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Bacteriological Health Status of Adjoining Dumpsite Soils in Uyo, Akwa Ibom State, Nigeria

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Authors' contributions

This work was carried out in collaboration with all authors. Author EJE designed the study and wrote the protocol of the study. Author UUNN managed the analyses and performed statistical analysis of data. Author UAO managed literature searches and materials required for the study. All authors proofread and approved the final manuscript.

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ABSTRACT

The bacterial population, distribution and physicochemical properties of soils adjoining a major dumpsite in Uyo, Nigeria were investigated to assess the effect of dumpsite wastes on the soil health. Composite soil samples (0-20 cm depth) collected from four (4) sampling points I, II, III, and IV were analysed using standard bacteriological and analytical techniques. Statistical analysis was performed using SPSS statistics 21 software. The results of the bacterial groups enumerated revealed counts ranging from $3.5\pm0.26\times10^5$ cfu/g to $6.0\pm0.10\times10^6$ cfu/g; $2.8\pm0.17\times10^5$ cfu/g to $2.4\pm0.20\times10^6$ cfu/g; $1.5\pm0.10\times10^5$ cfu/g to $1.8\pm0.17\times10^6$ cfu/g and $9.0\pm0.10\times10^4$ cfu/g to $1.3\pm0.10\times10^6$ cfu/g for Total heterotrophic bacteria (THB), Coliform bacteria (CB), Nitrifying bacteria (NB) and Phosphate solubilizing bacteria (PSB) respectively. At each sampling point, the distribution of THB was significantly higher ($p<0.05$) than all other bacterial groups. The bacterial isolates were mostly mesophilic species of *Proteus, Streptococcus, Bacillus, Micrococcus, Pseudomonas*, *Staphylococcus*, *Citrobacter*, *Escherichia*, *Salmonella* and *Shigella* with *Bacillus* predominating at every sampling point. Whereas physicochemical parameters were highest at

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sampling point I (closest to the dumpsite), the highest bacterial count were recorded at sampling point II and both reduced progressively away from the dumpsite. This study revealed that wastes generally increased bacterial proliferation as well as temperature with the release of nutrients, leachates and heavy metals which could adversely affect the health of soils at close proximity to the dumpsite. Hence, it is recommended that sanitary landfill with leachate cover should be constructed at designated locations so as to prevent surface/ground water pollution. Waste recycling technology should also be encouraged.

Keywords: Dumpsite waste; soil health; bacterial proliferation; physicochemical analyses and adjoining soil.

1. INTRODUCTION

Nigeria, like most developing countries is faced with daunting environmental and waste management challenges such that about 90% of waste disposal methods are open dumps [1]. In the early 18th century, the amount of solid waste generated by man was insignificant due to low population density [2] however, with current civilization and increasing urbanization, the volume of wastes generated in cities have resulted in rapid deterioration in sanitation levels and air quality in these areas thus municipal waste management has therefore emerged as a significant challenge in our municipalities.

According to World Watch Institute [3], current global municipal solid waste generation levels are approximately 1.3 billion tonnes/day and are expected to increase to approximately 2.2 billion tonnes/ year by 2025; representing a significant increase in per capita waste generation rates from 1.2 to 1.42 kg per person per day. Global annual waste generation reveals that the Organization for Economic Cooperation and Development (OECD) countries generate about 572 million tonnes of waste which represents 44% of waste generated worldwide whereas South Asia and Africa produce 70 and 62 million tonnes of waste respectively (Table 1).

Open dumps have been the oldest method of solid waste disposal, although some have been closed in recent years, many are still in use [4]. Other waste disposal methods such as composting, pyrolysis, reuse, recovery, incineration, recycling and sanitary landfills [5] are also used frequently. Municipal waste dumps present a threat to soil health because of surface run-off which carries dissolved chemical compounds and wide variety of microorganisms as well as leachate leakages [6].

Inappropriate waste management operations have negatively impacted the environment causing uncontrolled emissions of greenhouse gases, leachates with high concentrations of phenols, pesticides and toxic chemicals that can contaminate ground and surface water resulting in eutrophication [7]. According to Ogwueleka [8], solid waste management in Nigeria is characterized by inefficient collection methods, insufficient coverage of collection system and improper disposal mechanism. In Uyo metropolis for instance, there is no clear responsibility pattern between government and waste generators as waste generation and management are haphazardly carried out [9]. In 2013, an estimated 30,327 tonnes of solid waste was generated in Uyo according to earlier report [9]. Of this amount, organic wastes contribute over half of the entire waste generated in the metropolis (56.30%) while bottles / glasses and medical wastes contribute 3.70% and 0.60% respectively as shown in Table 2.

