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Impact of Solid Waste on Soil Bacterial and the Municipal Waste Management in Some Communities of Lagos Island

Yakubu J.M[1] and Udochukwu U[2]*.

[1]Department of Microbiology, Federal University Wukari, Wukari-Nigeria
[2]Department of Biosciences, University of Agriculture and Environmental Sciences, Umuagwo, Imo State

Abstract
The effects of solid waste on soil and soil sentinels cannot be over emphasized. On the other hand, managing municipal waste has a serious challenge. This study focused on the impact of solid waste on soil bacteria and the municipal waste management in some communities of Lagos Island which are Dolphin and Adeola Odeku Village. This study aimed at examining the present municipal waste management practices in Lagos Island and how they can be improved upon. Random sampling was used to administer 100 questionnaires to households while the different heavy metal concentrations in the soil samples were determined using Buck 200 Atomic Absorption Spectrophotometer (AAS). The wastes were mainly composed of food wastes, plastics/pet bottles and nylon. Although the majority of the respondents (65%) had waste bins/bags assigned to their houses, about 73.86% did not sort their wastes. The concentrations of the heavy metals (Co, Zn, Ni, and Mn) in the soil samples were higher in Dolphin and Adeola Odeku village compared to the control soil sample. The bacterial isolates identified from the soil samples are *Corynebacterium* spp., *Enterobacter* spp., *Flavobacterium* spp., *Acinebacter* spp., *Escherichia coli*, *Proteus* spp., *Bacillus subtilis* and *Micricoccus leteus*. SWOT analysis revealed the need to improve environmental awareness to minimize the threat of low sorting of wastes. Also, opportunities exist for recycling plastics/pet bottles and nylon while wastes from food materials could benefit agriculture through composing. This study suggests that more environmental awareness, policies, and better administration are needed to improve the status of waste management in urban communities of Lagos Island.

Keywords: Urban Communities, Waste Management, Heavy Metals, Health Impact, Lagos
***Corresponding Author E-mail:** rev.dr.ud@gmail.com

Introduction

Solid waste management is a global concern ranging from local to international communities, which is as a result of a continuous increase in solid waste and the cost implication on the government (Joseph et al., 2022). Around the world, waste generation rates are rising. In 2016, the worlds' cities generated 2.01 billion tonnes of solid waste, amounting to a footprint of 0.74 kilograms per person per day (World Bank, 2016). With rapid population growth and urbanization, annual waste generation is expected to increase by 70% from 2016 levels to 3.40 billion tonnes in 2050 (World Bank, 2016). Compared to those in developed nations, residents in developing countries, especially the urban poor, are more severely impacted by unsustainably managed waste. In low-income countries, over 90% of waste is often disposed of in unregulated dumps or openly burned (Dasgupta, 2013). These practices create serious health, safety, and environmental consequences. Poorly managed waste serves as a breeding ground for disease vectors, contributes to global climate change through methane generation, and can promote urban violence. Managing waste properly is essential for building sustainable and livable cities, but it remains a challenge for many developing countries and cities. Effective waste management is expensive, often comprising 20%–50% of municipal budgets. Operating this essential municipal service requires integrated systems that are efficient, sustainable, and socially supported (Blight and Mbande, 1996; Ramakrishna, 2013).

Lagos is one of the major cities in Nigeria with increasing rapid urban growth. This whooping increase in population definitely will lead to rapid industrialization, urbanization and economic growth, which are the contributory factors of increased solid waste generation (Joseph et al., 2022). The waste generated by urban residents is expected to almost double from 3.5 million metric tons/day in 2002 to 6.1 million metric tons/day in 2025, and a total of $375 billion will be spent for its management in 2025 (World Bank, 2012). It has been a local government responsibility to provide the service of urban solid waste management. The governments spend about 20 – 50% of their budget in solid waste management, however only 20 – 80% of the waste is managed (Simon, 2008; Tchobanoglous et al., 2002).). Therefore, management procedures of municipal waste in many developing countries are rather chaotic and need to be analyzed and strengthened further (Bandara, 2013).

