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Evaluation of Microbial Load and Physicochemical Characteristics of Soils in Electronic Waste Dumpsites of Oluku and Osasogie in Benin, Edo State and Alaba in Lagos State, Nigeria

OCHEOIBO, SJ; ATUANYA, EI*

Department of Microbiology, Faculty of Life Sciences, University of Benin, P.M.B 1154, Benin City, Edo state, Nigeria.

**Corresponding Author Email: ernest.atuanya@uniben.edu*
**Tel: +2348033434241*
**ORCID ID: https://orcid.org/0000-0003-0720-6522*

Co-Author Email: ocheoibo@gmail.com
Tel: +2347037670291

ABSTRACT: The objective of this paper was to evaluate the microbial load and physicochemical characteristics of soils in electronic waste dumpsites of Oluku and Osasogie in Benin, Edo State and Alaba in Lagos State Nigeria using appropriate standard procedures. Data obtained show that the total bacterial count was not significantly different across the sites, the mean bacterial counts on Nutrient agar (NA) ranges between 9.00±2.646 cfu/g and 5.33±1.202 cfu/g, the former is for Oluku while the latter is for Osasogie respectively and are not significantly different across the four locations while the fungal counts showed a significant difference. The highest fungal count recorded in the control site (10.67±1.764 cfu/g) and the lowest count (3.33 ±0.882 cfu/g) was recorded at Alaba. Bacterial and fungal species isolated includes, *Bacillus* sp., *Clostridium* sp., *Pseudomonas* sp., *Yersinia* sp. , *Serratia marcescens, Klebsiella* sp., *Providencia* sp, *Aspergillus* sp., *Geotrichum* sp., *Rhizopus* sp., and *Penicillium* sp. respectively, Most of these isolated organisms are those microorganisms known to possess the capacity to biodegrade e-waste. The mean available phosphorous (19.04±0.147) and total nitrogen (6.263±0.049) shows a significant difference in the control soil compared to the three e-waste soil samples. These significant difference in available phosphorus and nitrogen between the control and the three e-waste soil samples shows that, e-waste negatively affects soil fertility, as phosphorous and nitrogen are the major elements that determine soil fertility.

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Electronic waste: This is the used electronic merchandise that require recycling or different proper types of disposal (Mohammed *et al.,* 2013). E-waste, often referred to as Waste Electrical Electronic Equipment (WEEE), is a time period used for unwanted EEE that are obsolete, discarded, or at the cease of their lives (UNEP, 2005). Electronic and Electrical waste, popularly known as e-waste products, do not decompose or rot away (Pandve, 2007). In the era of rapid technological advancement and widespread digitalization, the proliferation of electronic devices has become an integral part of modern life. However, the convenience of these gadgets comes at a cost, with the accelerated generation of electronic waste (E-waste) posing a significant environmental challenge. As our reliance on electronic devices continues to grow, it becomes imperative to scrutinize the far-reaching consequences of E-waste on the environment. This study delves into the intricate web of effects that electronic waste exerts

**Corresponding Author Email: ernest.atuanya@uniben.edu*
**Tel: +2348033434241*
**ORCID ID: https://orcid.org/0000-0003-0720-6522*

