Biophysicochemical Characterization of Soils of Abandoned and Active Solid Waste Dumpsites in Rivers State Southern Nigeria

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Abstract: **- Waste generation is continuous from daily human activities, and due to lack of adequate treatment facilities, waste dumpsites are opened at designated sites. Overtime, active waste dumpsites have been closed or abandoned and new sites are created. However, there is dearth information on the comparison between the microbiological and physicochemical properties of active and abandoned waste dumpsites' soils. This research therefore was aimed at characterizing the microbial content of active and abandoned waste dumpsite soils and assessing changes in the physicochemical properties of the dumpsite soils as to ascertain the public health concern of the two types of dumpsites. Forty soil samples were collected from the two types of solid waste dumpsites and control sites. Biological characterization of soils involved determining the counts of heterotrophic bacteria and fungi of soil samples as well as characterizing the microbial isolates using standard plate count method. Some physicochemical properties of soils were determined using standard analytical procedures. Mean ranges of physicochemical parameters were: pH 5.85±0.40 to 6.63±0.14, EC 90.38±55.92 to 625.17±356.49µS/cm, Av. P 29.41±8.99 to 54.97±19.24mg/kg, TOC 0.92±0.36 to 1.94±0.98%, TOM 2.20±0.04 to 3.42±1.69%, TN 0.02±0.01 to 0.04±0.02%, Sand 79.23±1.85 to 83.81±5.64%, Silt 5.04±2.31 to 12.3±4.44%. Clay 7.01±0.18 to 11.98±3.02%, CEC 6.68±3.08 to 12.19±5.50cmol/kg. Significant difference at $p<0.05$ were observed in the mean values of some physicochemical properties such as pH, EC, %TN, CEC, %sand, %clay and %silt of the sampling locations at the two depths and between control, historical and active dumpsite soils. However, some values showed no statistical significant difference. Mean ranges of microbial counts at 0–15cm and 15–30cm depths were: THB 9.4±4.39 to 22.4±5.78x10^5cfu/g and 13.8±7.78 to 16.1±13.45x10^5cfu/g, THF 2.37±0.45 to 7.1±1.85x10^5sfu/g and 3.9±2.29 to 6.4±2.09x10^5sfu/g respectively. Mean bacterial counts at the two depths were higher in control soils than the dumpsite soils, and lower in historical dumpsite soils compared to active dumpsite soils while fungal counts were higher in control soils than the dumpsites but lower in historical dumpsite soils compared to active dumpsite soils. Eleven (11) bacterial species isolated from the soil samples include *Bacillus tequilensis, Bacillus pumilus, Bacillus licheniformis, Bacillus species, Pseudomonas, Raoultella ornithinolytica, Pantoa ananatis, Serratia liquefaciens, Serratia odonifera, Staphylococcus* species and *E. coli. All the bacterial species* were found in active and historical dumpsite soils as well as in control soils except *Serratia liquefaciens* which occurred only in historical waste dumpsite soils, and *E. coli* which did not occur in the control soils. Order of predominance of bacteria was *Bacillus* > *Pantoa* > *Pseudomonas* > *Serratia* > *Staphylococcus* > *E. coli*. Order of predominance of fungal isolates was *Penicillium* > *Aspergillus* > *Rhizopus* >*Fusarium* >*Mucor* > *Trichoderma*. All the fungal species were isolated in all the soil samples.**

Keywords: **Biophysicochemical, Active, Historical, Waste dumpsites, Soil, Bacteria, Fungi.**

I. INTRODUCTION

Waste is any substance, solution, mixture or article for which no direct use is envisaged but which is transported for reprocessing, dumping, elimination by incineration or other methods of disposal (Obire *et al*., 2002). Urban industrialization, social development and population increase have led to rapid increase in waste production, making garbage pollution a serious problem (Khupe, 1996; Yaliang, 1996). A waste is said to be hazardous if it contains viable microorganisms or other toxins which are known to cause disease in animals and humans (Obire *et al*., 2002). When wastes are dumped on land, soil microorganisms such as bacteria and fungi colonize the wastes, degrade and transform the organic materials in the waste into other substances (Strainer *et al*., 1989). Microorganisms in waste dumps use the constituents of the waste as nutrients, thereby detoxifying the materials, as their digestive processes breakdown complex organic molecules into simpler less toxic molecules (Pavoni *et al*., 1975). This metabolic activity of microorganisms can be attributed to their growth rate, metabolism and their collective ability to degrade a vast variety of naturally occurring organic material (Strainer *et al*., 1989). In Nigeria, there are no established sanitary landfills (Moffat and Linder, 1996) and so wastes are not properly managed. Solid wastes that are improperly disposed are not only harmful to humans but also constitute a threat to ecological community (Yaliang, 1996), as pathogens, microorganisms and harmful chemicals can be introduced into the environment (Wai-Ogosu, 2004; Ogbonna, and Igbenijie (2006). These can contaminate surface water, ground water, soil and air which pose more problems for humans, other living species and the ecosystem (Obire *et al*., 2002). The aim of this study therefore, was to determine the microbiological

and physicochemical characteristics of active and abandoned (historical) waste dumpsites and control soils.

