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Research Article

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Characterization of Municipal Solid Waste for Effective Planning of Municipal Waste Management Scheme in *Uyo Metropolis*

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Abstract This paper presents the characterization of Municipal Solid Waste (MSW) for planning Municipal Waste Management Scheme (MWMS) in Uyo Metropolis. Waste characterization is an important component in any waste management scheme. The MSW samples were collected and characterized using spot sampling method. The Uyo waste dumpsite was divided into four blocks namely North, South, East and West for the purpose of sample collection. Thirty kilograms (30 kg) of raw MSW were manually and randomly collected at each of the four spots and bulked to form a composite sample of 120 kg. The sample was then sorted out and characterized into various components namely: Vegetable/food wastes, plastics, papers, metals, glasses, textiles, nylons and others. Others represent solid wastes that do not fall into the first seven categories. Sorting and weighing of collected waste were done at the dumpsite. The study was undertaken in the wet and dry seasons. The sampling was done thrice a month for a total of five months in each season: wet season (April to August, 2021) and dry season (October to December, 2021 and January and February, 2022). A total of fifteen composite samples totaling one thousand eight hundred kilograms (1800 kg) of MSW samples were collected from the four spots per season. The components of the wastes were weighed using weighing balance and their percentages were calculated. Results showed that vegetable/food wastes occupied the largest proportion of MSW in the study area accounting for 42.79 % of MSW in the dumpsite followed by nylon with 23.24 % to plastics with 11.02 % while glasses had the least (4.88 %). Seasonal variability of MSW in the dumpsite showed low variability between wet and dry seasons confirming that MSW in the study area contained almost similar materials within the year. The difference was not significant among wet and dry seasons. Proximate composition of MSW of the study area showed that moisture content occupied the largest with 67.59 % followed by ash (19.49 %) while volatile matter had the least (2.88 %) indicating that food waste contributes significantly to leachate production in the waste dumpsite. It is therefore recommended that proper monitoring of the waste dumpsite should be done to ensure strict compliance with the guidelines of National Environmental Standard and Regulation Enforcement Agency (NERSEA).

Keywords Food Waste, Waste Management, Dumpsite, Proximate, Plastic

1. Introduction

Municipal solid waste (MSW) is the stream of garbage collected by sanitation services from homes, business centers and institutions to dispose at a waste dumpsite [1]. MSW varies widely in composition and contains both dissolved and suspended materials which depend on the age of the dumpsite and type of solid waste [2]. Okey *et al.* [3] classified MSW into seven categories which include: vegetables and food waste, plastics, papers, metals, textiles, glasses and others. According to Sehker and Beukering [4], the generators of municipal solid waste are broadly classified as residential, industrial, commercial, institutional, construction/demolition, municipal and agricultural types. According to Ogwueleka [5], municipal solid waste varies according to season, income level, population, social behaviour, climate and industrial production. Generated MSW constitute a growing problem which have gained increased awareness and also arouse the interest of researchers to seek mitigation measures [6]. Amoah and Enoch [6] also stated that the generated MSW constitute a growing problem which has gained increased awareness and also arouse interest of researchers to seek mitigation measures. Inappropriate municipal solid waste (MSW) disposal has major negative consequences for soil and water quality, the ecosystem, and human health [7]. Waste characterization is an important component in any Municipal Waste Management Scheme (MWMS). The waste characterization data consist of information on types and amount of materials in the waste stream.

The rudimentary nature of MSW characterization, especially in developing countries makes waste management more difficult. Besides the absence of data, waste management solutions in developing countries are usually constrained by financial deficiencies and lack of policy implementation. The availability of data on MSW characterization is the first vital step in developing an integrated solid waste management plan, an approach which seeks to protect human health and the environment. However, there is little information on characterization of MSW in Uyo Waste Dumpsite. With availability of data, a well-designed Municipal Waste Management Scheme (MWMS) could be formulated to promote the quality of urban environment, generate employment and income, protect environmental health and support the efficiency and productivity of the economy. This study therefore aims at characterizing MSW in the only municipal waste dumpsite in Uyo, the capital city of Akwa Ibom State in order to assist the management authority in developing a Municipal Waste Management Scheme (MWMS).

