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Research article

EFFECT OF HEAVY METALS IN MUNICIPAL WASTES LEACHATES ON SOIL MICROORGANISMS IN OBIO AKPOR, NIGERIA

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ABSTRACT

Soil samples from three municipal dumpsites in Obio Akpor Local Government Area (Alakahia, Ada George, off Iwofe Rd and Nsirim by OCC park dumpsites) with control sites 100m from the dumpsites were collected at two depths (0-15 and 15-30cm) and analyzed for heavy metals: lead(Pb), cadmium(Cd), copper(Cu) and zinc(Zn) and also microbial (fungal and bacteria) population. The metals were detected in all the samples though in trace amount except for Zn which was in higher quantity especially for samples collected at the Ada George dumpsite at the 0-15cm depth. Cadmium had the least occurrence in all the samples with a negative mean range for most of the samples. For the micro organisms, the bacteria species *Baccillus* was common in all the soil samples from OCC at 15-30cm depth having the highest >300 and Alakahia control the lowest 4×10^{-5}. For the fungal species yeast was present in all the samples, the highest population also was in the OCC dumpsite, 120×10^{-3} and the lowest population in the Ada George control at 15-30cm, 6×10^{-3}.All the detected elements were well below the contamination and toxicity level in the soil and so may not have had any adverse effect on these microbial communities under study. Further studies in the greenhouse with chemicals containing heavy metals and isolated micro-organisms from municipal dumpsites are warranted.

Key Words: Heavy Metal, Obio Akpor, Microorganisms, Municipal Solid Waste, Dumpsites

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Introduction

Heavy metal is a term commonly adopted as a group name for the metals that are associated with pollution and toxicity but also includes some elements which are essential for living organisms at low concentrations. The main elements usually considered as heavy metals include: Arsenic (As), Antimony (Sb), Cadmium (Cd) Copper (Cu, Chromium (Cr), Cobalt (Co), Gold (Au), Lead (Pb), Mercury (Hg), Manganese (Mn), Selenium (Se), Silver (Ag), Thallium (Tl), Uranium (U), Vanadium (V) and Zinc (Zn).

Among these heavy metals, some have been found to be of greatest hazard to plants, animals and microorganisms and have been listed by the European commission. They include, Arsenic, Mercury, Cadmium, Chromium, Copper, Lead, Nickel and Zinc.

Studies of heavy metals in ecosystems have indicated that many areas near urban complexes, metalliferous mines or major road systems, contain anomalously high concentration of heavy metals. This is associated with pollution problems which can be hazardous to man and other organisms. A source of introduction of these heavy metals in the soil is from municipal solid waste, MSW (Akpan and Akpanidiok 2006).

MSW refers to waste that arise from man's activities in the cities. MSW consist of solid materials discarded by offices, homes, factories, retail stores, restaurants, schools, hospitals, prisons and other commercial institutions. It is a heterogeneous mixture composed primarily of paper, yard waste, glass, metals, plastics, food waste and other materials like rubber, leather and textiles. Apart from designated areas for waste dumps, some of these wastes are indiscriminately dumped along some streets and around market areas especially in big cities such as Lagos, Ibadan, Port Harcourt, Aba, Calabar, etc in Nigeria (Akpan and Akpanidiok 2006).

Over the years, the effective management of refuse or solid waste has been a major problem in the city of Port Harcourt and its environs. This, according to Gobo (2002) may be due to several factors, including a poorly managed and uncoordinated approach to waste management practices, unhealthy cultural attitudes and habits, urbanization patterns, population growth, non- mechanized waste disposal methods and poor financing of the sector, Ayotamuno and Gobo (2004) further observed that solid waste management systems options that have been carried out without success to solve the problem of refuse disposal in Port Harcourt and its environs over the years include incineration, composting, transfer stations and landfilling.

Maintenance of good soil quality is of prime importance for sustainable agriculture and other activities. Heavy metal pollution of soil is a concern for human health and ecosystem function. The microbial community is a sensitive indicator of metal contamination effects on bioavailability and biogeochemical processes.