on the microbial flora, physicochemical properties, and overall fertility of soil—an often overlooked yet critical facet of the broader impact of technological consumption on our planet. Unraveling the complexities of this issue is not only vital for understanding the ecological repercussions but also for formulating sustainable strategies to mitigate the adverse effects of E-waste on our precious soil ecosystems. The word waste refers to discarded fabric which are no longer in use and discarded by way of the possessor. Every day, a good sized quantity of waste is produced, presently requiring immediate attention (Zaved *et al.,* 2008). The superb advancements in current times have certainly improved the standard of living for humanity. "These problems have resulted in several problems, one of which is the era of large quantities of hazardous waste and different substances stemming from electronic products, generally referred to as Electronic-waste or E-waste. With the presence of deadly chemicals and toxic components in the digital gadgets, disposal of e-waste is becoming an environmental and health nightmare (Saoji, 2012). The accrued quantity of broken and old-fashioned electronic waste produced in India is estimated to be about 146,000 metric tonnes annually. "Europeans produce approximately 20 kilograms of e-waste/person/year, whilst U.S. residents produce about 7 kilograms of e-waste/person/year (Jennifer, 2013). Hence, it is integral on an international scale to implement high-quality measures to curb the escalation of electronic waste, as projections indicate an attainable 50% increase over the next decade, leading to heightened environmental air pollution and health risks. (Mohammed *et al.,* 2013). It includes over a thousand awesome substances, categorized as either hazardous or nonhazardous. Generally, these resources encompass metals such as aluminum (Al), copper (Cu), and treasured metals like Palladium (Pd), gold (Au), Platinum (Pt), and silver (Ag), etc. Exceeding threshold stages of factors such as cadmium, hexavalent chromium, mercury, lead, arsenic, selenium, and flame retardants can lead to damaging effects on each residing organisms and the environment (Zaved *et al.,* 2008). "Discarding of electronic waste poses a sizeable task in numerous areas worldwide, notably due to concerns related to the toxicity and attainable carcinogenicity of certain components when no longer competently managed (Saoji, 2012). The earth's habitability depends on the roles of soil microorganisms in cycling nutrients and supporting food chains. The marine ecosystems are also vulnerable to lasting environmental changes caused by human activities such as dumping electronic wastes. Microbes are vital for how ecosystems deal with pollutants, which affect nutrient cycles and food chains, and how microbes react to toxins in an ecosystem will largely influence the outcome of that ecosystem when the tolerance limit has not been reached" (Aquastel, 2007). Microbes, which are essential for the operation of most ecosystems, are susceptible to environmental change due to their fast growth and active metabolism (Cantarel *et al.,* 2012). Many studies have shown that environmental pollution (organic pollutants and heavy metal) can reduce enzyme activities, impair microbial metabolic function, lower the resilience of soil microbial community to further disturbance and diminish the microbial diversity (Liu *et al.,* 2011). Moreover, these pollutants change the microbial composition by increasing the abundance of some species with remarkable adaptability or biodegradability and decreasing the abundance of other species (Liu *et al.,* 2011). Therefore, the microbial community in e-waste sites could be the potential indicators of soil environmental quality and the ecological risk to the environment (Zhang *et al.,* 2012). Recently, the impact patterns of microbes by organic pollutants and heavy metals in e-waste recycling sites have attracted considerable interests. Several laboratory experiments were conducted to examine the ecotoxicological effects of e-waste pollution on microbes. It was reported that PBDEs and Cu had combined toxic effects on urease, catalase, saccharase (Zhang *et al.,* 2012). PBDEs and Pb reduced the microbial biomass and inhibited microbial basal respiration (Chen *et al.,* 2015). The presence of heavy metals in the soil affects how microbes breathe and break down organic nitrogen, but only at very high levels. Some studies suggest that low levels of heavy metals may actually increase soil respiration and organic matter accumulation" (Ghorbani *et al.,* 2002). However, other factors such as soil pH, organic matter, organic pollutants and Zn also influence the microbial community and interact with the heavy metals (Jiang *et al.,* 2017). Heavy metals can also reduce the number and diversity of soil microbes and their toxicity depends on the soil characteristics" (Chibuike and Obiora, 2014). For example, heavy metals have been shown to decrease microbial biomass and N2 fixation (Lenart-Boroń and Piotr Boroń, 2014). In contrast, a study found that soil samples from three e-waste sites in Nigeria had more bacteria and fungi than a control sample, with *Bacillus* sp. and *Aspergillus* sp. being the most common (Taiwo *et al.,* 2018). This suggests that heavy metal and organic pollutant contamination can also select for microbes that are resistant and able to degrade them (Jiang *et al.,* 2017). By improving the quantity and efficiency of nutrient intake and recycling, controlling the retention and flow of water and nutrients, and maintaining a healthy physical structure for the soil, soil biological activities help to improve soil fertility. Through nutrient cycling,