2. Methodology

2.1 Study Area

The study was conducted at Uyo Municipal Solid Waste Dumpsite in Uyo Local Government Area, Akwa Ibom State, Nigeria. Uyo, the capital of Akwa Ibom State lies between latitude $4^0$30" and $5^0$30"N and longitudes $7^0$30" and 8^0 30"E. Uyo is within the equatorial region characterized by wet and dry seasons. According to Robert [8], the most outstanding feature of the equatorial climate is its uniformity of temperature throughout the year. Rainfall begins about March and ends around October with a little dry spell called "the August break" occurring in August [9]. With its location within the tropical rainforest and dense population, Uyo, like other major cities in Nigeria generates enormous municipal solid waste which is not adequately managed. The site is used by Environmental Protection and Waste Management Agency for waste disposal. This dumpsite is operated as an open dumpsite. The waste dumpsite has function efficiently for about twenty years.

2.2 Collection of Samples

The spot sampling method presented by Ityona *et al.* [10] was adopted in the sampling and sorting protocol of the MSW. The spot sampling method requires that equal amount of samples be taken at each dumpsite or various spots in a dumpsite and put together to form a composite sample representing the municipality. The Uyo waste dumpsite was divided into four blocks namely North, South, East and West for collection of samples. MSW samples were collected from the four (4) spots at the dumpsite and bulked to form a composite sample. Thirty kilograms (30 kg) of raw MSW were manually and randomly collected at each of the four spots and bulked to form a composite sample of 120 kg. The sample was then sorted out and characterized into various components namely: Food/vegetables wastes, plastics, papers, metals, glasses, textiles, nylons and others. Others represent solid wastes that do not fall into the first seven categories. Sorting and weighing of collected waste were done at the dumpsite. The study was undertaken in the wet and dry seasons. The sampling was done thrice a month for a total of five months in each season: wet season (April to August, 2021 and dry season (October to December, 2021 and January and February, 2022). A total of fifteen composite samples totaling one thousand eight hundred Kilograms (1800 kg) of MSW samples were collected from the four spots per season. The materials used at the dumpsite for data generation were sorting platform, weighing balance, bins for all the sorting categories, hand gloves and nose mask, a calculator and trained assistants. The components of the wastes were weighed using weighing balance and their percentages were calculated.

2.3 Methodology for Analysis of Samples (Proximate Composition)

2.3.1 Determination of moisture contents

The percent moisture of the MSW samples were determined by weighing 1 kg of the samples into a pre weighed dish and drying the samples in an oven at 105^0 C to a constant weight (ASTMD 3173). The percentage moisture content was determined as a percentage loss in weight before and after drying using the expression:

$$Mc\ (\%) = \frac{(Ww - Wd)}{Ww} \times 100 \qquad 1$$

Where

Mc = moisture content
Ww = wet weight
Wd = dry weight

2.3.2 Determination of ash and volatile matter contents

Ash content of waste is the non-combustion residue left after waste is burnt, which represents the natural substances after carbon, oxygen, sulfur and water. The volatile matter content was determined by the method of ignition of the sample at 950^o C. The samples were weighed and placed in a muffle furnace for seven minutes at 950^0C (ASTMD3175). After combustion, the samples were weighed to determine volatile matter content using the expression:

$$Vs\ (\%) = \frac{(Wd - Wa)}{Wd} \times 100 \qquad 2$$

Where

Vs = volatile matter content
Wa = ash weight
Wd = dry weight

2.3.3 Determination of fixed carbon contents

Fixed carbon is defined by carbon found in material which is left after volatile test. In the experiment, samples were dried in the oven at 750^0 C for 1 hour (ASTMD 3174). Fixed carbon was determined by removing the mass of volatile from the original mass of sample as in this expression:

$$Fc = 100 - Mc + Wa + Vs \qquad 3$$

Where

Fc = fixed carbon in wet base
Mc = moisture content
Wa = ash weight
Vs = volatile matter content