The effects of heavy metals are found to vary with the conditions prevailing in the dumpsites and its binding forms. The open dumpsite being exposed to the atmospheric condition produces different effects due to oxygen diffusion. Under high redox conditions, the binding of metals to Mn and Fe oxide increases, whereas binding to carbonate, organic compound and sulphide tends to decrease (Prechthai et al., 2008). With more possibility of oxygen diffusion through the upper layer of the dumpsite and with sufficient moisture content, the degradation rate and the acid buffer capacity of the dumpsite is highly influenced. Under this condition, there is a drop in alkalinity, pH, and sulphide oxidation, where heavy metals are easily available and released (Bozkurt et al., 2000; Prechthai et al., 2008; Udochukwu et al., 2022). Professionals in municipal solid waste management often require interpretation of the leachability of metals to assess the risk of dumping sites to human health and environment (Scott et al., 1990). The mobility and toxicity of heavy metals present in dumping sites depend on the chemical form of the metals (Marine et al., 2005). Knowledge of heavy metal contents, their species and leachability at various environmental conditions from the dumping site is a prerequisite for assessing hazardous potential to the environment. Therefore, the hazardous potential of dumpsites can be better evaluated by fractionation of the metal contents into bio-available, exchangeable, water soluble, reducible, oxidizable, and residual fractions. The exchangeable and bio-available fractions are easily available for biological functions and can easily enter the food chain (Duribe et al., 2007; Ukpebor and Unigbe, 2003). Emission of heavy metals to the environment occurs via a wide range of processes and pathways (Esarru et al., 2003). Solid waste can affect the soil and soil bacteria in so many ways: the release of degradative components of solid waste which additives and heavy metal affects the pH of the soil (Udochukwu et al., 2021; Udochukwu et al., 2022). Solid wastes block air from entering the soil and make it difficult from earthworms and other soil animals to borrow the soil which affects soil aeration and ultimately soil fertility (Udochukwu et al., 2021; Udochukwu et al., 2022). This study examined the impact of solid waste on soil bacteria and the municipal waste management in some communities of Lagos Island.

Materials and Methods

Study Area: The study area is Victoria Island Lagos. The two sampled areas are Dolphin and Adeola Odeku which are located in Victoria Island Lagos.

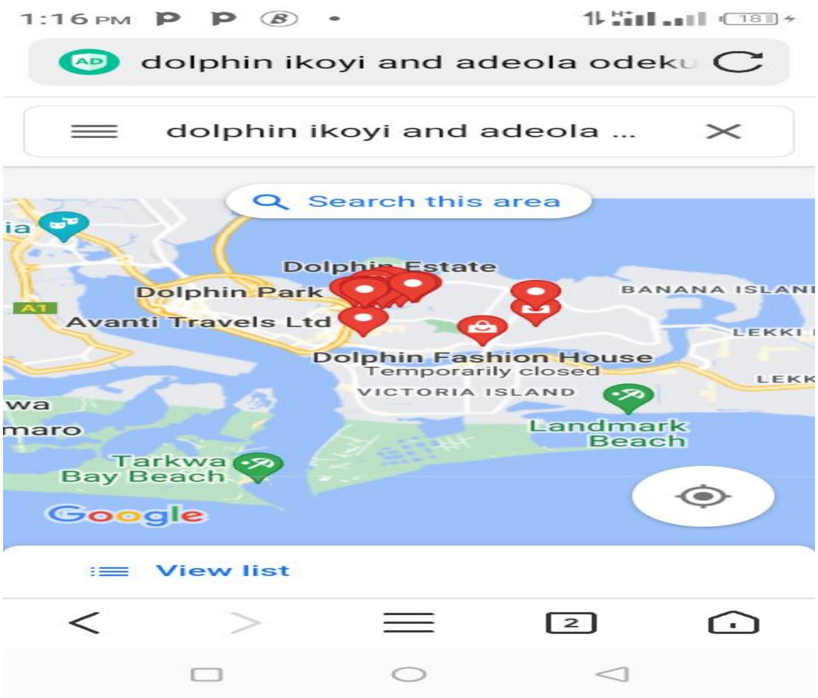

Plate 1: Map of Victoria Island Lagos
(Source: Google Map)

Study Approach
Data were collected through soil analysis and structured questionnaires. A sample size of 100 respondents for the questionnaires and two (2) composite soil samples were collected from each of the two sampling locations.