Table 1. Annual waste generation in the world

Region	Million tonnes	Waste generation per capita (Kg/capita/day)	Percentage contribution
Africa	62	0.09 – 3.00	5
East Africa and the pacific region	270	0.44 – 4.30	21
South Asia	70	0.12 – 5.10	5
Eastern Central Asia	93	0.29 – 2.10	7
Middle East and North Africa	63	0.16 – 5.70	6
Northern America/the Caribbean	160	0.11 – 5.50	12
OECD countries	572	1.10 – 3.70	44

Source: [2]

Table 2. Solid waste generation in Uyo metropolis

Type of waste	Percentage contribution	Source of generation
Organic wastes (vegetable, food remnants, fruits etc)	56.30	Markets, households, hotels/hostels
Cans, scap metals	11.40	Mechanic village/workshops, building/construction sites etc
Bottles/glasses	3.70	Housing estates, schools, super stores etc
Plastic and polythene materials	12.80	Hospitals/Clinics, markets, schools, Government establishments etc
Medical wastes	0.60	Hospitals/Clinics, diagnostic centres
Carton/Paper, wood	7.20	Schools, super stores, markets etc
Others	8.00	

Source: [9]

Acquiring adequate knowledge of the influence of dumpsites on the environment, human and soil health requires comprehensive long-term monitoring [6]. Its importance cannot be over-emphasized, particularly due to the re-use of reclaimed dumpsites for recreational purposes. At present, there is no reported incidence/outbreak of disease traced to the indiscriminate management of waste in Uyo, Akwa Ibom, Nigeria. However, studies have shown that some microbes (bacterial indicators) of public health significance can persist in dumpsites. Therefore this work hopes to provide baseline information on the bacteriological health status of adjoining dumpsite soil as information on their identity, abundance and distribution is inadequate.

2. MATERIALS AND METHODS

2.1 Study Area

This study was carried out around the biggest dumpsite within Uyo metropolis (Fig. 1a). Uyo, the capital of Akwa Ibom State, Nigeria is located around latitude 5°2'N of the equator and longitude 7°55'E of the Greenwich meridian with a population of approximately 309,573 people. Using geometric method, the total population was projected to be 430,518 in 2013 at a growth rate of 3.5 percent [10]. This dumpsite particularly receives household, municipal and industrial wastes. Heavy presence of insects and rodents are found within the dumpsite area which is close to many residential buildings.

2.2 Sample Collection

Composite soil samples were collected aseptically using ethanol disinfected soil auger from four (4) transect sampling points marked horizontally away from the sample site. These points were:

> Sampling point I – located 0m at the edge of the dumpsite;
> Sampling point II – located 10m away from the dumpsite edge;
> Sampling point III – located 100m away from the dumpsite edge;
> Sampling point IV – located 10000m away from the dumpsite edge. This also served as control.

Surface layer of soil (up to 20 cm depth) was collected from plots marked 25m^2 [11]. The samples were placed in sterile glass jars and in portable ice bag and transported to the Microbiology laboratory of the University of Uyo, for microbiological analysis while air dried samples were analyzed for physicochemical properties after sieving through a 2 –3 mm mesh.

2.3 Microbiological Analysis

The plate count technique was employed after a 10-fold serial dilution of each soil sample for enumeration of bacterial population. Samples were vigorously mixed during dilution to dislodge bacterial cells from the soil particles. Each sample was inoculated into a specific medium using pour plate technique [12], incubated aerobically and observed for growth after 24-48 hours. The physiological groups of bacteria (Total heterotrophic bacteria - THB, Coliform bacteria - CB, Nitrifying bacteria - NB, and Phosphate solubilizing bacteria - PSP) and their distribution in the soil were enumerated on triplicate plates of Nutrient agar, MacConkey agar, Mineral Salt agar and Pikovskaya agar respectively. Pure cultures of the isolates were identified using their cultural, morphological and biochemical characteristics [13].

Fig. 1a. Map of Uyo showing study location

2.4 Physicochemical Analysis

Physicochemical parameters of the soil samples such as pH, temperature, organic carbon, total nitrogen, Zn^{2+}, Ca^{2+}, K^{+}, Na^{+}, $Pb^{2+}$and Mg^{2+} were analysed using standard analytical techniques [14].

2.5 Statistical Analysis

Statistical analysis of data was performed using SPSS statistics 21 software. Significant differences in the effect of the different sampled points on the bacterial density and distribution were tested using two-way ANOVA. Differences were considered statistically significant at $p<0.05$. Pearson Product Moment Correlation Coefficient (PPMCC) analysis was used to determine the relationship between the physicochemical factors and the counts of bacterial groups in the soil.

3. RESULTS AND DISCUSSION

The waste stream of the dumpsite under study comprises approximately 70% of compostable materials. This causes an increase in the nutrient/mineral contents of the soil, resulting in higher bacterial populates obtained at sampling point I (Fig. 1), closest to the dumpsite.