organic matter transformation, microbial decomposition, and nutrient retention, soil biological activities affect ecosystem functioning (Adeduntan, 2010). Therefore, the objective of this paper was to evaluate the microbial load and physicochemical characteristics of soils in electronic waste dumpsites of Oluku and Osasogie in Benin, Edo State and Alaba in Lagos State Nigeria.

MATERIALS AND METHODS

Study Area: Soil samples were collected from 3 major e-waste dumpsites, Alaba (6°28'00" N 3°10'59" E) is located in Ojo local government area, Lagos State, South Western part of Nigeria. It hosts the popular Alaba international market, the largest electronics market in West Africa. Oluku (6°43'05" N 5°59'32" E) is a town in Benin city and Osasogie (6°33'52" N 5°61'69" E) is also a town in Benin city located in Ovia North-East local government area, Edo State, south-South Nigeria. The control soil sample was obtained at University of Benin (UNIBEN) (6°20'1.32 N" 5°36'0.53" E), Ugbowo campus free from e-waste dumpsite. Most of the wastes found at these 3 dumpsites are imported second-hand products which include electronics products such as communications, broadcasting, computers, televisions, videos, home appliances, refrigerators, video games, generators, satellite etc. The scavengers or e-waste collectors, are indulge in burning and other crude recycling practices at the dumpsites without care for their health or environment, in an attempt to recover some useful parts/scrap from e-waste. Make shift structures are also erected on the sites for accommodation.

Collection and Preparation of Soil Samples: Soil sample were collected from Alaba International market e-waste dump site, Lagos state and e-waste dump site in Oluku and Osasogie, Edo state while the control soil was obtained from UNIBEN at a depth of 0-15 cm using a sterile soil auger. The samples were taken to the laboratory in a box containing ice for analysis. The soil samples were air-dried and sieved with a 2 mm mesh size to remove stones and other extraneous materials.

Chemical Analysis of Soil Samples: The soil characteristics, including pH, moisture content, and total nitrogen (N), were assessed following the procedures outlined by Oyeyiola (2004) and Riegel *et al.,* (2002). Available phosphorus and organic carbon were determined calorimetrically as described by Riegel *et al.,* (2002), while the concentrations of calcium, magnesium, sodium, and potassium were analyzed using the AOAC method (AOAC, 2000)

Total Heterotrophic Bacterial Count: Total Heterotrophic Bacterial Count (THBC) of the soil samples were determined using the method suggested by Akintokun and Taiwo. One millitre each of serially diluted samples (10) were inoculated on sterile Plate Count Agar using the pour plate method and incubated invertedly at 37 ºC for 24 h. Colonies were counted and reported after 24 hours as colony forming units (CFU/g). (Akintokun and Taiwo, 2016).

Total Fungal Count: Total Fungal Count (TFC) were determined by inoculating 1 mL each of serially diluted (10) samples on sterile Potato Dextrose Agar incorporated with 1 % (v/v) Chloramphenicol using pour plate method and then incubated at 28 ºC for 72 h. The 1% chloramphenicol was added to Potato Dextrose Agar to inhibit bacteria growth. Colonies were counted and reported as the colony forming units per gram (Akintokun and Taiwo, 2016). All media were prepared as directed by the manufacturers.

Purification of Bacterial and Fungal Isolates: Nutrient Distinct colonies on different media were isolated and purified on nutrient agar by repeated sub-culturing and pure cultures of the isolates were maintained on nutrient agar slants and stored at 4°C for all bacterial isolates while the fungal colonies were purified and maintained on potato dextrose agar incorporated with 1% Chloramphenicol and also stored at 4°C for further analysis. (Taiwo *et al.,* 2018). Nutrient broth single and double strengths were also prepared following manufacturer's directive.