Questionnaire
The survey took into consideration population, types of income and types of houses. The questionnaires were distributed randomly in the selected locations in Dolphin Ikoyi and Adeola Odeku in Victoria Island. Primary data sources were utilized to examine the waste management system in Lagos urban and suburb. The research design used for the questionnaire consisted mainly of two parts. In the first part, a detailed SWOT analysis was performed based on the research questions developed to determine the strengths, weaknesses, opportunities, and threats of urban and suburban waste management in Lagos State. Second. Answers to those questions were abstracted by analysing information obtained from questionnaires distributed randomly among residents of the sampled locations.

Soil Sample Collections
Soil samples (500g each) from the two-study area (Dolphin Ikoyi and Adeola Odeku) and a control soil sample were also collected. The soil samples were collected at 30cm depth using a standard soil auger. The soil samples were carefully labelled according to the sampled area and taken to the laboratory in a black polyethylene bag and air dried for two weeks. The physico-chemical and heavy metal analysis were carried out which includes pH, electrical conductivity, Lead, Cobalt, Copper, Zinc, Iron, Nickel, and Manganese were analysed (Udochukwu et al., 2017a; Atuanya et al., 2016a)

Estimation Of Heterotrophic Bacterial Counts
Soil samples were collected in polyethylene bags from various treatments. Each sample was mixed and a suspension of 1 g (dry weight equivalent) in 9 ml sterile distilled water. One ml of the soil suspension was then diluted serially (Tenfold) and used in the estimation of aerobic heterotrophic bacteria by pour plate method. Winograsky medium was used for Nitrifying bacteria isolation and incubation was at 28^{o}C for 48 hr. The number of bacteria colonies was counted and expressed in colony forming units per gram (cfu/g) (Udochukwu et al., 2017a; Atuanya et al., 2016a).

Biochemical Identification of Heterotrophic Bacteria
After counting and estimation of total bacterial load, morphologically distinct colonies were picked using a sterile inoculation needle and aseptically transferred to sterile nutrient agar slants for further biochemical analysis. The following biochemical tests were used in the identification of bacteria isolates: motility test, oxidation fermentation test, indole test, oxidase test, catalase test, Gram staining and spore staining (Udochukwu et al., 2017). A bacterial toxicity test

was carried out and analyzed using Probit analysis (Atuanya et al., 2016a).

Results

Table 1: Physico-chemical parameters of the soil samples

Parameters	Adeola Odeku	Dolphin	Control
pH	6.750 ± 0.05b	6.020 ± 0.00c	7.900±0.00bc
EC (µscm-1)	158.000 ±2.00c	102.000 ±2.00b	87.000±1.00a
Pb (mg/kg)	0.012 ± 0.00b	0.036 ± 0.00d	0.007 ± 0.00a
Co (mg/kg)	0.013 ± 0.00a	0.012 ± 0.00a	0.005 ± 0.00a
Cu (mg/kg)	4.136 ± 0.00c	3.936 ± 0.00b	2.926 ± 0.01a
Zn (mg/kg)	6.733 ± 0.00c	4.314 ± 0.00b	3.745 ± 0.05a
Fe (mg/kg)	56.265 ± 0.15d	42.766 ± 0.05b	20.151±0.01a
Ni (mg/kg)	0.013 ± 0.00a	0.015 ± 0.00a	0.015 ± 0.00a
Mn (mg/kg)	0.010 ± 0.00ab	0.015 ± 0.00c	0.008 ± 0.00a

ND- Not Detected

Table 2: Heterotrophic bacterial growth from the soil samples

Incubation Time (Days)	Adeola Odeku	Dolphin	Control
1-3	$2.6 \times 10^2 \pm 0.11$	$3.0 \times 10^2 \pm 0.12$	$6.8 \times 10^3 \pm 0.10$
4	$3.0 \times 10^2 \pm 2.10$	$3.0 \times 10^2 \pm 3.10$	$8.5 \times 10^3 \pm 0.11$
5	$1.0 \times 10^2 \pm 1.10$	$2.0 \times 10^2 \pm 0.70$	$8.2 \times 10^3 \pm 0.20$
6	No growth	$1.0 \times 10^2 \pm 5.20$	$6.1 \times 10^3 \pm 0.50$
7	No growth	No growth	$2.0 \times 10^3 \pm 0.10$

