



Bacteriological Analysis of Top Soil from an Electronic Waste Dumpsite in Port Harcourt Metropolis

Janet Olufunmilayo Williams^{1*}, C. J. Ugboma¹ and Faith Ibiene¹

¹*Department of Microbiology, Faculty of Science, Rivers State University, P.M.B. 5080, Nkpolu Oroworukwo, Port Harcourt, Nigeria.*

Authors' contributions

This work was carried out in collaboration among all authors. Author JOW designed the study, wrote the protocol and supervised the work. Author CJU managed the statistical analysis and supervised the work while. Author FI wrote the first manuscript, managed the analyses of the study and literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aim: To determine the bacterial and physicochemical analysis of topsoil from an electronic waste (e-waste) dumpsite within Port Harcourt metropolis using standard procedures.

Place and Duration of Study: The study area was Kaduna street, beside Fruit and Vegetable Garden Market, Mile I which is located in Port Harcourt, Rivers State, Nigeria. The coordinates are 4°47'57.5" N 7°00'02.7" E. The duration of study was between March and September, 2019.

Methodology: The waste disposed were mainly television sets, computer monitors, radio sets, stoves, laptops and central processing units. Soil samples were cleared off top debris, collected within 5cm of the top soil from four (4) different points of the dumpsite and a control was collected from area devoid of waste disposal, 20m away from the dumpsite. The five samples were kept in clean sterile polythene bags. Contamination observed from soil samples was attributed to the waste disposal. The total heterotrophic bacterial count was performed using 1 gram of soil from e-waste dumpsite in a 9-fold serial dilution using a spread plate method, in duplicates on dried nutrient agar plates and incubated at 30°C for 24hours. Centrimide agar plates were used to obtain *Pseudomonas*

*Corresponding author: Email: Janet.williams@ust.edu.ng;

isolates and incubated at 37°C for 24 hours while MacConkey agar plates were used to isolate coliform bacteria, incubated at 37°C for 48 hours. The physicochemical parameters were determined using standard methods.

Results: Seven (7) bacterial genera were isolated from the topsoil of the e-waste dumpsite and they were *Staphylococcus*, *Pseudomonas*, *Kluyvera*, *Bacillus*, *Micrococcus*, *Chromobacterium* and *Pectobacteria* species. *Staphylococcus* spp. had the highest percentage composition of 42.3% and *Kluyvera* spp, the lowest percentage composition of 1.9% of bacterial isolates found in the topsoil of the electronic waste dumpsite. The total heterotrophic bacterial count ranged from 1.30×10^6 to 1.97×10^6 cfu/g, total coliform count was 3.05×10^3 to 7.98×10^3 cfu/g and total *Pseudomonas* count ranged from 1.00×10^2 to 2.88×10^3 cfu/g with a significant difference at .05 probability level to the control samples. The temperature ranged from $27.67 \pm 0.58^\circ\text{C}$ to $28.00 \pm 1.00^\circ\text{C}$ with a control of $29.00 \pm 1.00^\circ\text{C}$, pH value ranged from 6.33 ± 0.58 with a control of 7.00 ± 0.00 . The pH values were lower than the control indicating that the soil was slightly acidic to neutral. Moisture content had 4% with a control of 2.7%, an organic matter of 17.33 ± 0.58 with a control of 4.47 ± 0.58 .

Conclusion: The presence of the isolated organisms could cause public health risk or environmental hazard. Proper education and legislations on handling of e-waste in the society should be intensified to forestall waste related problems along the food chain.

Keywords: Bacteriological; topsoil; electronic waste dumpsite; Port Harcourt metropolis.