Morphological Characterization of bacterial Isolates: A clean, grease-free glass slide was smeared with a single, isolated colony from 24-48 hour culture. It was air dried and Gram-stained. With the application of a drop of immersion oil, the smear was examined under the light microscope

Biochemical Characterization of bacterial isolates: The biochemical tests such as Oxidase, Catalase, Citrate utilization, capsule staining, Voges-Proskaeur, Methyl red and Sugar fermentation tests were carried out on the isolates. The sugars include glucose, sorbitol, maltose, lactose and sucrose. These were done as outlined by Bergey's manual of systematic bacteriology.

Cultural and Morphological Characterization of Fungal Isolates: The fungal isolates were identified based on cultural and morphological characterization with reference to (Ellis *et al.,* 2007).

Statistical Analysis: Analysis was done in triplicate. Data obtained from the study using Statistical Package

for Social Science version 21, PAST version 2.17c and Microsoft Excel version and SPSS were examined, employing Analysis of Variance and descriptive statistics (Ogbeibu, 2019).

RESULTS AND DISCUSSION

Microbial analysis of E-waste soil: E-waste soil samples collected from three locations and control soil were analysed for bacteria and fungi as well as its impact on microbial flora. Table 1 showed that the bacterial count was not significantly different across the sites, the mean bacterial counts on NA ranges between 9.00±2.646 cfu/g and 5.33±1.202 cfu/g, the formal is for Oluku while the latter is for Osasogie respectively and are not significantly different across the four locations while the fungal counts showed a significantly difference. The highest fungal count was recorded in the control site (10.67±1.764 cfu/g) and the lowest count (3.33 ±0.882 cfu/g) was recorded at Alaba (Table 1) while Table 2 and 3 revealed the identity of isolated bacteria and fungi respectively. The e-waste soil samples and the control soil were found to contain bacterial and fungal species including, *Bacillus* sp., *Clostridium* sp., *Pseudomonas* sp., *Yersinia* sp., *Serratia marcescens, Klebsiella* sp., *Providencia* sp, *Aspergillus* sp., *Geotrichum* sp., *Rhizopus* sp., and *Penicillium* sp. respectively. Bacteria isolated were both Gram positive which includes, (*Bacillus* sp,and *Clostridium* sp) and Gram-negative (*Pseudomonas* sp. *Yersinia* sp.· *Serratia marcescens, Klebsiella* sp. and *Providencia* sp) were isolated from the various soil samples. The isolation of *Bacillus* sp, *Pseudomonas* sp, *Klebsiella* sp, *Aspergillus* sp from the soil samples was similar to a report by Sanusi; and Taiwo (Sanusi, 2015; Taiwo *et al.,* 2018) which reported similar microorganisms in soil collected from Alaba e-waste dump sites. However, all the microbial isolates identified from the soil samples, have been reported to be associated with waste biodegradation (Taiwo *et al.,* 2018). *Aspergillus, Penicillium, Rhizopus* have also been previously reported to be associated with waste biodegradation (Adebisi *et al.,* 2014). The mechanisms employed by microorganisms for remediating heavy metal contamination are biosorption, bioleaching, precipitation and transformation

Table 1: Total microbial count from the e-waste soil samples

Parameters	Control n= 3 $\bar{X}$±SE (min-max)	Oluku n= 3 $\bar{X}$±SE (min-max)	Alaba n= 3 $\bar{X}$±SE (min-max)	Osasogie n= 3 $\bar{X}$±SE (min-max)
HBC (NA) × 10,000,000 bacteria cfu/g (Mean)	7.33±1.764[a]	9.00±2.646[a]	5.00±0.577[b]	5.33±1.202[b]
HFC (PDA) × 200,000 fungi cfu/g (Mean)	10.67±1.764[a]	7.33±1.856[a]	3.33 ±0.882[b]	6.00±1.000[a]
HBC (MCA) × 20,000 bacteria cfu/g (Mean)	7.00±0.577[a]	4.33±0.882[c]	5.33±1.764[b]	2.33±0.882[d]