Soil microorganisms are very sensitive to environmental change (Turco *et al.*, 1994) and significant changes of the microbial community can occur following disturbance both in terms of total biomass and species composition, (Harris *et al.*, 1991, 1993). Measures of the microbial community following imitation of reclamation efforts could be used as an indicator of the restoration process (Harris *et al.* 1991).

The microbial community of the soil includes. bacteria, fungi, algae, viruses and protozoa which are of wide varieties. They are found in large numbers in soil, usually between one and ten million microorganisms are present per gramme of soil, with bacteria and fungi being the most prevalent.

Heavy metals are known as harmful pollutants in soil having a negative effect on soil biota including microorganisms. Some heavy metals such as lead even at low levels are toxic while others such as zinc and copper at low concentrations are essential for microorganisms (Hughes and Poole 1989). Toxicity may also be exerted by many inorganic and organic metal complexes (Bewley and Stotzky, 1983). Heavy metals affect microorganisms in soil in various ways. They shift the structure of microbial populations, impoverish their diversity, affect species compositions, reproduction and activity of indigenous microorganism (Arnebrant *et al.*, 1987; Frostegrad *et al.* 1996). The major objectives of this study were therefore to: i) evaluate the physico-chemical properties of the soil; ii) examine the presence of heavy metals in soil of municipal solid waste sites; iii) determine the species composition of microbial community in the soil at the dumpsites; iv) assess the effect of heavy metals in MSW leachates if any on the soil microorganisms.

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MATERIALS AND METHODS

Description of Study Area

The study area is within Obio/Akpor Local Government Area. Due to its proximity to the capital Port Harcourt (which is the most important city in the Niger Delta Region) it is most times referred to as Port Harcourt. It falls within the sub equatorial climate belt. Temperature and humidity are high throughout the year. The area is marked by two distinct seasons: the wet and the dry seasons, with 70 percent of the annual rains falling between April and August, while 22 percent is spread in the three months of September to November. The driest months are from December to March (Ayotamuno *et al.*, 2000; Gobo, 1998). The soil type consists mainly of poorly-drained silt clays mixed with sand which is geologically classified under the Benin formation.

It is an important industrial city with a lot of industrial waste being generated combined with the household and commercial waste. The management of this waste is vested in the Rivers State Environmental Sanitation Authority (RSESA) who in turn employs waste contractors to manage various dumpsites.

For purposes of this study three (3) major dumpsites has been earmarked and they are sited at: a) Ada George Road, Off Iwofe road; b) Alakahia (along East -west road); c) Nsirim Street by OCC Park

Control samples of about 100m northwards from each dumpsite at two depths of 0-15cm and 15-30cm were taken. The above mentioned dumpsites are major sites of waste in the city hence their utilization because of the high level of contamination of the soils in these areas. In addition, unpolluted sites were also analyzed during the study.

Collection of Soil Samples

Soil samples were collected by using an auger and spreading it on polythene sheets placed in Aluminum trays and allowed to air dry. The soil was further broken down into fine particles and then sieved using an Aluminum sieve of 2mm mesh.

Soil Analytical Methods

The particle sizes of the soils were determined using the hydrometer method as described by Bouyoucos (1962).

The pH of sample were determined by the electrometric method, in a 1:2.5 soil water ratio, using a pH meter. Organic carbon was determined by the Walkley and Black Wet Oxidation method as modified by Nelson and Sommer (1982). The organic matter content of each sample was determined by multiplying % organic carbon by a factor 1.724. The total Nitrogen content of the soil was determined by the Macro-Kjedahl method (Bremner and Mulvaney, 1982).

Bray 1 method as modified by Olsen and Sommers (1994) was used to extract available phosphorus. The percentage transmittance of the extracted sample was measured on the spectrometer at 660nm wavelength.

Exchangeable bases in the soil samples were extracted with neutral normal ammunion acetate buffered at pH 7.0 after shaking for 2 hours (Rhoades, 1982). Exchanageable Ca and Mg were determined by EDTA complexometric titrations (Heald, 1965) while the concentration of exchangeable K and Na were determined by flame Photometry (Knudsen *et al*., 1992).