Table 3: Bacterial Acute and Chronic toxicity test

Time (hrs)	Adeola Odeku		Dolphin		Control	
	EC_{50}	LC_{50}	EC_{50}	LC_{50}	EC_{50}	LC_{50}
1	46.90	50.73	40.00	51.03	26.90	30.23
2	68.76	70.00	52.16	73.80	28.76	40.01
3	81.75	88.11	76.15	86.10	81.75	49.91
4	102.86	120.01	112.00	110.01	102.86	57.00

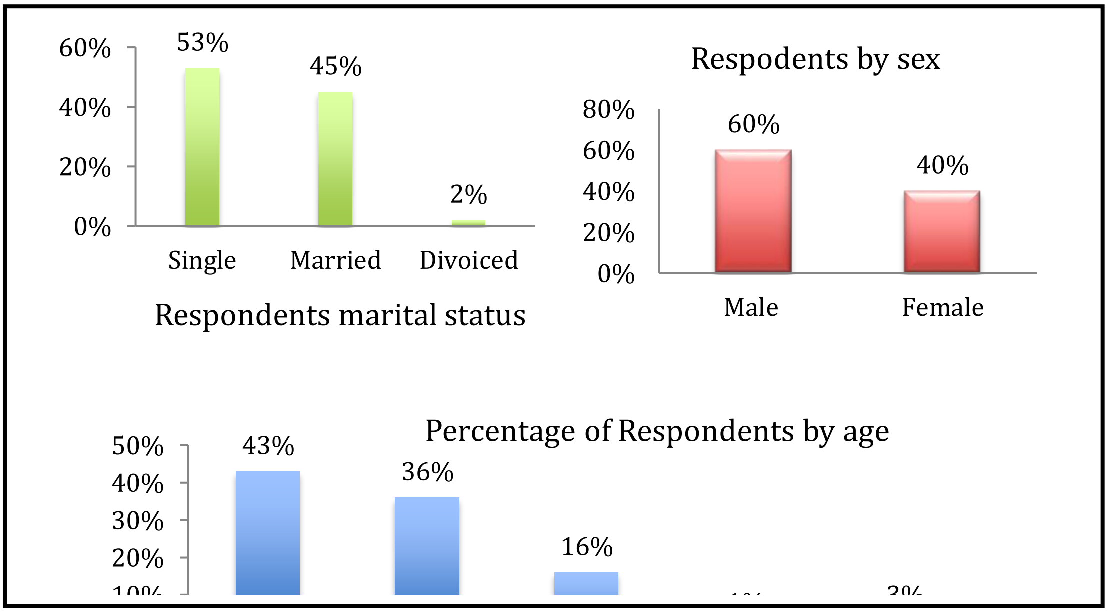

Fig. 1: Respondents demographical information

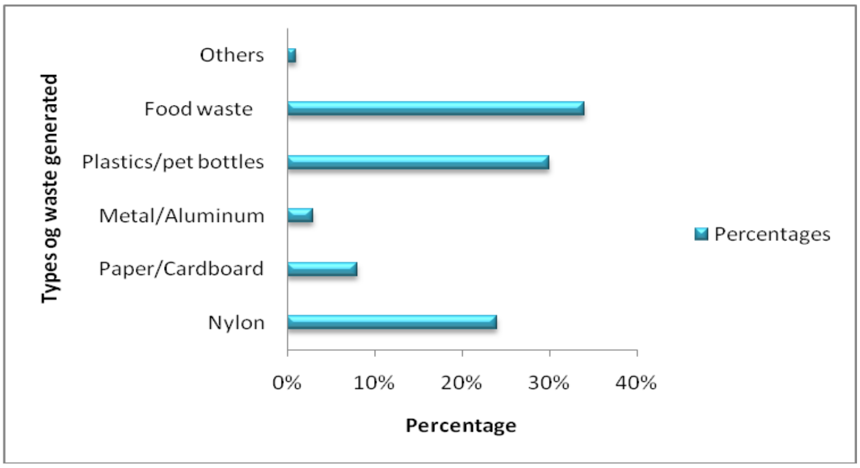

Fig. 2: Type of Waste Generated