3. Results and Discussion

Figure 1 shows the physical composition of MSW while Tables 1 and 2 show the seasonal variability of MSW in the study area. The result has shown that vegetable and food wastes occupied the largest proportion of MSW in the study area (Figure 1) accounting for 42.79 % of MSW in the waste dumpsite followed by nylon with 23.24 % to plastics with 11.02 % while glasses had the least (4.88 %). This is expected because most of the wastes generated are from kitchens which are mostly contaminated food and food related products. The composition of the MSW from the study area agrees with Onibokun [11] and Ojolo [12] who reported food waste as the highest occurring item in the waste dumpsite.

Result of seasonal variability of the solid waste materials in the dumpsite shows slice variation in wet and dry season waste distribution (Table 1). The mean of the vegetable/food wastes was 52.80 ± 1.89 kg in wet season slightly lower than 53.31 ± 1.30 kg in dry season; mean plastics of 8.72 ± 1.28 kg was obtained in wet season slightly higher than 8.63 ± 0.69 kg in dry season, 5.37 ± 0.98 and 5.60 ± 0.48 kg papers were obtained in wet and dry seasons respectively. Distribution of metals showed mean of 6.47 ± 0.88 kg in wet season and 6.49 ± 0.88 kg in dry season. Others include glasses with 4.29 ± 0.38 and 5.59 ± 1.14 kg in wet and dry seasons respectively, textile with 5.11 ± 0.56 and 5.39 ± 0.86 kg in wet and dry season respectively and Nylon with

14.31 ± 1.06 and 12.03 ± 1.72 kg for wet and dry seasons respectively. The result reflects low variability suggesting that MSW in the study area contained almost similar material within the year. The highest variability was obtained in other food items with coefficient of variability (CV) of 31.38 % followed by glasses (20.32 %) while vegetable/food waste had the least (3.37 %).

Low variability of vegetable/food wastes suggests that food waste is always available in every solid waste disposed at a time while items like glasses and those in the 'others' class may not occurred on daily basis. The result agrees with Ogwueleka [5], who stated that municipal solid waste varies according to season, income level, population, social behaviour, climate and industrial production.

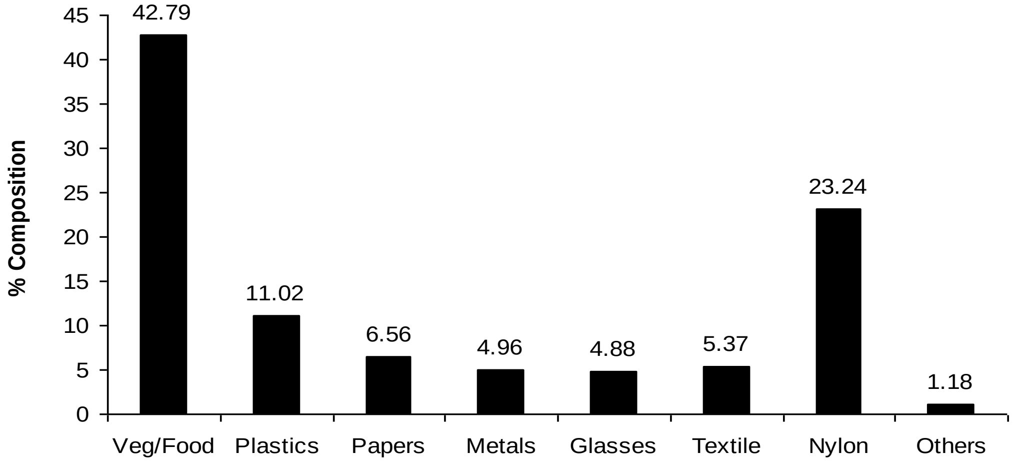

Figure 1: Physical Composition of MSW in Uyo Waste Dumpsite

Food waste is the major contributor to leachate production. This is because biological organisms may not breakdown plastics, metals and glasses to release leachate to the proximate composition of the materials indicating that the entire leachate is obtained from food wastes during their decomposition processes. Apart from their proximate composition, materials like nylon and plastic which are also high in the solid waste samples collected, could contribute to soil compaction and low porosity which could impede free transport of leachate in the soil. High proportion of metals in these wastes could suggest the presence of various heavy metals in the leachate even in the surface soil as well. On the whole, almost half of the entire wastes in the dumpsite are biodegradable, suggesting high volume of leachate from the wastes.