Table 2: Distribution pattern of Bacterial isolates across e-waste locations

	Source											
Probable Organism	**Control 1**	**Control 2**	**Control 3**	**Oluku 1**	**Oluku 2**	**Oluku 3**	**Alaba 1**	**Alaba 2**	**Alaba 3**	**Osasogie 1**	**Osasogie 2**	**Osasogie 3**
Bacillus Sp	+	-	+	+	-	-	-	-	+	-	-	-
Bacillus cereus[1]	-	-	-	-	-	-	-	-	-	+	-	+
Yersinia sp [1]	+	-	-	-	-	-	-	-	-	-	-	-
Pseudomonas aeruginosa	-	+	-	-	-	-	-	-	-	-	-	-
Clostridium Sp[1]	-	-	+	-	-	-	+	-	+	-	-	-
Bacillus subtilis	-	-	-	-	-	-	-	+	-	-	-	-
Bacillus cereus[2]	+	-	-	-	-	-	-	-	-	-	-	-
Serratia marcescens	-	-	-	+	-	+	-	-	-	-	-	-
Providencia Sp	-	-	-	-	-	-	+	-	-	-	-	-
Yersinia Sp[2]	-	-	-	-	-	-	-	-	-	+	-	+
Klebsiella Sp	-	-	-	-	-	-	-	-	-	-	+	-
Bacillus cereus[3]	-	-	-	-	-	-	-	+	-	-	-	-
Clostridium Sp[2]	-	-	-	+	-	-	-	-	-	-	-	-

Physicochemical properties from the E-waste sites: The physicochemical properties across the e-waste soil were determined, and the pH of the soil samples range from 6.83 to 8.45. PH mean value of the samples; Control (6.830 ± 0.051^{c}), Oluku (8.393 ± 0.018^{a}), Alaba (8.453 ± 0.023^{a}), Osasogie (8.160 ± 0.017^{b}); There was no significant pH difference between the pH of Oluku and Alaba but there was significant difference between three e-waste soil and the control soil samples. The PH of Alaba is 8.45 this is similar to a report of a research done by Jiang *et al.,* (2019) but conversely, Taiwo *et al.,* (2018) observed a decreased PH of 6.40 at Alaba. The highest pH value was recorded at Alaba 8.45 and the lowest was recorded at the control soil sample 6.83. The pH values of the three e-waste sites were higher than the control which is slightly acidic.

Table 3: Cultural and morphological characteristics of fungi isolates from the E-waste soil samples.

Cultural characteristics	**Morphological characteristics**				
Nature of colony	**Nature of hyphae**	**Spore type**	**Organism**	**location**	**Plate**
Powdery colonies with black spores and a yellow reverse side	Septate	Conidiophore	Aspergillus niger[1]	Control	1
Fluffy dark colonies with black spores and a yellow reverse side	Septate	Conidiophores	Aspergillus niger[2]	Control	2
Powdery colonies with black spores and a yellow reverse side	Septate	Conidiospore	Aspergillus specie	Control	3
Fluffy dry cream colonies with dark reverse side	Septate	Arthrospores	Geotrichum spp	Oluku	1
Fluffy dark colonies with brown reverse side	Sepate	Conidiophores	Aspergillus specie[1]	Oluku	2
Fluffy black colonies with dark reverse side	Sepate	Conidiospore	Aspergillus Specie	Oluku	3
Fluffy grayish brown colonies with a dark colour reverse side	Non-septate	Sporangiophores	Rhizopus specie	Alaba	1
Fluffy black colonies with dark reverse side	Septate	Conidiophores	Aspergillus specie[2]	Alaba	2
Fluffy black colonies with dark reverse side	Septate	Conidiospore	Aspergillus Specie	Alaba	3
Wooly greenish colonies with a yellow colour reverse side	Septate	Conidiospore	Penicillium specie	Osasogie	1
Dark colour colonies with entire margin	Sepate	Conidiospore	Aspergillus specie[3]	Osasogie	2
Dark colour colonies with entire margin	Septate	Conidiospore	Aspergillus specie	Osasogie	3