II. MATERIALS AND METHODS

Study Area

The study area was Rivers State which is located in the Niger Delta Area of Southern Nigeria. It is bounded to the South by the Atlantic Ocean, to the North by Imo, Abia and Anambra states, to the East by Akwa Ibom State and to the West by Bayelsa and Delta states, and lies between latitude $4^{o}45'$N and longitude $6^{0}50'$E. The inland part of the state consists of tropical rain forest, and towards the coast, the typical Niger Delta environment features many mangrove swamps. Rivers State is a low–lying pluvial state with a topography that ranges from flat plains, with a network of rivers to tributaries. Rainfall in Rivers State is generally seasonal, variable as well as heavy and occurs between the months of March and October. The peak of the wet season is in July. The dry months are November to February. Total annual rainfall ranged from about 1700mm in the extreme North to about 4700mm on the coast. Temperature throughout the year is constant between 25^{0}C to 28^{0}C with little variations. Relative humidity fluctuates between 90% and 100% for most of the year (Weather and Climate, 2017). The study locations were: Igwuruta in the North, old Port Harcourt in the South, Rumuekini in the West, Oyibo and Eleme in the East, and the study was carried out from November 2017 to May, 2018. The sampling stations include eleven (11) historical or abandoned waste dumpsites, three (3) active dumpsites and six (6) control sites which were about 100m from the study dumpsites. The geographical coordinates of the sampled locations are provided in Table 1.0.

Table 1.0: Geographical coordinates of the Sampling Locations of the Study Stations

Station code	Location	Geographical coordinates
Historical 1	Alode dumpsite, Eleme	N 04º 46'16.5" E 07º' 08' 17.1"
Historical 2	Rukpokwu/Eneka	N 04º 54' 00.3" E 07º 00' 52.4"
Historical 3	Eneka/Igwuruta	N 04º 56 '41.85'E 07º 01' 31.1"
Historical 4	East-west road (Obirikwere)	N 04º 52' 21.4" E 06º 57' 47.4"
Historical 5	Alakahia, East- west road	N 04º 53' 25.0" E 06º 55' 6.9"
Historical 6	OCC park boro pit, mile 4 Agip estate	N 04º 49' 11.7" E 06º 58' 48.7"
Historical 7	Timothy lane, by psychiatric road, Rumuola	N 04º 50' 09.3" E 07º 00' 0L0"
Historical 8	Mile 3 slaughter	N 04º 48'19.80"E 06º 59' 42.0"
Historical 9	Njemanze waterside by Abonema wharf	N 04º 47' 6.20" E 07º 00' 10.2"
Historical 10	Eastern bye pass by Redemption ministry	N 04º 47' 27" E 07º 00' 59.1"
Historical 11	Circular road, Elekahia	N 04º 49' 11.0" E 07º 01' 46.7"
Active 1	Igbo- Etche	N 04º 53' 45.8" E 07º 06' 57.5"
Active 2	Eliozu dumpsite	N 04º 53' 8.93" E 07º 00' 54.14"
Active 3	Igwuruta, km 6,Ikwere road	N 04º 56' 5.62" E 07º 01' 55.01"
Control 1	Control for Igbo- Etche	N 04º 53' 45.8" E 07º 06' 57.5"
Control 2	Control for Eliozu dumpsite	N 04º 53' 8.93" E 07º 00' 54.14"
Control 3	Control for Igwuruta, km 6, Ikwere road	N 04º 56' 5.62" E 07º 01' 55.01"
Control 4	Control for East-west road (Obirikwere)	N 04º 52' 21.4" E 06º 57' 47.4"
Control 5	Control for Alakahia, East- west road	N 04º 53' 25.0" E 06º 55' 6.9"
Control 6	Chapel of Redemption, RSU, Nkpolu-oroworukwo	N 04º 48'10.62" E 06º 59' 60.33"

Collection of Soil Samples

Soil samples were collected from waste dumpsites and control sites at depths of 0 - 15cm and 15 - 30cm. The soils were collected with the aid of a clean soil auger at three different points in each sampling station, composited and then put into sterile sampling bottles for microbiological analysis. Samples for physicochemical analysis were collected into fresh unused polythene bags. The samples were preserved in ice-cooled container and transported to the laboratory for analysis. Soil samples for microbiology study were analysed within two (2) hours of collection in Microbiology laboratory of Rivers State University, Port Harcourt.

Biological analysis of Soil Samples

Biological study of soils involved microbiological analysis of soil samples in which aerobic heterotrophic bacteria and fungi were enumerated and isolated from the soil samples. Serial tenfold dilution of Harrigan and MacCance (1990); Obire and Wemedo, 1996; Ofunne (1999); Nester *et al* (2004) was employed, in which dilutions of the soil samples were made up to 10^{-3} dilutions. Aliquots (0.1ml) of appropriate dilutions were spread plated, using a sterile bent glass rod, onto the surfaces of fresh sterile dried nutrient agar plates for bacteria and sabouraud dextrose agar plates for fungi. The inoculated plates were incubated at 37^{0}C for 24 hours for bacteria and 2-3 days for fungi. After incubation, plates that had significant growth were counted and the population of bacteria were

recorded in colony forming unit per gram (cfu/g) while population of fungi were recorded in spore forming units per gram (sfu/g) soil. Representative discrete bacterial colonies were purified by sub culturing onto fresh sterile nutrient agar plates which were incubated at 37^0C for 24 hours and used as pure cultures for characterization of the isolates. Similarly, colonies of fungi were sub cultured onto fresh sterile SDA plates which were incubated at 28^0C for 3–5 days and the pure cultures were used for characterization of fungal isolates.