Heavy Metal Analysis

The soils were digested using HCl/HNO_3 procedure of Anderson (1974) and Bloom and Ayling (1977). The concentrations of the heavy metals were determined using AAS by comparison to aqueous standards.

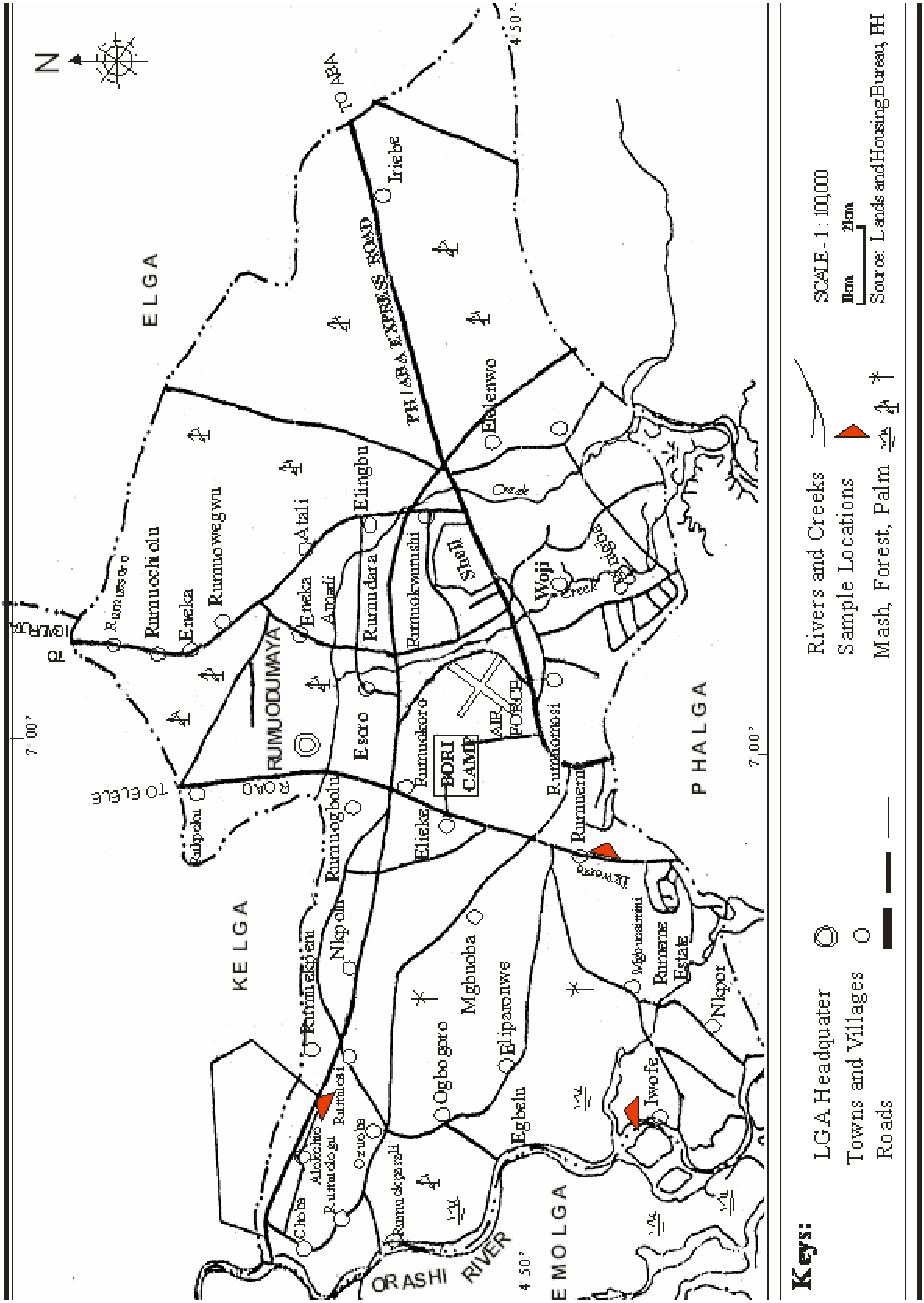

Fig 1: Map of Obio/Akpor Local Government Area showing the Study Sites

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ANALYTICAL METHODS FOR BACTERIAL AND FUNGI COUNTS

Analytical Procedure

The soil samples were weighed as 1g each and dissolved in 10ml of sterile distilled water. This formed the neat solution. This was further diluted by pipetting 1ml of the original solution and adding 9ml of sterile water until the dilution of 10^{-5} was achieved for bacteria and 10^{-3} for fungi. 0.1ml of the 10^{-5} was plated on nutrient and MacConkey agar and 0.1ml of 10^{-3} was plated out on Sabourand Dextrose Agar. Incubation was 18-24hrs for the bacteria culture and 3-7days for the fungi plates (Ogbubie, 2001).

Isolation and Enumeration of Bacteria and Fungi

Pure culture of bacteria was taken aseptically streaking representative colonies of different morphological types 0-the cultured plates into freshly prepared Nutrient agar plates which was incubated at 37°C for 24hrs.

Pure cultures of fungi were obtained by sub culturing discrete colonies into freshly prepared Sabourand's dextrose agar plates and incubated at 28°C for 5 to 7 days.

RESULTS AND DISCUSSION

Soil Physico-chemical Properties

Ada George Dumpsite: The result of the particle size analysis showed that the soils were generally clayey loam mixed with sand with the clay content increasing with depth (Table 1). The properties when compared to that given by Black for Soil data analysis had the following: The soil pH values showed a range of 4.30-6.40 indicating different levels of acidity with an average of 4.25 for the control and 6.30 