1. INTRODUCTION

An electronic is a device with small parts, such as microchips and an electron that is negatively charged which controls and directs electric current. Devices like phones, computers, tablets, televisions, radio, game consoles and smart kitchen appliances are made of hundreds of components and thousands of chemicals so when they are destroyed and disposed of, they are referred to as Electronic wastes [1]. An electronic waste is simply described as discarded electronic devices. Electronics are further made up of hazardous and non-hazardous substances. Hazardous substances are substances that are dangerous to living health. They are composed of metals and organic/inorganic compounds. Hazardous substances include lead, Mercury, Cadmium, Tin, Antimony, Arsenic, Asbestos, Barium, Beryllium, Chromium, Nickel, Selenium, Yttrium, Zinc etc. while the non-hazardous compounds or substances are substances which have no threat to living health such as Aluminum, Plastic, Silver, Gold, palladium and rubber [2]. Informal processing of electronic waste in developing countries may cause serious health and pollution problems, though these countries are also most likely to reuse and repair electronics [2]. Activities such as uncontrolled burning, disassembly and disposal causes a variety of environmental problems such as ground water contamination, atmospheric pollution or even water pollution either by immediate discharge or due to surface runoff (especially near coastal areas) as well as health hazards which affect those within the area

directly or indirectly due to the method of processing of the waste [3]. Despite the best attempts at waste avoidance, reduction, reuse and recovery (recycling, compositing and energy recovery), landfill and waste disposal sites are still the principal focus for ultimate disposal of residual waste and incineration residues world-wide.

Soil plays a vital role in the Earth's ecosystem. And provides plants with the foothold for their roots and holds the necessary nutrients for plants to grow. Soil filters, regulates the discharge of excess rainwater preventing flooding and is capable of storing large amounts of organic carbon. It buffers against pollutants, thus protecting groundwater quality [4]. Microbes play essential roles in maintaining soil fertility through recycling nutrients and influencing their availability to plants, improving soil texture and degrading organic pollutants [4]. The research work is of great interest due to the comparison of the proliferation of microbial conditions in the municipal electronic waste dumpsite and that of the control site in Port Harcourt Local Government Area of Rivers State, Nigeria.

2. MATERIALS AND METHODS

The study area was Kaduna street, beside Fruit and Vegetable Garden Market, Mile 1 which is located in Port Harcourt, Rivers State, Nigeria. The coordinates are given as $4^\circ 47' 57.5''$ N $7^\circ 00' 02.7''$ E (Fig. 1). The waste disposed were mainly television sets, computer monitors, radio sets, stoves, laptops and central processing

units. Soil samples were cleared off top debris, collected within 5cm of the top soil from four (4) different points of the dumpsite and a control was collected from the area devoid of waste disposal 20m away from the dumpsite. The five samples were kept in clean sterile polythene bags. Contamination observed from the soil samples was therefore attributed to the waste disposal.

2.1 Bacteriological Analyses

The total heterotrophic bacterial count was performed using 1 gram of soil from e-waste dumpsite in a 9-fold serial dilution using a spread plate method, in duplicates on dried nutrient agar plates and incubated at 30°C for 24h [5]. At the end of the incubation period, isolation of pure culture was done. Centrimide agar plates were used to obtain *Pseudomonas* isolates. The plates were incubated at 37°C and observed after 24

hours. MacConkey agar plates were used to isolate coliform bacteria, included at 37°C 48 hours [6].

2.2 Identification and Characterization of Isolates

The pure bacterial isolates were identified on the basis of their morphological °c and biochemical tests. 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. In order to determine the identity of bacterial isolates, results were compared with standard references of Bergey's Manual of Determinative Bacteriology [7].



Fig. 1. Electronic waste dumpsite at Kaduna Street in Port Harcourt, Nigeria (Ibiene, 2020)

2.3 Physicochemical Analyses

The physicochemical parameters of soil samples were determined using standard methods [8]. The pH of the soil was determined using the Jenway pH meter (3015 model). The mercury thermometer was used to determine temperature, moisture content and total nitrogen were determined using methods described by [8]. Calorimetric determination of available phosphorus and organic carbon were done using methods of [9].

2.4 Statistical Analysis

Results were subjected to statistical analysis employing the student t-test at 95% probability levels using SPSS (VERSION 14.0) statistical package.