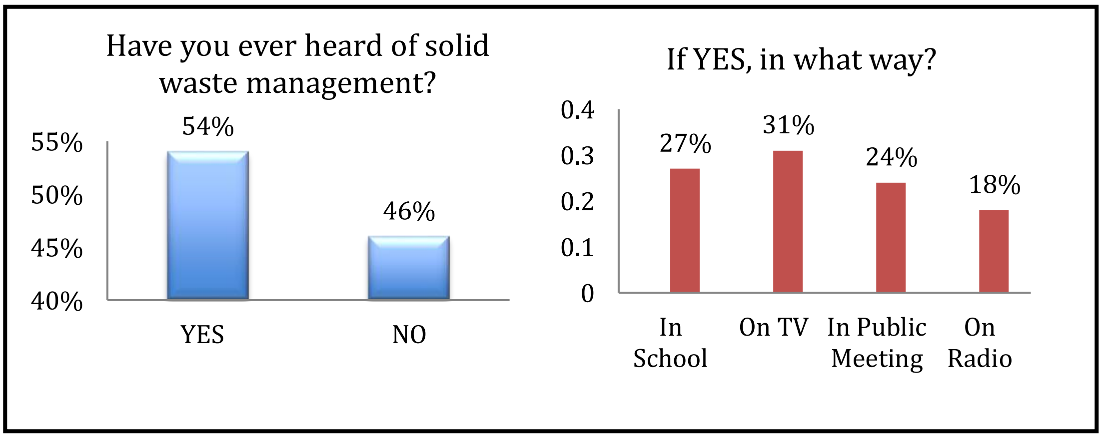

Fig. 3: Respondents waste management awareness

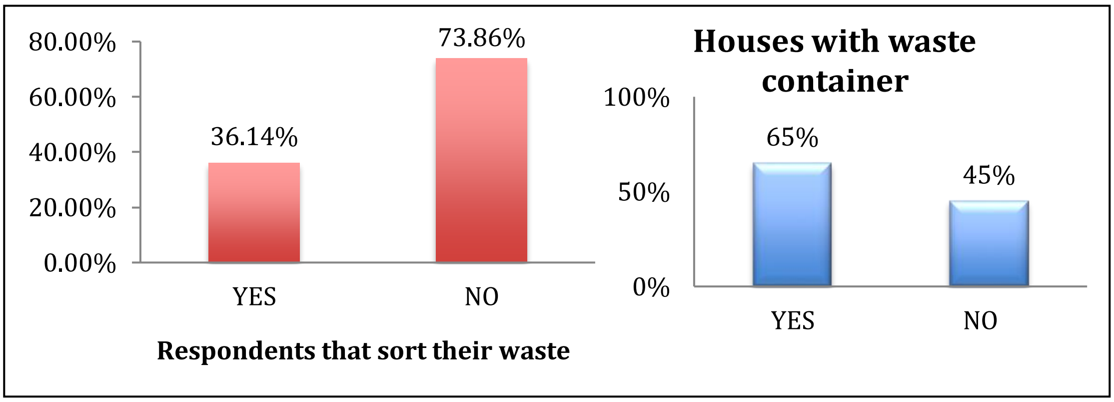

Fig. 4: Waste Management by Respondents

Table 4: Bacterial isolates from the soil samples and their percentage occurrence

S/N	*Bacterial isolates*	Percentage occurrence (%)
1	*Corynebacterium* spp.	20
2	*Enterobacter* spp.	13
3	*Flavobacterium* spp.	10
4	*Acinebacter* spp.	19
5	*Escherichia coli*	16
6	*Proteus* spp.	7
7	*Bacillus subtilis*	4
8	*Micrococcus leteus*	11