for the dumpsite. Varying degree of organic carbon was noticed with higher values in the dumpsite. The concentration of phosphorus was very high in the control and moderate in the dumpsite with the surface soil having a higher concentration. The level of exchangeable bases (i.e Ca, K, Na, Mg) was higher in the control than in the dumpsite. Calcium levels were very high so also were Mg and K but Na had a low concentration. Total nitrogen levels were generally moderate for both the dump and control sites. Electrical conductivity was higher for the dumpsite than in the control sites with higher values noticed in the subsurface soil.

Alakahia Dumpsite: The result of the particle size analysis showed that the soils were sandy clay loam with clay content also increasing with depth (Table 2). Soil pH ranged from 3.70-6.30 indicating varying levels of acidity with an average value of 3.6 for the control site and 6.2 for the dumpsite. Organic carbon content was higher in the control site than in the dumpsite with the surface soils having a higher concentration. For the levels of exchangeable bases, K had very high concentration, Composition of Ca was high and Mg was moderate, while Na was high for the dumpsite and low for the control site.

Table 1: Soil Physico-Chemical properties of Ada George Dumpsite.

Soil Properties	Dumpsite		Control site	
	0-15cm	15-30cm	0-15cm	15-30cm
pH	6.20±3.21	6.40±3.41	4.30±1.21	4.20±1.19
EC (µg/g^{-1})	143±27.40	230±30.10	29±5.61	31±6.12
AV.P (µg/g^{-1})	18.79±5.20	13.16±4.11	52.62±8.46	32.89±7.31
Total N(%)	0.14±0.00	0.21±0.12	0.09±0.02	0.05±0.00
Org.C(%)	2.89±1.31	3.01±1.36	2.17±1.89	1.15±1.45
K^+(cmol/kg^{-1})	1.54±0.51	1.74±0.18	0.10±0.00	0.09±0.00
Na^+ (cmol/kg^{-1})	0.34±0.12	0.42±0.17	0.07±0.00	0.16±0.15
Ca^{++} (cmol/kg^{-1})	25.50±4.73	27.80±5.78	1.50±0.45	1.70±0.67
Mg^+(cmol/kg^{-1})	2.40±1.45	2.30±1.34	0.60±0.12	0.10±0.10