3. RESULTS AND DISCUSSION

The quality of soil depends more on the natural composition and changes caused by human use and management and the physicochemical properties of the soil [10]. Despite the observed dumping of electronic waste materials on the top soils by individuals, varying microbial load was recorded from the receiving soil. The colony forming unit for total heterotrophic bacteria from sample locations, A to E were 1.69×10^6 , 1.97×10^6 , 1.30×10^6 , 1.57×10^6 , 1.95×10^6 respectively as shown in Table 1.

The bacterial load of different soil samples from the five (5) sample locations (A, B, C, D and E) were analyzed for total heterotrophic bacteria (THB), total coliform count (TCC) and Total Pseudomonas Count (TPC). The result is presented as mean \pm Standard deviation, where the mean with same alphabet have no significant difference at $P < 0.05$ as presented on Table 2.

The superscripts (^a, ^b, ^{ab}) indicate the different levels of significant difference, In THB, sample A (6.21 ± 0.13^{ab}) is not significantly different from sample (B, C, D, E) but sample B (6.29 ± 0.07^a) and E (6.29 ± 0.03^a) are significantly different from sample C (6.11 ± 0.06^b). In TCC, sample A (3.86 ± 0.22^a) is significantly different from sample E (3.48 ± 0.08^b) but not significantly different from sample B, C and D. There were no significant differences in TPC.

The result of this study revealed higher count of microorganisms in the control soil of THB and TPC perhaps due to its proximity to the fruit garden market and a higher microbial count of

the dumpsite in TCC due to direct link with the use of electronics and intense human activities in that area. However, the high bacterial count in the soil is an indication that the soil is rich in organic matter which allows growth of microorganism which is in line with the report of [11].

The Physicochemical parameters of the soil sample from the e-waste dump site is presented on Table 3 below. Temperature ranged from $27.67 \pm 0.58^{\circ}\text{C}$ to $28.00 \pm 1.00^{\circ}\text{C}$ with a control of $29.00 \pm 1.00^{\circ}\text{C}$, pH value of 6.33 ± 0.58 , with a control of 7.00 ± 0.00 . The pH values were lower than the control indicating that they were slightly acidic to neutral. The acidic nature of the soil could be attributed to the effect of the burning on the dumpsite which is similar to the report of [12] who reported that pH influences a number of factors affecting microbial activities like solubility and ionization of inorganic and organic soil solution constituents and this will in turn affect soil enzyme activity. Soil with acidic pH levels tend to have an increased micronutrient solubility and mobility as well as increased heavy metals concentration thus, rendering the particular soil unsuitable for wasteland filling [7]. Moisture content had 4% with a control of 2.7%, an organic matter of 17.33 ± 0.58 , with a control of 4.47 ± 0.58 . Increased moisture content in dumpsites could enhance the utilization and degradability rate of the organic matter by microbes in e-waste dumpsites.

Table 4 shows the mean of Heavy metal concentrations of the soil samples from the e-waste dump site and control site. The heavy metals analyses of the soil samples revealed that soil from e-waste dumpsites had higher quantity of heavy metals in mg/kg than soil without e-waste (control). Of all the heavy metals assessed, Lead (mg/kg), Cadmium(mg/kg), Nickel(mg/kg), Zinc(mg/kg) exceeded the limits of heavy metals by [13,14]. High quantity of heavy metals in the soil could affect microflora in such soil, these metals could hamper the health of humans if they find their way into the body. Lead has been found to be the major cause of hypertension, impairment of central nervous system and other respiratory problems in adults [15]. Zinc and lead are amongst the metals referred to as common urban pollutants [16]. Therefore, it is highly recommended that the indiscriminate dumping of electronic waste into the environment should be discouraged and the e-waste can be transferred into factories for recycling.