Table 4: Physicochemical parameters from the e-waste soil samples

Parameters	**Controln= 3** $\bar{X}\pm$**SE** **(min-max)**	**Oluku n= 3** $\bar{X}\pm$**SE** **(min-max)**	**Alaba n= 3** $\bar{X}\pm$**SE** **(min-max)**	**Osasogie n= 3** $\bar{X}\pm$**SE** **(min-max)**
Ca	1.013 ± 0.009^{c}	1.273 ± 0.043^{a}	1.127 ± 0.009^{b}	1.340 ± 0.010^{a}
Mg	0.560 ± 0.010^{d}	0.757 ± 0.012^{b}	0.640 ± 0.006^{c}	0.817 ± 0.007^{a}
Na	0.413 ± 0.003^{c}	0.723 ± 0.007^{a}	0.670 ± 0.006^{b}	0.740 ± 0.021^{a}
K	0.467 ± 0.009^{b}	0.743 ± 0.003^{b}	0.553 ± 0.008^{b}	5.707 ± 2.438^{a}
Available Phosphorus	19.04 ± 0.147^{a}	10.23 ± 0.027^{d}	11.26 ± 0.063^{c}	14.19 ± 0.038^{b}
Total Nitrogen	6.263 ± 0.049^{a}	2.463 ± 0.064^{c}	2.307 ± 0.024^{d}	3.273 ± 0.027^{b}
Organic Carbon	9.983 ± 0.072^{d}	12.22 ± 0.700^{c}	13.95 ± 0.332^{b}	17.34 ± 0.109^{a}
Moisture	9.533 ± 0.120^{a}	8.087 ± 0.060^{d}	9.377 ± 0.055^{a}	8.523 ± 0.223^{b}
pH	6.830 ± 0.051^{c}	8.393 ± 0.018^{a}	8.453 ± 0.023^{a}	8.160 ± 0.017^{b}

The mean value of the organic carbon across the soil samples; control (9.983 ± 0.072^{d}), Oluku (12.22 ± 0.700^{c}), Alaba (13.95 ± 0.332^{b}), Osasogie (17.34 ± 0.109^{a}), There was a significant difference of organic carbon across the e-waste soil sites, Osasogie (17.34±0.109) record the highest organic carbon while

control (9.983±0.072) has the lowest organic carbon. The mean value of the moisture content across the soil samples; Control (9.533±0.120[a]), Oluku (8.087±0.060[d]), Alaba (9.377±0.055[a]), and Osasogie (8.523±0.223[b]); The moisture content of the soil shows a significant difference across the e-wastes soil sites but the control (9.533±0.120) and Alaba (9.377±0.055) are not significantly different. Alaba (9.377±0.055) has the highest moisture content while Oluku (8.087±0.060) has the lowest moisture content. The mean value of potassium (K) are; Control (0.467±0.009[b]), Oluku (0.743±0.003[b]), Alaba (0.553 ±0.008[b]), and Osasogie (5.707±2.438[a]); Osasogie shows a significant difference from the other three samples while Control, Oluku and Alaba are not significantly different from each other. The mean value of available phosphorus (P) from the samples includes; Control (19.04±0.147[a]), Oluku (10.23±0.027[d]), Alaba (11.26±0.063[c]), Osasogie (14.19±0.038[b]).