Table 2: Soil Physico- Chemical properties of Alakahia Dumpsite

Soil Properties	Dumpsite		Control site	
	0-15cm	**15-30cm**	**0-15cm**	**15-30cm**
pH	6.10±2.34	6.30±2.45	3.70±1.45	3.50±1.67
EC (µg/g^{-1})	372±34	258±26.6	38±6.67	27±5.78
AV. P(µg/g^{-1})	7.99±3.56	6.11±3.23	67.18±8.56	29.13±6.34
Total N(%)	0.08±0.00	0.05±0.00	0.11±0.10	0.06±0.00
Org. C(%)	1.19±0.23	0.66±0.10	2.34±1.34	1.33±0.13
K^+(cmol/kg^{-1})	1.13±0.13	1.64±0.23	0.12±0.11	0.07±0.00
Na^+ (cmol/kg^{-1})	2.43±1.34	0.80±0.24	0.12±0.11	0.26±0.15
Ca^{++} (cmol/kg^{-1})	13.20±4.56	8.00±3.98	0.70±0.23	2.20±1.12
Mg^+(cmol/kg^{-1}	1.20±0.30	1.00±0.30	0.50±0.53	1.00±0.30

Nsirim Street Dumpsite: The particle size analysis result showed the soil type to be silty clay loam. The pH ranged from 3.80-5.30 showing and acidic soil with an average of 5.35 for the dumpsite and 4.15 for the control site. The level of exchangeable bases showed Ca, Mg and Na having low concentrations, K ranging from moderate to low levels from both the control and dumpsites (Table 3).

Table 3: Soil Physico- Chemical properties at Nsirim street dumpsite.

Soil Properties	Dumpsite		Control site	
	0-15cm	**15-30cm**	**0-15cm**	**15-30cm**
pH	5.30±2.10	5.40±2.11	4.50±2.11	3.80±1.34
EC (µg/g)	102±34.0	141±31.2	38±8.78	41±9.77
AV. P(µg/g)	54.50±7.89	60.61±8.78	59.20±8.99	99.61±13.67
Total N(%)	0.06±0.0	0.10±0.00	0.06±0.00	0.06±0.00
Org. C(%)	1.54±0.78	3.57±1.78	1.74±0.98	1.29±0.45
K^+(cmol/kg)	0.41±0.21	0.38±0.23	0.17±0.17	0.10±0.00
Na^+ (cmol/kg)	0.20±0.12	0.28±0.13	0.18±0.21	0.19±0.12
Ca^{++} (cmol/kg)	3.80±1.23	3.70±1.23	1.40±1.34	0.50±0.25
Mg^+(cmol/kg)	0.40±0.23	1.10±0.14	0.10±0.00	0.70±0.12

NOTE: Electrical Conductivity, Available Phosphorus, Nitrogen and Organic Carbon

HEAVY METAL CONCENTRATION IN DUMPSITE SOILS

Ada George Dumpsite: For the metals analyzed, zinc had the highest levels and it was more in the dumpsite than in the control site, with higher levels in the surface soils for both of them. The values ranged from 1.8210-6.0314mg/l with an average value of 6.1806mg/l for the dumpsite and 1.74765mg/l for the control site (Table 4).

Cadmium had the lowest concentrations in the soil with the dumpsites having higher values than the control site. The concentrations of copper were found in negligible amount in the control while the dumpsite had significant amount. Lead concentrations were in minute amount for both the dump and control sites.

Table 4: Concentration of heavy metals in Ada George Dumpsite Soil

Heavy metal	Concentration in mg/l Dumpsite 0-15cm	Dumpsite 15-30cm	Control site 0-15cm	Control site 15-30cm
Lead	0.9793	0.7689	0.0529	0.0481
Cadmium	0.1717	0.0666	0.0112	0.0100
Zinc	6.3298	6.0314	1.8210	1.6743
Copper	3.4812	3.2275	0.1321	0.1183

Alakahia Dumpsite: From Table 5, Zinc also had the highest level of concentrations though not as high as the Ada George Dumpsite with the concentrations higher in the dump than control sites. The concentration level of cadmium was negligible for both the control and dumpsites. For lead, the concentration was also found in little quantity with the subsurface soil of the dumpsite having a negative value. Copper concentrations were also in small amounts with the surface soils having more concentration than subsurface soils. When compared with the EGASIN standard, the heavy metal values are well below the given limits.