Table 1. Bacterial counts of soil samples (cfu/g)

Sample Locations	THB	TCC	TPC
A	1.69×10 ⁶	7.98×10 ³	8.75×10 ²
B	1.97×10 ⁶	4.6×10 ³	1.63×10 ²
C	1.3×10 ⁶	4.2×10 ³	2.88×10 ²
D	1.57×10 ⁶	5.2×10 ³	1.9×10 ²
E	1.95×10 ⁶	3.1×10 ³	4.0×10 ²

THB-Total Heterotrophic Bacteria, TCC-Total coliform count, TPC-Total Pseudomonas Count

Table 2. Mean bacterial counts of soil samples from e-waste dump site

Sample location	10 ⁶ CFU/g)	10 ³ CFU/g)	TPC (10 ² CFU/g)
A	6.21±0.13 ^{ab}	3.86±0.22 ^a	1.12±1.29 ^a
B	6.29±0.07 ^a	3.64±0.17 ^{ab}	2.04±0.43 ^a
C	6.11±0.06 ^b	3.61±0.11 ^{ab}	2.29±0.47 ^a
D	6.18±0.12 ^{ab}	3.69±0.16 ^{ab}	1.15±1.33 ^a
E	6.29±0.03 ^a	3.48±0.08 ^b	2.47±0.36 ^a

THB-Total Heterotrophic Bacteria, TCC-Total coliform count, TPC-Total Pseudomonas Count.

Result presented as mean ± SD, means with same alphabet have no significant difference at P ≤ 0.05

Table 3. Physicochemical parameters of soil samples from waste dump site

	A	B	C	D	E(control)
Moisture(%)	4.00±0.0	4.00±0.00	4.00±0.00	4.00±0.00	2.67±0.58
Nitrogen	35.5±1.00	30.1±1.00	38.2±1.00	30.6±1.00	12.7±0.58
Organic Carbon	9.00±1.00	9.00±1.00	9.00±1.00	9.00±1.00	2.33±0.58
Organic Matter	17.33±0.58	17.33±0.58	17.33±0.58	17.33±0.58	4.67±0.58
pH	6.33±0.58	6.33±0.58	6.33±0.58	6.33±0.58	7.00±0.00
Phosphorus	141.33±1.16	141.00±1.00	140.67±1.53	141.33±1.16	160.67±7.10
Temperature(°C)	27.67±0.58	28.00±1.00	28.00±1.00	28.00±1.00	29.00±1.00

Table 4. Heavy metal concentration (Mean) of the soil sample from the e-waste dump site

Elements (mg)/kg)	A	B	C	D	E	WHO permissible limits (mg/kg)
Arsenic	4.00 ±00	4.00±00	4.00±00	4.00±00	1.00±00	0.9-10.0
Beryllium	2.00 ±00	2.00 ±00	2.00 ±00	3.00 ±00	1.00 ±00	2.0-6.0
Cadmium	2.00±00	2.00±00	1.00±00	1.00±00	1.00±00	0.002-0.5
Cobalt	1.00±0.00	1.00±0.00	1.00±0.00	1.00±0.00	.00±0.00	1.0-10.0
Lead	13.00±00	14.00±00	15.00±00	15.00±00	1.00±00	0.3-10.0
Nickel	15.00±00	15.00±00	16.00±00	15.00±00	5.00±00	0.1-5.0
Zinc	115.00±00	113.00±00	117.00±00	116.00±00	9.00±00	12.0-60.0

In Table 5, bacteria such as *Staphylococcus sp*, *Bacillus sp* and *Pectobacillus sp* were predominant in all the locations. *Kluyvera sp* was found in location C while *Chromobacterium sp* was found in location A, *Pseudomonas sp* was found location B, C & E(control) while *Micrococcus sp* was found in location A, D & E (control). Microorganisms found in the control site were *Staphylococcus sp*, *Bacillus sp*, *Pseudomonas sp*, *Micrococcus sp*, *Pectobacteria sp*. The presence of *Kluyvera* and *Chromobacterium spp.* was observed in the dumpsite but not in the control site Both