The presence of different species of *Proteus, Streptococcus, Bacillus, Micrococcus, Pseudomonas*, *Staphylococcus*, *Citrobacter*, *Escherichia*, *Salmonella* and *Shigella* (Fig. 2) observed in this study agrees with earlier studies [15-19] who also reported these isolates as major indigenous microbial genera associated with waste materials and waste degradation. *Bacillus, Pseudomonas, Staphylococcus, Citrobacter, Streptococcus* and *Salmonella* species were detected at all the sampling points whereas *Proteus* species was detected at points I and II only (Table 3). According to Chilakos and Kavouras [17], *Bacillus* and *Pseudomonas* species are the predominant microorganisms associated with waste and are involved in biogeochemical cycling. The presence of spore-forming *Bacillus* species which are the aetiological agent of anthrax calls for serious health concern. This is because spores of *Bacillus* are easily carried by air current and dust particles onto exposed foods thereby causing food poisoning [18]. Most of the microorganisms identified in this study are considered as bioaerosols [20] which cause allergies in immunocompromised patients [21]. The endotoxins of these microbes have been reported to cause occupational lung disease including asthma [22].

In a separate study, Karin [23] revealed that *Pseudomonas aeruginosa* was present at low levels of leachate and its abundance increased with rainfall. The presence of coliform bacteria and other enteropathogens observed in this study (Fig. 2) suggest that the landfill also received large amounts of faecal wastes and corroborates with the report by Kalwasinska et al. [6]. These organisms are implicated in food borne infections such as typhoid, diarrhoea and gastroenteritis [16].

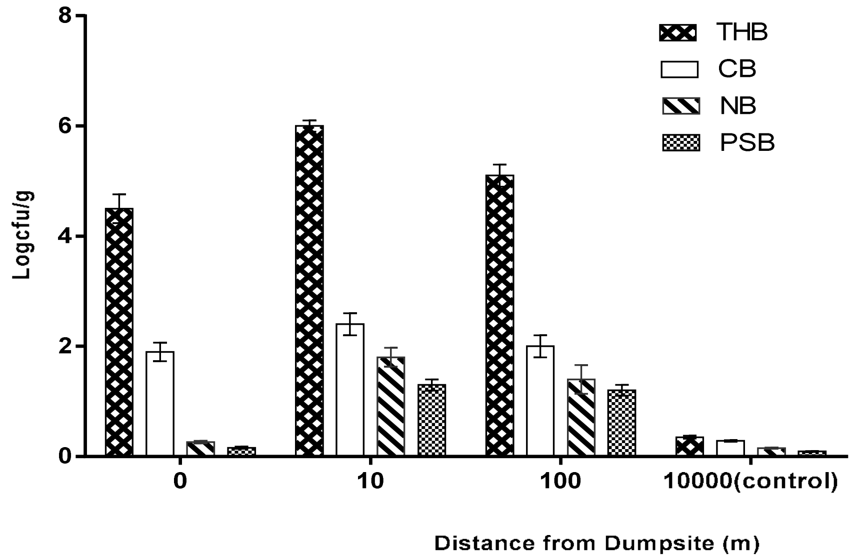

Fig. 1. Bacterial populations at different sampling points

Key: 0, 10, 100 and 10000 are sampling points. Counts are mean values of triplicate plates with standard deviation

THB - Total Heterotrophic Bacteria; CB - Coliform Bacteria; NB - Nitrifying Bacteria; PSB - Phosphate Solubilizing Bacteria