Table 5: Concentration of heavy metals in Alakahia Dumpsite Soil

Heavy metal	Concentration in mg/l Dumpsite 0-15cm	Dumpsite 15-30cm	Control site 0-15cm	Control site 15-30cm
Lead	0.0504	N.D	0.0085	0.0053
Cadmium	N.D	N.D	N.D	N.D
Zinc	2.8765	1.2779	0.2196	0.1290
Copper	0.5439	0.4537	0.2015	0.1728

ND denotes not detectable.

Nsirim Street Dumpsite: Zinc levels had the highest concentrations from the analysis, with the dumpsites having higher amounts than the control sites and the concentrations more in the surface soils (Table 6). The concentration of cadmium was negligible for both the dump and control sites. Though copper and lead had positive values the concentration levels found in the soil were of negligible amount.

Table 6: Concentration of Heavy metals at Nsirim Street Dumpsite Soil

Heavy metal	Concentration in mg/l Dumpsite 0-15cm	Dumpsite 15-30cm	Control site 0-15cm	Control site 15-30cm
Lead	0.0320	0.0020	0.0018	0.0021
Cadmium	N.D	N.D	N.D	N.D
Zinc	2.5731	1.7719	0.1942	0.1571
Copper	0.2533	0.2082	0.1340	0.1562

ND denotes not detectable.

MICROBIAL COUNT IN DUMPSITE SOILS

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The microbial contents in soils of the three dumpsites for both the dump and control sites were almost similar.

Ada George Dumpsite

Table 7: Bacterial count and species isolation composition in soil at Ada George Dumpsite

Sites	(Depth)	Bacterial species	Bacterial count
Dump site	0-15cm	*Bacillus spp*	105×10^{-5}
	15-30cm	*Bacillus spp*	120×10^{-5}
Control	0-15cm	*Bacillus spp*	53×10^{-5}
	15-30cm	*Bacillus spp*	65×10^{-5}

Table 8: Fungal count and species isolation composition in soil at Ada George

Site	(Depth)	Fungal species	Fungal count
Dump site	0-15cm	*Yeast spp,Penicillin spp Mucus spp, Aspergillus spp*	45×10^{-3}
	15-30cm	*Yeast spp, Mucus spp*	50×10^{-3}
Control	0-15cm	*Yeast spp,Penicillin spp*	7×10^{-3}
	15-30cm	*Yeast spp, Penicillin spp*	6×10^{-3}

The bacterial composition of the soil from the Ada George Dumpsite all had only one species which is the Bacillus sp. The bacterial count of the samples were of significant amount with the highest concentration found in the sub surface soil (15-30cm) of the dumpsite, 120×10^{-5} and the least in the surface soil (0-15cm) of the control site, 53×10^{-5}. For the fungal population, Y*east sp* was the most prevalent, found in all the samples with a mixture of fungal species such as P*enicillin, Mucus* and *Aspergillus*. The highest fungal count was found in subsurface soil (15-30cm) of the dumpsite 50×10^{-3} and the least in the subsurface soil of the control sample $6 \times 10^{-3.}$

Alakahia Dumpsite

Table 9: Bacterial count and species isolation composition in soil at Alakahia Dumpsite.

Site	(Depth)	Bacterial species	Bacterial count
Dump site	0-15cm	*Bacillus spp, Pseudomonas spp*	80×10^{-5}.
	15-30cm	*Bacillus spp*	70×10^{-5}.
Control	0-15cm	*Bacillus spp*	40×10^{-5}.
	15-30cm	*Bacillus spp*	30×10^{-5}.