Characterization and Identification of Bacterial and Fungal Isolates

Pure cultures of bacteria were obtained and subjected to various characterization procedures. The standard characterization tests performed included: Gram stain, motility test, catalase, methyl red and Vogues Proskauer test. Others are urease, indole, oxidase, nitrate reduction, starch hydrolysis and sugar fermentation tests. The isolates were identified on the basis of their colonial, morphological and biochemical reactions, and by reference to Cowan and Steel, 1974; Buchanan and Gibbons, 1994; Winn *et al*., 2006. Bacterial species were confirmed using ABIS Online Laboratory Software tool based on morphological and biochemical characters (ABIS Encyclopedia, 2019). Fungal isolates were macroscopically characterized by observing their colonial morphology, colour of colony, texture, shape, surface appearance, and colour on the reverse plates, and microscopically using the wet preparation and slide culture techniques by observing cultural characteristics to reveal the asexual and sexual reproductive structures like sporangia, conidial head, vegetative mycelia, septate and non-septate hyphae, and by reference to Alexopoulos and Sun, 1962; Barnett and Hunter, 1972; Winn *et al*., 2006, and confirmed by ABIS online software tool.

Determination of Physicochemical properties of the soil samples

Soil samples were air dried on large wooden trays for 72 hours, ground to homogenize the soil samples and sieved with a 2mm iron mesh sieve. Soil pH was determined by modified method of McLean (1982) and use of digital pH meter. Electrical conductivity was analysed by USEPA 120.1 (1982). Phosphorus was determined by Bray & Kurtz No. 1 method as modified by Nelson and Sommers (1982). Organic carbon was determined by Walkley & Black method as described and modified by Nelson and Sommers (1982). Particle size was analysed by Hydrometer method of Bouyoucos (1951) while Total nitrogen was determined by semi-micro kjeldahl digestion and distillation method (USEPA, 2001).

III. RESULTS

Mean concentrations of physicochemical parameters of the soil samples are shown in Figs 1- 4. Results of microbial counts of the soil samples at the two depths are shown in Fig 5. Ranges and Means ±SD of the physicochemical parameters and microbial load of the historical dumpsites, active dumpsites and control sites respectively were: Depth 0 – 15cm: pH 5.5 to 6.8 (6.45±0.45), 6.5 to 6.8 (6.63±0.14) and 5.8 to 6.5 (6.18±0.30); EC(µS/m) 84.2 to 522 (224.96±131.25), 153.5 to 912 (625.17±356.49) and 40.7 to 195.2 (90.38±55.92); Av. P.(mg/kg) 8.77 to 133.3 (44.58±35.53), 29.82 to 71.93 (54.97±19.24) and 20.32 to 45.61 (29.41±8.99); %TOC 0.59 to 3.86 (1.94±0.98), 1.72 to 1.83 (1.76±0.16) and 0.98 to 1.52 (1.27±0.22); %TOM 1.02 to 6.65 (3.42±1.69), 2.97 to 3.14 (3.03±0.09), and 1.69 to 2.62 (2.20±0.4); %TN 0.02 to 0.08 (0.04±0.02), 0.03 to 0.05 (0.04±0.01) and 0.02 to 0.06 (0.03±0.02); %Sand 72.6 to 90.6 (83.15±5.69), 76.6 to 84.6 (78.56±0.06), and 73.7 to 87.7 (81.03±5.90); %Silt 3.7 to 11.1 (7.82±2.13), 5.4 to 10.8 (7.77±2.39) and 5.4 to 19.4 (12.3±4.44); %Clay 4.3 to 20.3 (10.82±4.46), 8.9 to 8.9 (8.9±0.09) and 7.2 to 16.3 (11.98±3.02); CEC (CMOL/G) 3.56 to 32.25 (9.81±8.24), 5.08 to 17.28 (12.19±5.50) and 2.55 to 11.78 (6.68±3.08); THB($X10^5$CFU/G) 3.0 to 18.0 (9.4±4.39), 14.9 to 27.6 (22.43±5.78) and 5.8 to 24.4 (14.62±7.62); THF($X10^5$CFU/G) 1.4 to 3.2 (2.37±0.45), 2.9 to 3.4 (3.1±0.24) and 4.4 to 9.7 (7.1±1.85); Depth 15 –pH 5.5 to 6.6 (6.01±0.3), 6.4 to 6.6 (6.47±0.1) and 5.2 to 6.4 (5.85±0.04); EC(µS/m) 61.9 to 458 (215.1±118.1), 89 to 1036 (513.01±416.7) and 28.4 to 213 (98.02±0.28); Av. P.(mg/kg) 7.02 to 129.6 (30.91±34.5), 12.28 to 56.14 (29.82±20.0) and 12.28 to 42.11 (21.79±11.16); %TOC 0.35 to 3.2 (1.29±0.85), 0.9 to 1.6 (1.13±0.4) and 0.43 to 1.4 (0.92±0.36); %TOM 0.6 to 5.52 (2.25±1.41), 1.554 to 2.76 (1.95±0.62), and 0.74 to 2.41 (1.58±0.62); %TN 0.01 to 0.07 (0.02±0.02), 0.02 to 0.03 (0.02±0.01), 0.01 to 0.03 (0.02±0.01); %Sand 69.7 to 90.6 (83.81±5.64), 78.0 to 81.7 (79.23±1.85) and 71.7 to 87.7 (81.32±6.25); %Silt 3.1 to 9.7 (5.04±2.31), 5.4 to 7.1 (5.96±0.85) and 5.1 to 13.4 (8.92±3.44); %Clay 3.7 to 19.9 (9.15±4.45), 6.9 to 7.2 (7.01±0.18) and 6.9 to 12.92 (10.05±2.29); CEC(CMOL/G) 5.25 to 31.19 (9.28±7.83), 4.66 to 14.69 (9.10±4.42) and 1.79 to 17.04 (6.98±5.44); THB($X10^5$CFU/G) 4.8 to 27.2 (13.79±6.60), 6.2 to 34 (16.10±13.45) and 5.6 to 27.6 (13.83±7.78); THF($X10^5$CFU/G) 0.9 to 6.5 (3.97±1.69), 1.3 to 6.6 (3.93±2.29) and 3.1 to 8.7 (6.35±2.09). Seven (7) species of bacteria isolated include: *Bacillus* species, *Pseudomonas* species, *Serratia* species, *Staphylococcus* species, *Raoultella species, Pantoa species* and *E. coli*. *Bacillus* species was the most prevalent bacteria as it was present in all the soil samples. All the bacterial species were found in both active and historical dump sites and control sites except *Serratia liquefaciens* which was found only in some historical dumpsite soils, and *E. coli* which did not occur in control soil sites. Six (6) genera of fungi identified include: *Aspergillus* species, *Fusarium* species, *Mucor* species, *Penicillium* species, *Rhizopus* species and *Trichoderma* species. All the organisms occurred in waste dumpsites and control soils.