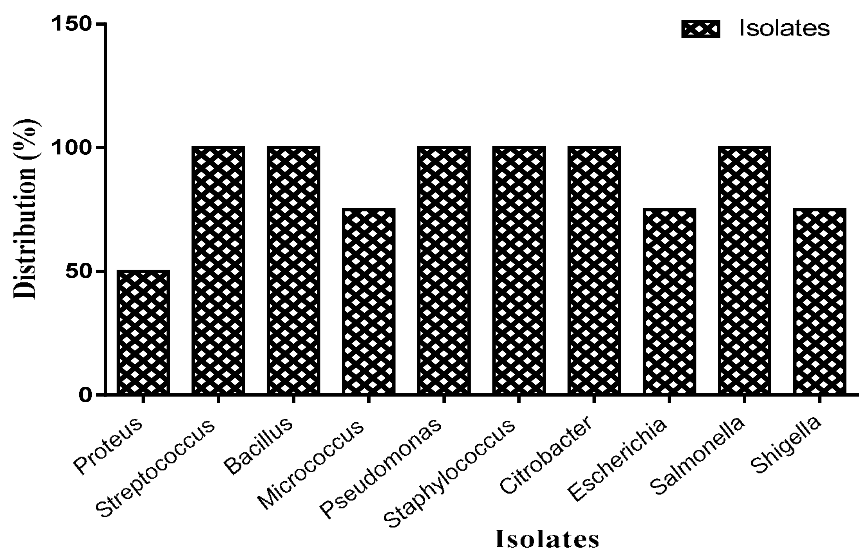

Fig. 2. Distribution of bacterial isolates

Table 3. Occurrence of bacterial isolates per sampling point

Isolates	Sampling points			
	I	II	III	IV
Proteus species	7(8.2%)	6(8.1%)	ND	ND
Streptococcus species	9(10.6%)	7(9.4%)	6(11.8%)	4(11.3%)
Bacillus species	12(14.1%)	12(16.2%)	10(19.5%)	10(25.8%)
Micrococcus species	7(8.2%)	6(8.1%)	ND	4(11.3%)
Pseudomonas species	9(10.6%)	8(10.9%)	6(11.8%)	3(8.6%)
Staphylococcus species	10(11.7%)	9(12.2%)	8(15.8%)	6(17.2%)
Citrobacter species	8(9.5%)	6(8.1%)	5(9.9%)	4(11.3%)
Escherichia species	6(7.0%)	5(6.8%)	4(7.8%)	ND
Salmonella species	9(10.6%)	8(10.9%)	7(13.6%)	5(14.4%)
Shigella species	8(9.5%)	7(9.4%)	5(9.9%)	ND
Total	85(100%)	74(100%)	51(100%)	36(100%)

Key: I, II, III and IV are sampling points, ND = Not Detected

Table 4. Physicochemical properties of dumpsite soils

Paramrters	Sampling points			
	I	II	III	IV
pH	5.90±0.10	6.30±0.06	7.20±0.06	7.50±0.12
Temperature (℃)	28.60±0.12	28.30±0.06	27.80±0.06	2 7.50±0.10
Organic Carbon (%)	15.05±0.03	3.65±0.02	10.72±0.03	7.22±0.02
Total Nitrogen (%)	14.72±0.03	12.88±0.03	9.43±0.03	7.66±0.02
Zinc (mg/kg)	2.11±0.02	1.47±0.02	1.36±0.02	1.13±0.01
Calcium (mg/kg)	2.03±0.02	1.57±0.01	1.35±0.10	1.08±0.01
Potassium (mg/kg)	0.49±0.05	0.38±0.02	0.31±0.01	0.26±0.02
Sodium (mg/kg)	0.14±0.02	0.12±0.02	0.08±0.01	0.07±0 .01
Lead (mg/kg)	3.29±0.02	2.53±0.01	1.76±0.01	1.07±0.0 2
Magnesium (mg/kg)	47.93±0.02	28.93±0.03	18.22±0.02	11.13±0.02

Key: I, II, III and IV are sampling points. Results are mean values of triplicate readings with standard deviation

The population of the different bacterial groups was statistically significant at sampling point II, whereas the population of NB and PSB at sampling points III and IV were statistically not significant at $p<0.05$.

Total heterotrophic bacterial (THB) counts in all the sampling points were statistically significant ($p<0.05$) with highest count at sampling point II and least at sampling point IV revealing the influence of dumpsite wastes on microbial activities. The decrease in microbial counts away from the dumpsite may be attributed to a decrease in nutrient concentration in these areas. This agrees with Akinbile [7] who stated that the quantity and quality of nutrients available in the soil determines the total microbial count in such location.

The physicochemical parameters assessed in this study also showed statistical significance ($p<0.05$) in all the sampling points, suggesting the impact of heavy metal contamination on soil microorganisms. According to Etim and Ofem [24], the nutritional characteristic of Akwa Ibom people (predominantly Ibibio tribe) which is largely a high rate of vegetable consumption could be at the risk of heavy metal contamination from soil. The temperature range (27.5±0.10 to 28.6±0.12℃) generally supported the growth of most isolates and agrees with Karin [23] who reported that mesophilic flora predominate initial development of composting and are responsible for most metabolic activities. The organic carbon content which reduced progressively at each sampling point (Table 4) also contributed to microbial proliferation and hence, increased microbial population. The gradual decline in acidity, temperature, nutrient and heavy metal concentrations away from the edge of the dumpsite relatively influenced the population and distribution of soil bacterial community as evinced in the study. The correlation analysis showed that temperature and pH had moderate positive effect ($r = 0.712$; $r = 0.531$) on the number of THB and CB respectively. In contrast, heavy metals (Pb^{2+} and Zn^{2+}) had a moderate negative influence ($r = -0.654$; $r = -0.678$

respectively) on the number of coliforms in adjoining soils.

4. CONCLUSION

Although frequent monitoring is required, the presence of indicator organisms and enteropathogens reveal the poor health status of adjoining dumpsite soils and could pose serious health risks to the inhabitants of neighboring settlements. Integrated and effective waste management strategies and its operations are needed in order to achieve and/or maintain a standard / sanitary environmental health.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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