Table 10: Fungal count and species isolation composition in soil at Alakahia Dumpsite

Site	(Depth)	Fungal species	Fungal count
Dump	0-15cm	Yeast spp, Rhizopus spp	90×10^{-3}
	15-30cm	Yeast spp, Penicillin spp	12×10^{-3}
Control	0-15cm	*Yeast spp,Penicillin spp Rhizopus spp*	33×10^{-3}

15-30cm	*Yeast spp, Aspergillus spp*	20×10^{-3}

Bacillus species was also the most prevalent of the bacterial spp, found in all the sites. The surface soil of the dumpsite had in addition to the B*acillus*, P*seudomonas spp*. The highest count was seen in surface soil (0-15cm)of the dumpsite 80×10^{-5} and the least count in the subsurface site (15-30cm) of the control sample $30\times10^{-5.}$ For the fungal species, *yeast* was the most prevalent, and was found in all the samples, and a combination of others like R*hizopus*, *Penicillin,* and *Aspergillus*. The highest count was in the surface soil (0-15cm) of the dumpsite and the least in the subsurface (15-30cm) soil of the dumpsite.

Nsirim Street Dumpsite

Table 11: Bacterial count and species isolation composition in Soil at Nsirim Street Dumpsite

Site (Depth)	Bacterial species	Bacterial count
Dump 0-15cm	*Bacillus spp*	95×10^{-5}.
15-30cm	*Bacillus spp*	more than<300
Control 0-15cm	*Bacillus spp, Serratia spp*	45×10^{-5}.
15-30cm	*Bacillus spp*	67×10^{-5}.

Table 12: Fungal count and species isolation composition in Soil at Nsirim Street Dumpsite

Site (Depth)	Fungal species	Fungal count
Dump 0-15cm	*Mucus spp, Yeast, Penicillin spp*	65×10^{-3}
15-30cm	*Yeast spp*	120×10^{-3}
Control 0-15cm	*Yeast spp, Aspergillus spp* *Penicillin spp, Mucus spp*	20×10^{-3}
15-30cm	*Mucus spp, Yeast spp* *Penicillin spp*	45×10^{-3}

NB: 10^{-3} and 10^{-5} are the number of serial dilutions that were done on the fungal and bacteria counts respectively to reduce the average load for easy culturing and counting.

Like the other sites, *Bacillus* was also the most prevalent bacteria found in this dumpsite with an addition of S*erratia* found in the surface soil of the control site. The highest count was in subsurface soil of the dumpsite which had an amount greater than 300 indicating a very high microbial load.

For the fungal species yeast was noticed in all the samples with the subsurface soil of the dumpsite having the highest fungal load 120×10^{-3} and the surface soil of the control having the least, 20×10^{-3}.

CONCLUSION

Soil properties of the dumpsites showed that Ada George had the highest clay content. The pH for all the three sites was mildly acidic tending towards neutral. The highest electrical conductivity was observed in Alakahia site. For the exchangeable bases, calcium was the highest in concentration with the highest result concentration observed in Ada george dumpsite.

Due to the fact that the heavy metals under study were well below the target and intervention values for soil/sediment as given by the Department of Petroleum Resources (DPR) as Environmental Guidelines and Standards for the Petroleum Industry (2002) there may not have been any adverse effect on the microbial communities with respect to reproduction, metabolism and species population. However further studies in this direction to authenticate this claim, is warranted.

REFERENCES

[1] Akpan I.O and Akpanidiok A.U. (2006) Heavy metal status of municipal waste in Calabar metropolis using atomic Absorption spectrophotometric technique. Journal of Nigerian Environmental society, University of Calabar. Vol. 3 pp119-125.

[2] Anderson J. (1974). Wet digestion versus dry ashing for the analysis of fish tissue for trace metals. Atomic Absorption Newsl. 11:89-99.

[3] Arnebrant, K, Baath .E and Nordgren .A. (1987). A copper tolerance of Micro fungi isolated from polluted and unpolluted forest soiI. Mycologia. Vol. 79,pp890-895.