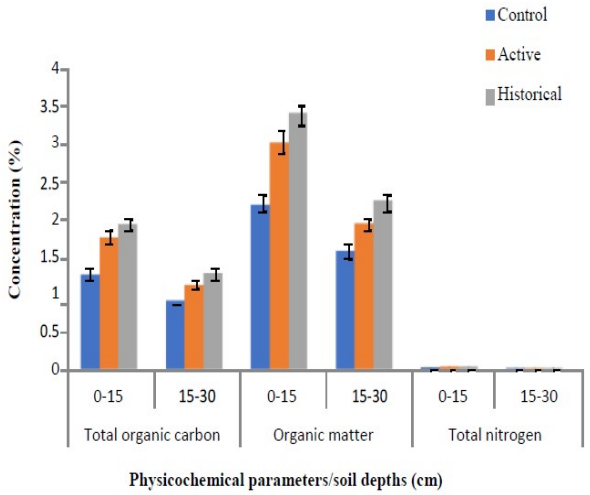

Fig 1: Mean concentration of physicochemical parameters of two soil depths of solid Waste dumpsites and control sites.

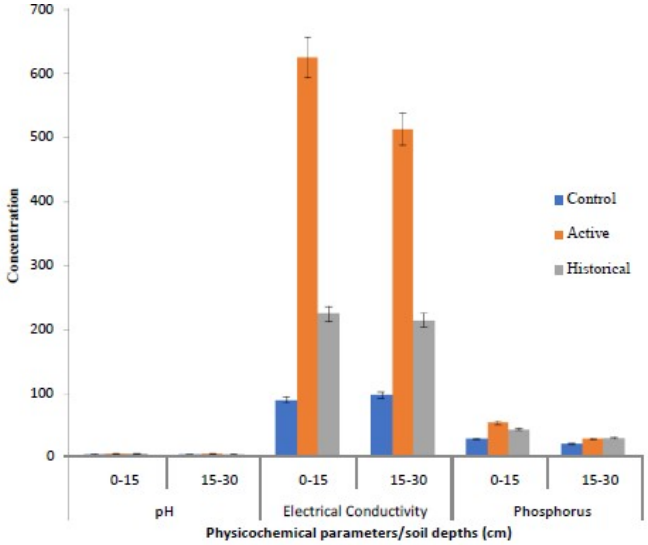

Fig 2: Mean concentration of physiochemical parameters of two soil depths of solid waste dumpsites and control sites

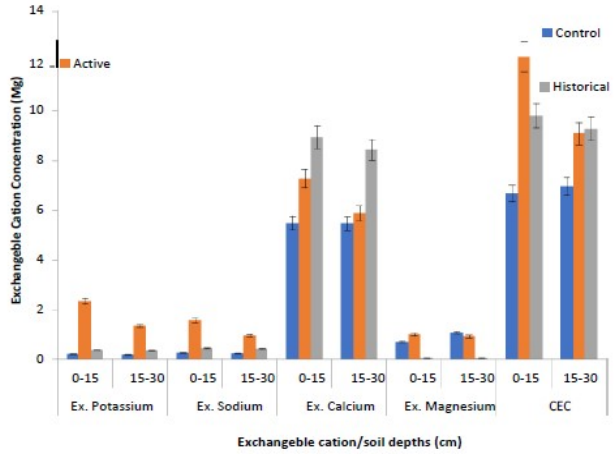

Fig 3: Mean concentration of physiochemical parameters of two soil depths of solid waste dumpsites and control sites

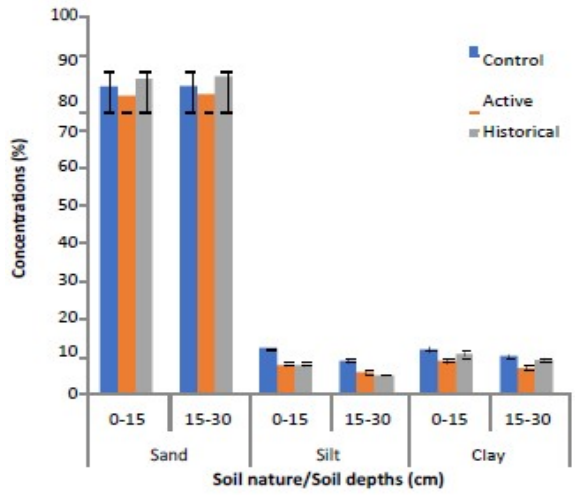

Fig 4: Mean Concentration of particle size of two soil depths of solid Waste dumpsites and control sites.