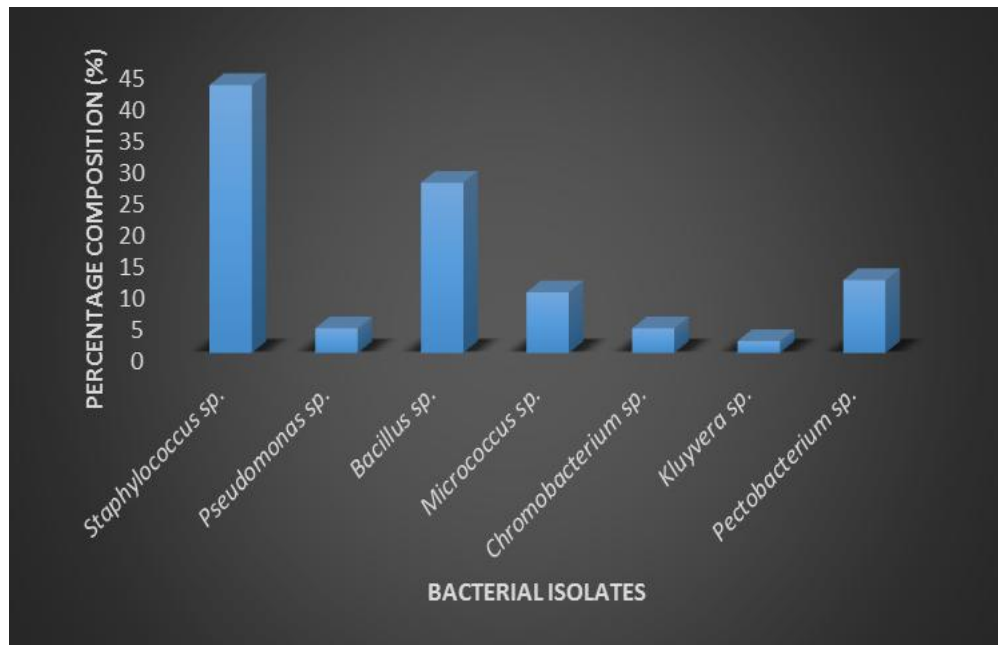
microorganisms (*Kluyvera* and *Chromobacterium spp.*) have degradative capabilities and could favor degradation of electronic materials. The observation in this study was also in line with that of [17] who identified the presence of *Bacillus* and *Staphylococcus* from a waste dumpsite located at Eagle Island, River state.

The frequency occurrence of bacteria isolated from e-waste dumpsite showed that *Staphylococcus spp.* had the highest percentage composition of 42.3% and *Kluyvera spp* had the

Table 5. Distribution of bacterial isolates across the locations

Isolates	A	B	C	D	Control
<i>Staphylococcus sp</i>	+	+	+	+	+
<i>Pseudomonas sp</i>	-	+	-	-	+
<i>Kluyvera sp</i>	-	-	+	-	-
<i>Bacillus sp</i>	+	+	+	+	+
<i>Micrococcus sp</i>	+	-	-	+	+
<i>Chromobacterium sp</i>	+	-	-	-	-
<i>Pectobacteria sp</i>	+	+	+	+	+

Key: +ve = Presence of organism, -ve = Absence of organism

**Fig. 2. Frequency occurrence of bacteria isolated from e-waste dumpsite**

lowest percentage composition of 1.9% as shown in Fig. 2. The high percentage of *Staphylococcus spp* is directly linked to the use of electronics since the hand (the part of the body that has the greatest contact with electronics) is highly implicated with bacteria especially *Staphylococcus spp.*

4. CONCLUSION

Electronic waste dumpsite is hazardous due to the build-up of heavy metals and pathogenic bacteria and is detrimental to the health of humans. The levels of pH, organic matter, organic carbon favour the biotransformation of electronic waste. Some organisms found in the e-waste dump site have degradative capabilities though are pathogenic.

Proper education and legislations on handling of E-wastes in the society should be intensified to

forestall waste related problems along the food chain. A further research should be carried out on bacteria found in the dumpsite and their association with the degradation of electronic waste.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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