Proximate composition of MSW of the study area (Table 2) showed that moisture content occupies the largest proportion with 67.59 % followed by ash with 19.49 % while volatile matter had the least (2.88 %). High moisture content suggests high rate of waste decomposition and high leachate production from the wastes. The materials dumped on the soil surface are bound to change the chemical and physical nature of soil introducing large quantity of pollutant to groundwater. The volatile materials could be the reason foul smell and disturbed air composition as often noticed in dumpsite soil.

Table 1: Seasonal variability of MSW (kg) in the study area

Season	**Variable**	**Vegetables/ Food**	**Plastics**	**Papers**	**Metals**	**Glasses**	**Textiles**	**Nylon**	**Others**
Wet	Min	50.56	7.24	4.52	5.60	3.92	4.48	13.20	2.52
	Max	54.33	9.52	6.40	7.36	4.68	5.56	15.32	3.68
	Mean	**52.80**	**8.72**	**5.37**	**6.47**	**4.29**	**5.11**	**14.31**	**3.24**
	Sd (±)	1.89	1.28	0.98	0.88	0.38	0.56	1.06	0.63
	CV (%)	3.59	14.71	17.72	13.61	8.86	10.98	7.43	19.40
Dry	Min	51.85	8.12	5.21	5.52	4.36	4.52	10.36	2.06

Max	55.32	9.42	6.14	7.23	6.60	6.24	13.80	3.92
Mean	**53.31**	**8.63**	**5.60**	**6.49**	**5.59**	**5.39**	**12.03**	**2.97**
Sd (±)	1.30	0.69	0.48	0.88	1.14	0.86	1.72	0.93
CV (%)	3.37	8.01	8.65	13.53	20.32	15.97	14.32	31.38

Table 2: Proximate composition (%) of MSW of the study area

Season	Variable	Moisture Contents	Ash	Volatile Matter	Fixed Carbon
Wet	Min	66.57	18.98	2.43	9.65
	Max	68.46	20.12	3.66	10.73
	Mean	**67.59**	**19.49**	**2.88**	**10.04**
	Sd (±)	0.95	0.58	0.68	0.60
	CV (%)	1.41	2.97	23.66	5.97
Dry	Min	55.72	26.78	4.02	11.80
	Max	57.02	27.69	4.79	12.18
	Mean	**56.57**	**27.10**	**4.35**	**11.98**
	Sd (±)	0.74	0.51	0.40	0.19
	CV (%)	1.30	1.89	9.08	1.60

4. Conclusion

The starting point in waste management is to gain understanding of the waste types being generated in order to design effective Municipal Waste Management Scheme (MWMS) and this can be achieved through characterization of waste. MSW of Uyo wastes dumpsite contains all kinds of items but major ones include vegetable/food wastes, plastics, papers, metals and nylon. Their proportion however varies among types of wastes item in the following order vegetable/food wastes > nylon > plastics > papers > textile > metal > glasses. Seasonal variability in the solid waste materials in the dumpsite showed low variability between wet and dry seasons waste distribution confirming that MSW in the study area contained almost similar materials within the year. Proximate composition of MSW of the study area showed that moisture content occupies the largest proportion indicating that food waste contributes significantly to leachate production from the wastes. Therefore, the management authority could adopt a bottom-up approach for effective planning of MWMS through resource recovery using available proportion of biodegradable waste from the study to address environmental pollution of the resources at the study area. Based on the study, it is therefore recommended that proper monitoring of the waste dumpsite should be done to ensure strict compliance with the guidelines of National Environmental Standard and Regulation Enforcement Agency (NERSEA).

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