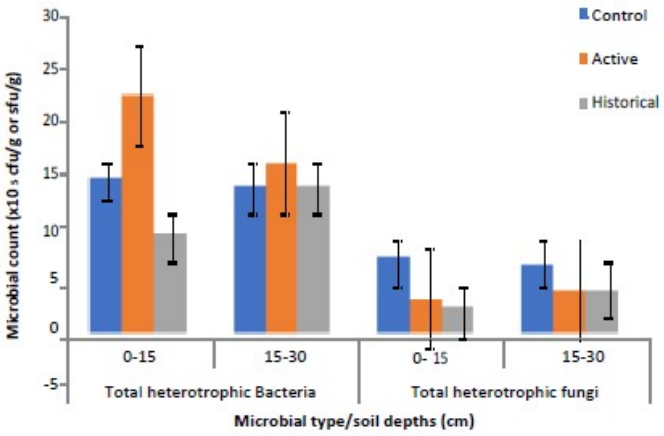

Fig 5: Mean ±SD of microbial counts of two soil depths of solid waste dumpsites and control sites.

IV. DISCUSSION

Concentrations of physicochemical parameters and microbial populations fluctuated between the soil types and soil depths. The values of physicochemical parameters showed that there was significant difference at $P<0.05$ confidence level in silt, electrical conductivity, phosphorus, organic carbon, organic matter, exchangeable potassium, sodium and magnesium between control sites, active and historical waste dumpsites. The pH of the studied soil samples tended to acidic range. The highest mean pH was recorded at the 0 - 15cm depth in the active waste dumpsite soils while the lowest mean pH was recorded at 15 - 30cm depth in control soils (Fig 2). The order of variations in mean pH for the various sites at 0 – 15cm depth was Active dumpsites > Historical dumpsites > Control sites while the order of variations of mean pH at 15 – 30cm depth was Active dumpsites > Historical dumpsites >Control sites. The highest mean electrical conductivity (EC) value at 0 - 15cm was in active dumpsite while the least mean EC value was recorded in control site at 0 – 15cm depth (Fig 2). The

highest mean percentage phosphorus at 15 - 30cm was recorded in active dumpsite, while the lowest mean was recorded in control site at 0 – 15cm depth. Highest mean percentage organic carbon was observed in historical dumpsites at 0 - 15cm depth while the lowest mean percentage organic carbon was observed in control site at depth of 15 – 30cm (Fig 1). Percentage organic matter was higher in the dumpsite soils than control sites, with historical dumpsite soils having highest mean concentrations at 0 - 15cm depth while control site had the lowest mean concentration at depth of 15 - 30 cm (Fig 1). Total nitrogen was higher in the dumpsite soils, with active dumpsite and historical dumpsite soils having equal mean concentrations at 0 – 15cm depth compared to the control soils which had lowest mean concentration. Results showed that the mean concentration of sand was highest in the historical dumpsite soils at 15 – 30cm depth while active dumpsite soils had the lowest value at 15 – 30cm depth (Fig4). The value for silt was highest in the control soils at 0 – 15cm depth compared to the dumpsite soils with historical dumpsite soils having the lowest value at 0 – 15cm depth. The lowest mean value of clay was recorded in active dumpsite soils at 15 - 30cm depth while the highest mean concentration was recorded in control soils at 0 – 15cm depth. The highest mean cation exchange capacity was recorded in active dumpsite soils at 0 –15cm depth while the lowest mean value was recorded in control site soils at 0 – 15cm depth. Mean bacterial counts of the two soil depths were highest in control soils than the dumpsite soils but lower in historical dumpsite soils than active dumpsite soils while fungal counts were highest in control soil than the dumpsite soils but lower in historical dumpsite soils than active dumpsite soils. Therefore, the trend in mean heterotrophic bacterial counts at 0 - 15cm depth was in the order: Active dumpsite > Control sites > Historical dumpsites (Fig. 5). The order of variations of mean heterotrophic bacterial counts at 15 – 30cm was Active dumpsites > Control sites > Historical dumpsites. The trend in the variations of mean heterotrophic fungal counts at 0 – 15cm depth was Control sites > Active dumpsites > Historical dumpsites while the trend of variations of mean heterotrophic fungal counts at 15 – 30cm depth was Control sites > Historical dumpsites > Active dumpsites.

The higher pH values in the dumpsite soils than in the control soils could be as a result of liming materials and activities of some microorganisms in the solid waste (Ayade, 2003; Ideriah *et al*., 2006). Obire *et al* (2002) reported a pH range of 5.4 to 7.9 which is in agreement with the pH range observed in this study. Hagerty *et al* (1973) reported that the initial pH of 3 days old solid (refuse) waste is between 5.0 and 7.0. Abdus-Salem (2009) and Ogbonna *et al* (2009) reported similar acidic ranges of top soils from several municipal waste dumpsites in Ilorin, Central Nigeria and Port Harcourt, Southern Nigeria respectively. Soils in the acidic pH range tend to have increased micronutrient solubility as well as increased heavy metal concentration (Odu *et al*., 1985), thus rendering such soil unsuitable for waste land filling (Ogbonna *et al*., 2009).

The high electrical conductivity values in the waste dumpsite soils compared to the control site soils may be as a result of presence of metal scraps, a component of the waste. This also implies that the dumpsite soils contain more soluble salts (Arias *et al*., 2004; Singer and Munns, 1999) than the control site soils.

The values of organic matter which were higher in the dumpsite soils when compared to the control sites could be as a result of decomposition and composting of animal wastes such as cow dung, food remains, and animal blood. High level of organic matter in dumpsites favours moisture content, water holding capacity and permeability (Ibitoye *et al*., 2001). Solid waste dumpsites have been reported to be rich in organic matter which is the source of most of the nitrogen and phosphorus that enhance soil fertility and promote plant growth (Ideriah *et al*., 2010). The higher concentration of total nitrogen in the dumpsite soils compared to lower values in control soils could be due to the composition of the wastes, which are majorly household wastes that are high in organic matter content as well as the decomposition activities of soil organisms which could have accounted for the rich nutrient contents of the dumpsite soils (Obute *et al*., 2010; Amos-Tantua *et al*., 2014). This was confirmed by their acidic pH values and climate conditions as saline soils are found under arid or semi-arid climates (Oluyemi *et al*., 2008).

