigenous bacteria and fungi for organic waste biodegradation (Adeleke and Ogunseitan, 2021; Ogugbue and Sawidis, 2020).

CONCLUSION

This study, titled *"Assessment of Bacterial Isolates from Three Selected Dumpsites in Uyo, Akwa Ibom State, Nigeria for their Waste Degradation Potential,"* demonstrated that soils from Uyo Village, Calabar Itu, and Eka Street dumpsites harbor diverse bacterial and fungal communities with substantial enzymatic activity capable of degrading municipal waste. The dumpsites exhibited significantly higher Total Heterotrophic Bacterial Counts (THBC) and microbial enzyme activities—including cellulase, protease, amylase, lipase, pectinase, xylanase, and phytase—compared to the control soil, indicating that organic waste enrichment stimulates microbial functional diversity. The study also revealed that the dumpsite soils are enriched with Fe, Zn, Pb, Ni, Cd, and Cr, with cadmium (Cd) exceeding permissible international and national limits, representing a potential ecological and human health risk.

While the other metals were within safe limits, their presence may influence microbial activity and soil quality over time.

In conclusion, the research confirms that bacterial isolates from Uyo's dumpsites have high waste degradation potential, providing valuable insight into the functional capabilities of indigenous microbial communities in municipal waste environments. The findings support the use of these microbial communities for biotechnological applications in waste management, while emphasizing the need for continuous monitoring of heavy metal contamination to ensure environmental and public safety.

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