Discussion

The results of the physico-chemical analysis showed that the pH of the test soil samples (Adeola Odeku and Dolphin) were slightly acidic, the control soil sample was within the neutral pH range. It was observed that the test soil samples also had higher values of electrical conductivity and heavy metals like Co, Cu, Zn and Fe (Table 1). These heavy metals were released into the soil from the degradation of the solid waste over time which has now impacted and affected the pH of the soil and the electrical conductivity. This corroborates with (Zhang et al., 2018) which observed that an increase in heavy metal content of the soil will definitely alter the soil pH. This conforms to the report of Iranpour et al., (2014) that heavy metal pollution in soils is usually associated with higher electrical conductivity.

Heavy metal concentrations from the results were generally lower than permissible limits set by the European Union (EU) and United Nations Environment Programme (UNEP) for agricultural soils (David et al., 2019). These limits are Fe 50, 1000 mg/kg, Mn 2000 mg/kg, Pb 100 mg/kg, Zn 300 mg/kg, Cd 3 mg/kg, Co 50 mg/kg, Cr 100 mg/kg, Mn 50 mg/kg (FEPA, 1997; FEPA, 1999). The fact that cadmium was undetected in the soil samples also implies that it's much lower than the 0.80 mg/kg limit set by FEPA for Nigerian soil (FEPA, 1999; Adagunodo et al., 2018; Jiang et al., 2019). The report in this study was similar to that of school playgrounds in Port Harcourt Metropolis, Rivers State (Okereke and Amadi, 2017; Šrut et al., 2019).

Table 2, shows the heterotrophic bacterial counts from the soil samples. It was observed that soil samples from Adeola Odeku and Dolphin had lower counts respectively compared to the control garden soil sample which is as a result of altered pH of the soil which hindered bacterial growth Udochukwu *et al.*, (2016a) and Atuanya *et al.*, (2016b) also observed similar trend in their work on ecotoxicological effects of plastic waste on soil and soil biological sentinels. The bacterial toxicity test showed that the toxicity of the solid waste composted soil samples was higher than that of control soil samples. This further proves the reason behind the low bacterial counts observed in the test soil samples (Udochukwu et al., 2022).

A total of 100 questionnaires were administered and 88 were recovered which amount to 88 % of the sampled population. The respondents consist of 40 % female and 60 % male which shows that men participated more in the study (Fig. 1). From the results 53% of the populations were single and ages 18-28 had the highest participation in the study. The results in (Fig. 3) shows that 54 % of the respondents are aware of solid waste management and they got to know about it either in school, on television, in public meetings and on radio. Rahji and Oloruntoba, (2009), suggested that increasing the awareness of the people may have a positive impact on their attitude towards the environment. From the study in (Fig. 2), it was discovered that food waste, plastic/pet bottles and nylon are mostly generated by the respondents and this was in line with Ogwueleka (2009), who reported that solid waste in Nigeria are more corrosive, weighty and are saturated with water than those in industrialized nations, hence, a different solid waste management approach is required while Imam et al (2008) argues that since the waste composition in Abuja shows that a large percentage of the waste generated are organic in nature, compaction trucks may not be appropriate for their disposal. The study also showed in (Fig. 4) that majority of the respondents (65 %) have a waste bin/bag assigned to their houses where they dump their waste and this implies that majority of them in the studied locations dispose their waste lawfully while minority dispose their waste unlawfully either on the roadside, gutter/canal or other illegal methods, a habit which will eventually results in health hazards in the sampled locations over time. Many socio-economic and other variables influence the rate of waste generation; however, in this study; we assumed that all sections of the different income groups have been covered during the random sampling.

Conclusion

Waste should be treated before disposal into the soil ecosystem to prevent the toxic effect of solid waste on the soil and soil sentinels. Waste management requires the contributions from government, businessmen, politicians, religious organizations, civil servants and the public at large. Thus, to ensure the sustainability of Lagos state and other cities in Nigeria, there is a need for an effective solid waste management policy with a comprehensive and coordinated planning which will be combined with adequate legislation, fiscal provision, public involvement and awareness to bring about the expected improvement in the quality of our urban space.

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