Results of this study which showed high concentration of available phosphorus in the dumpsite soils indicated the presence of high amount of organic matter and plant decomposition products (Ideriah *et al.,* 2006). All the sampling locations had available phosphorus values greater than 10mg/kg considered suitable for crop production (FAO, 1976). Also high level of organic carbon at the dumpsites can be as a result of the type of waste (Stockdate *et al*., 2002) and burning of solid wastes in the dumpsites.

Cation exchange capacity (CEC) which is the amount of exchangeable cation per unit weight of dry soil plays an important role in soil fertility. It gives a buffering capacity to the soil which may slow down leaching of nutrient cations and positively charged pollutants because they affect both soluble and exchangeable metal levels (Stockdate *et al*., 2002) and depends on pH, clay and organic carbon. The CEC values at the dumpsites were higher than those of the control sites. This could be because a large part of exchangeable bases at the dumpsites which must have been existing in water-soluble form rather than in exchangeable form adsorbed at cation exchange sites.

All the soil samples had high calcium values which are above the lower limit of 4.0cmol/kg for fertile soil (FAO, 1976). Exchangeable potassium was higher in active dumpsite soils above the critical limit of 0.2cmol/kg for exchangeable potassium in soils (Unamba-Opara, 1985). This was an

indication that the soils are rich in nutrients and will give high crop yield even without application of fertilizers to the soils.

The percentage sand was higher in the three sites compared to silt and clay. The highest amount of sand was recorded in a historical site at 15 - 30cm depth while the lowest amount of sand occurred in an active dumpsite at 0 – 15cm depth. Soil texture is of great importance for improvement of cation exchange capacity of the soil and hence capacity to hold major and minor nutrients. This was corroborated with reports by Eneje and Lemoha (2013); Ideriah *et al*. (2010) which observed sandy nature of top soils from several municipal dumpsites in Owerri, Eastern Nigeria, Ile-Ife, Western Nigeria and Port Harcourt, Southern Nigeria. This trend however is in contrast with report by Ogbonna *et al*. (2009) which reported that majority of topsoil samples collected from waste dumpsites in Port Harcourt Nigeria were silty in nature. Oyedele *et al*. (2008) stated that the textural class of a particular soil is mainly from the soil-forming materials. The high sand content of the soil samples showed that the dumpsites from which the samples were obtained could be used as landfill sites. Ogbonna *and* Igbenijie (2006) reported that waste dumpsites with low sand fractions (<40%) were not suitable for waste landfilling since they are rapidly permeable and could allow large quantities of leachates from the waste to invade the deposited refuse and finally to the ground water resources. Intact soil is composed of mineral particles, organic materials, pore spaces and living organisms (Frey, 2007).

There was significant difference in counts of total heterotrophic bacteria and total heterotrophic fungi at $P<0.05$ confidence limit. The bacterial load from the control soil and historical dumpsite soil samples were lower compared to the counts of active dumpsite soil samples (Fig 4). This could be attributed to the increased availability of biodegradable organic and inorganic substrates from the different municipal wastes being continuously dumped at the active dumpsites. The nutrients in the wastes provided nourishment for the microbes to proliferate. Also, the control soil samples having the highest fungal counts could be attributed to presence of complex substrates of plant origin in the control soils studied (Thorn and Lynch, 2007). The historical waste dumpsites were long ago abandoned waste dumpsites without fresh wastes but with completely decomposed previously dumped wastes. The lower microbial counts could be attributed to accumulation of toxic materials from the old decomposed wastes and lack of nutrients supply from fresh wastes.

Bacillus species was the most prevalent bacteria as it was present in all the soil samples. All the bacterial species were found in both active dumpsites, historical dumpsites and control site soils except *Serratia liquefaciens* which was found in some historical dumpsite soils only. The control site soil samples did not harbour *E. coli* which occurred in active and abandoned solid waste dumpsite soils. *E. coli* could have been introduced into waste dumpsites soils through waste sources containing faecal matter. This bacterium (*E. coli*) lives in the intestine of warm-blooded animals including humans as its natural habitat, and is used as indicator of faecal contamination. Also, the occurrence of these bacterial and fungal species in the abandoned and active waste dumpsites' soils could raise some public health issues that could lead to spread of infectious diseases amongst inhabitants of the area. On the other hand, the elevated levels of some physicochemical parameters could serve as added soil nutrients for plants' growth, and for proliferation of soil microbes.

The microbes encountered in this study tend to produce enzymes, DNase, Staphylokinase and Staphylosin, among others that assist in degrading waste materials at the dumpsites. The microorganisms found in these waste dumpsites get their nutritional requirement from the wastes, hence the high bacterial growth profile in the waste dumpsites (Osazee *et al*., 2013). The microbial isolates identified from the soil samples have been reported to be associated with waste and waste biodegradation (Obire *et al*., 2002). Also, *Aspergillus, Fusarium, Mucor, Penicillium, Rhizopus* and a variety of yeast have also been reported to participate in waste biodegradation (Ekundayo, 1977; William and Hakam, 2016). This should be the case in this study which further suggests the participation of these bacteria and fungi in waste degradation.

V. CONCLUSION

The pH of the studied soil samples was acidic and hence the soil samples will have increased micronutrient solubility as well as increased heavy metal concentration. The physicochemical properties studied including electrical conductivity, organic matter, available phosphorus, total nitrogen, and CEC were higher in the dumpsite soils than in the control site soils. The bacterial and fungal densities were generally higher in the waste dumpsites' soils than the control soils which are indication of addition of nutrients from decomposing wastes onto the waste dumpsites' soils.