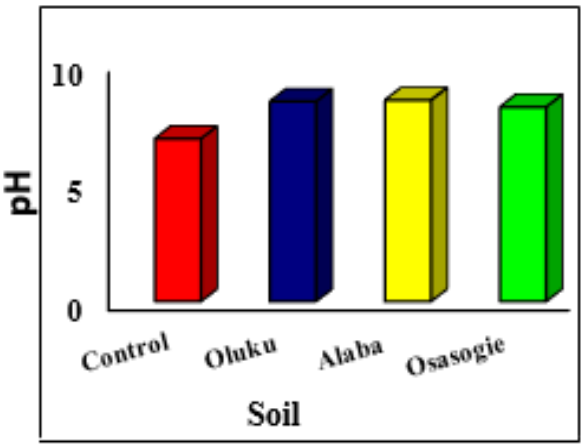

Fig 1: Variation of pH across the study Locations

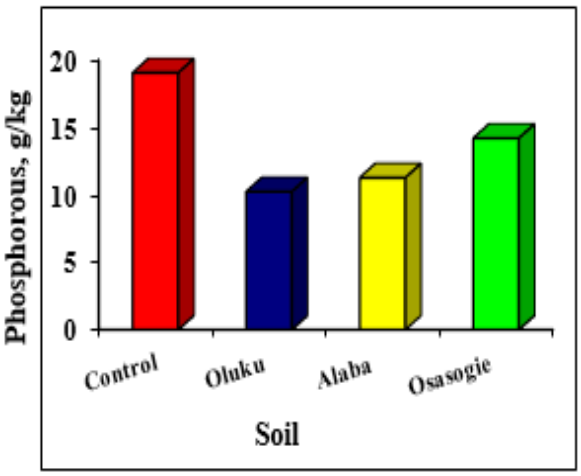

Fig 2: Variation of Available Phosphorus across the study Locations

Control mean value was significantly difference in available phosphorus compare with the three e-waste samples. The mean value of total Nitrogen (N) from the samples analysed are; Control (6.263±0.049[a]), Oluku (2.463±0.064[c]), Alaba (2.307±0.024[d]), Osasogie (3.273±0.027[b]); Control mean value for total Nitrogen was significantly difference compare with the three e-waste samples analysed. The mean of available phosphorus (19.04±0.147) and total nitrogen (6.263±0.049) shows a significant difference in the control soil sample compared to the three e-waste soil samples. The significant difference in available phosphorus and nitrogen in the control and the three e-waste sites shows that, e-waste negatively affects soil fertility, as phosphorous and nitrogen are the major elements that determine soil fertility.

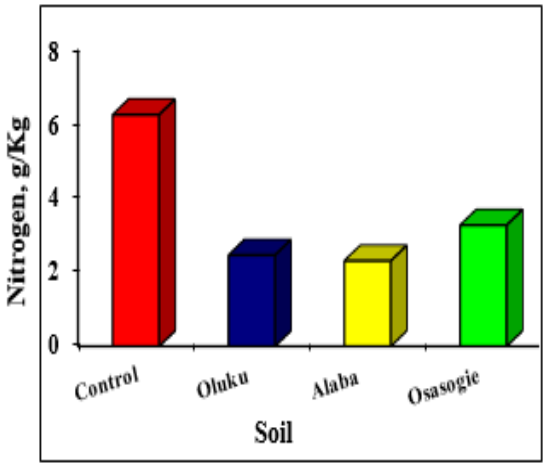

Fig 3: Variation of Total Nitrogen across the study Locations

Conclusion: The study has shown that the isolated organisms were those microorganisms known to possess the capacity to biodegrade e-waste. Certain microorganisms crucial for nutrient cycling and soil health may be negatively impacted, potentially leading to disruptions in ecosystem functioning. E-waste contamination has demonstrated adverse effects on soil fertility, as available Phosphorus and total Nitrogen were found to be high in the control soil compared to the e-waste soil. These changes can lead to decreased agricultural productivity and pose long-term risks to food security.

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