[4] Ayotamuno, M. J; Akor, A.J; Teme, S.C; Essiet, R.W.U; Isirimah, N.O and Idike, F.I (2000). Relating Corn yield to water use during the dry season in Port Harcourt area Nigeria. Agricultural Mechanization in Asia, Africa and Latin America, Vol 31 No. 4, pp47-51.

[5] Ayotamuno, M.J and Gobo A.E (2004). Municipal Solid waste Management in Port Harcourt, Nigeria,Obstacles & Prospects. Management of Environmental Quality. An international journal. Emerald Group Publishing Ltd. Vol 15(4) pp 389-398.

[6] Bloom H. and Ayling, G.M. (1977). Heavy metals in the dervent Estuary. Envir Geol. 2: 3 – 22.

[7] Bramner, J. M. and Mulvaney C. C. (1982). Total nitrogen determination In: Methods of Soil Analysis. Part 2 Chemical and Microbiological Properties. Agronomy Monograph No. 9 2nd Edition 199 – 224.

[8] Bouyoucos, C. J. (1962). Hydrometer method improved for making particles size analysis. Soil Sci Soc. Of AM. J. PNC 26: 46 – 405.

[9] Department of Petroleum Resources. (2002). Environmental Guidelines and Standards for the Petroleum Industry In Nigeria. Pp 280-281.

[10] Frostegrad, A, Tunlid .A and Baath E. (1996) Changes in Microbial Community structure during long term incubations of two soil experimentally contaminated with metals soil biology and chemistry Vol. 28, pp55-63.

[11] Gobo,A.E (1980). Meteorology and Man’s Environment, Afrika-Links-Books, Ibadan.

[12] Gobo,A.E (2002). Solid waste Management options for the Niger delta. Proceedings of the 3rd National Workshop on Waste management and Pollution in the 21st Century, Rivers State Ministry of Environment and Natural Resources, Port Harcourt.

[13] Harris, J.A, Benthan H. and Birch .P. (1991) Soil Microbial Community. Provide index to progress direction of restoration, manage notes 9.pp133-135.

[14] Harris, J.A, Birch P and Short K.C. (1993). The impact of storage of soils during opencast mining on the microbial community. A strategist theory Interpretation. Restor Ecol. I. pp88-100.

[15] Heald, W. R. (1965). Determination of Calcium and Magnesium. In: C.A Black (ed.) Methods of Soil Analysis Part 2. Agronomy Monograph No. 2. 999 – 1010.

[16] Hughes, M.N and Poole R.K. (1989). The functions of metals in microorganisms. Metals and microorganism. London Chapman and Hall pp265.

[17] Knudsan, D, Petterson, G. A. and Pratt, P. F. (1992). Lithium Sodium and Potassium. In: Page D. L. (ed.) Methods for Soil Analysis. Part 2. Chemical and Microbiological Properties. Agronomy Mongraph No. 9 2nd Edition

[18] Nelson, D. W. and Sommars L.E. (1982). Determination of organic carbon. In: Methods of Soil Analysis, Part 2. Chemical and Microbiological Properties. Agronomy Monography No. 9 2nd Edition.

[19] Ogbubie, J.N; Uwaezuoke, J.C and Ogiehor, S.I. (2001). Introductory Microbiology Practical. Concave publishers Owerri Nig (2) pp28-30.

[20] Olsen, S. R. and Sommers L. E. (1994). Determination of available Phosphorus. In: Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties. AGraonomy Monograph No. 9 2nd Edition.

[21] Rhoader J – D (1982). Cation Exchange Capacity. In: METHODS OF Soil Analysis. Part 2. Chemical and Microbiological Properties. Agronomy Monograph No. 9 2nd Edition.

[22] Turco, R.F; Kennedy, A.C. and Jawson M.D. (1994). Microbial indicators of soil quality. In; Dorcin J.W., Coleman, D.C. Bezdicek, D.F. Stewart B.A.(Ed.I).Defining soil quality for a sustainable environment SSSA Special Publication 35. pp 299.