Of the seven (7) genera of bacteria isolated and identified, *Bacillus* species was the most prevalent bacteria as it was present in all the soil samples. All the bacterial species were found in both active and historical dump sites as well as in the control soils except *Serratia liquefaciens* which was found in historical dumpsite soils only and *E. coli* which did not occur in control soils. The presence of *E. coli* in active and abandoned waste dumpsites' soils revealed dumping of faecal matter on the soils. All the six (6) genera of fungi isolated occurred in all the waste dumpsites and control soils.

Although, the disposal of municipal wastes in open dumpsites has positive impact on the microbial counts and organic properties of the studied soils; it is not a good choice in municipal waste management because such wastes' sites could be a source of infections to the inhabitants living around the open waste dumpsites. This in turn could lead to public health problem arising from spread of communicable diseases

carried by potential pathogenic bacteria and fungi occurring in the waste dumpsite soils. Hence, government should collaborate with interested companies or public-private partnership on a large-scale investment on the proper management of municipal wastes using sustainable alternatives such as recycling and energy generation from municipal wastes.

REFERENCES

[1] Abduls-Salem, N. (2009). Assessment of heavy metal pollution in waste dump sites in Ilorin metropolis. Ethiopian Journal of Environmental Studies and Management, 2(2): 92- 99.

[2] ABIS ENCYCLOPEDIA (2019). *Bacillus licheniformis*. http//www.tgw 1916.net/*Bacillus/licheniformis*.html. Retrieved 4-14-2019.

[3] Alexopoulos, C. J. and Sun, S. H. (1962). Introductory Mycology, 2nd Edition, John Willey and Sons Inc., New York, ISBN: 0-471-02215-2.

[4] Amos-Tautua, B. M. W., Onigbinde, A. O., and Ere, D. (2014). Assessment of some heavy metals and physicochemical properties in surface soils of municipal open waste dumpsites in Yenegoa, Nigeria. African Journal of Environmental Science and Technology, 8(1): 41 – 47.

[5] Arias, M. E, Gonzalez-Perez, J. A, Gonzalez-Vila, F. J. and Ball, A. S. (2005). Soil health – a new challenge for Microbiologists and Chemists. International Microbiology, 8: 13-21.

[6] Ayade, B. B. (2003). Indigenous Biological Treatment of hydrocarbon contaminated soil in the tropics. Africa Journal of Ecology, 44(3): 388 – 394.

[7] Barnett, H.C. and Hunter, B. B. (1972). Illustrated genera of imperfect fungi. 3rd Edition, Burgress Publishing Co., Minneapolis, pp: 20.

[8] Bouyoucos, G. H. (1951). A Recalibration of the Hydrometer for Making Mechanical Analysis of Soils. Agronomy Journal, 43, 434 – 438.

[9] Buchanan, R. E. and and Gibbons, N. E. (Eds.) (1994). Bergey's Manual of Determinative Bacteriology. 9th Edition, Williams and Wilkins Co., Baltimore, USA. pp: 112 – 142.

[10] Cowan, S. T. and Steel, K. J. (1974). Manual for Identification of Medical Bacteria. Cambridge University Press, London.

[11] Ekundayo, J. A. (1977). Environmental consequences of pollution of the Lagos Lagoon. Bulletin of the Science Association of Nigeria, 3(2): 290 – 299.

[12] Eneje, R. C. and Lemoha, K. T. (2012). Heavy metal content and physicochemical properties of municipal solid waste dump soils in Owerri, Imo state. International Journal of Modern Engineering Research, 2(5): 3795 – 3799.

[13] FAO (1976). A framework for land evaluation. Food and Agricultural Organization Soils Bulletin 32, United Nations.

[14] Frey, S. D. (2007). Spatial distribution of soil organisms, In: Soil Microbiology, Ecology, and Biochemistry, Paul, E. A., 3rd Edition, New York. Elsevier, 283 – 300.

[15] Hagerty, D. J., Paroni, J. L. and Heer, J. E. (1973). Solid Waste Management, John Wiley & Sons, New York.

[16] Harrigan, W. F. and McCance, M. E. (1990). Laboratory Methods in Food and Dairy Microbiology. 8th Edition, Academic Press, London, UK, pp. 136 – 138.

[17] Ibitoye, A. A. (2001). Effect of municipal refuse dump on soil and water quality in Akure Metropolis. Journal of Applied Soil Science, 2: 16 –24.

[18] Ideriah, T. J. K., Omuaru, V. O. T., and Adikwu, P.U. (2006). Soil quality around a solid waste dumpsite in Port Harcourt. African Journal of Ecology, 44(3): 388 – 394.

[19] Ideriah, T. J. K., Harry, F.O., Stanley, H.O. and Igbara, J. K. (2010). Heavy metal contamination of soils and vegetation around solid waste dumps in Port Harcourt, Nigeria. Journal of Applied Science and Environmental Management, 14(1): 101- 109.

[20] Khupe, J. S.N. (1996). Water Supply, Sewage and Waste Management for Garborone, Botwsana.

[21] McLean, E. O. (1982). Soil pH and Lime Requirement, Page, A. L. (Edn). Methods of Soil Analysis Part 2, Chemical and Microbiological Properties, American Society of Agronomy, Soil Science Society of America, Mardison, pp: 199 – 224.

[22] Moffat, D. and Linden, O. (1996). Perception and Reality Assessing Priorities for sustainable development in Niger Delta. Ambio. 24: 527-538.

[23] Nelson, D. W. and Sommers, L. E. (1982). Total carbon, organic carbon and organic matter. In: Page, A. L., Miller, R. H., and Keeney, D. R. (Eds.). Methods of Soil Analysis, American Society of Agronomy, Madison, USA, pp: 539 – 580.

[24] Nester, E. W., Anderson, D. G., Roberts, E. C. Jr., Pearsall, N. N. and Nester, M. T. (2004). Microbiology: A Human Perspective, 4th Edition, McGraw Hill Higher Education. The McGraw Hill Companies, Inc., 1221 Avenue of the Americas, New York, NY 10020.

[25] Obire, O., Nwabueta, O., and Adue, S. B. N. (2002). Microbial community of a waste dump site. Journal of Applied Sciences and Environmental Management: 6(1): 78 – 83.

[26] Obire, O. and Wemedo, S. A. (1996). The Effect of Oilfield Wastewater on the Microbial Population of a Soil in Nigeria. Niger Delta Biologia, 1(1): 77 - 85.

[27] Obute, C. C., Ndukwu, B. C. and Eze, E. (2010). Changes in species diversity and physicochemical properties of plants in abandoned waste dumpsites in parts of Port Harcourt, Nigeria. Scientia Africana, 9(1): 181 – 193.

[28] Odu, C. T. I., Nwoboshi, L. C. Esuruoso, O. F. and Ogunwale, J. A. (1985). Environmental study of the Nigeria Agip Oil Company Operational Areas, In: The Petroleum Industry and the Nigeria Environment Proceedings FMW&H and NNPC Conference, pp 274 – 283.

[29] Ofunne, J. I. (1999). Bacteriological Examination of Clinical Specimens. Achugo Publications, Ama J. K. Recreation Park, Owerri, Nigeria.

[30] Ogbonna, D. N., and Igbenijie, M. (2006). Characteristics of Microorganisms Associated with Waste Collection Sites in Port Harcourt, Nigeria. Nigeria Journal of Microbiology, 20(3): 1427 - 1434.

[31] Ogbonna, D.N., Kii, B.L. and Youdeowei, P. O. (2009). Some physicochemical and heavy metal levels in soils of waste dumpsites in Port Harcourt Municipality and Environs. Journal of Applied Sciences and Environmental Management: 13(4): 65 – 70.

[32] Osazee, O. J., Obayagbona, O. N. and Daniel, E.O. (2013). Microbiological and physicochemical analysis of top soils obtained from four municipal waste dumpsites in Benin City, Nigeria. International Journal Microbiology and Mycology, 1(1): 23 – 30.

[33] Oluyemi, E. A., Feuyit, G., Oyekunle, J. A. O. and Ogunfowokan, A. O. (2008). Seasonal variations in heavy metal concentrations in soil and some selected crops at a landfill in Nigeria. African Journal of Environmental Science and Technology, 2(5): 89 – 96.

[34] Oyedele, D., Gasu, M. B. and Awotoye, O. (2008). Changes in Soil Properties and Plant Uptake of heavy metals on selected municipal waste dumpsites in Ile-Ife, Nigeria. African Journal of Environmental Science and Technology, 3: 107 – 115.

[35] Pavoni, J. L., Heer, J. E., and Hagerty, D.L. (1975). Handbook of Solid Waste Disposal, Materials and Energy Recovery. Van Nostrand Reinhold Company, New York.

[36] Singer, M. J. and Munns, D. N. (1999). Soils: An Introduction, 6th Edition. Published by Prentice Hall College Division.

[37] Stockgate, E. A., Shepherd, M. A., and Cuttle, S. P. (2006). Soil fertility in organic farming systems-fundamentally different? Soil Use and Management, 18(1): 301 – 308.

[38] Strainer, R. J., Ingraham, J. L., Wheelis, M. L., and Painter, P. R. (1989). General Microbiology, Macmillian Education Limited. Pp: 234.

[39] Thorn, R. G, and Lynch, M. D. J. (2007). Fungi and Eukaryotic Algae. Soil Microbiology, Ecology and Biochemistry, 145 – 162.

[40] Unamba-Oparah, I. (1985). The potassium status of the sandy soils of Northern Imo State, Nigeria. Soil Science, pp: 437 – 335.
[41] USEPA (1982). Specific Conductance using surface water samples, Method 120.1, FWPCA Method Study 1, United States Environmental Protection Agency.
[42] USEPA (2001). Method 1687, Total Kjeldahl nitrogen in water and biosolids analysis by Automated Colorimetry with Preliminary Distillation Digestion. United States Environmental Protection Agency Vol. 3, pp 1 – 29.
[43] Wai-Ogosu, O. A. (2004). Monitoring and Evaluation of Industrial Waste Management Options in Rivers State. Paper presented at a workshop on Sustainable Environmental Practices in Rivers State, organized by Rivers State Ministry of Environment, Hotel Presidential, Port Harcourt, 23 – 24.
[44] Weather and Climate (2018). State of the Climate, Extreme weather and High Impacts, World Meteorological Organization Press Release 22032018, United Nations.
[45] William, O. J., and Hakam, K. (2016). Microorganisms associated with dumpsites in Port Harcourt Metropolis, Nigeria. Journal of Ecology and Natural Environment: 8(2): 9 – 12.
[46] Winn, W. C., Allen, S. D., Janda, W. M., Koneman, E. W., Procop, G. W., Schreckenberger, P. C. and Woods, G. L. (2006). Koneman's Color Atlas and Textbook of Diagnostic Microbiology. 6th Edn., Lippincott Williams and Wilkins, Philadelphia.
[47] Yaliang, Y. (1996). Water Supply, Sewage Treatment and Waste disposal Strategies for Sustainable Development, Ambio 25: 86 – 89.