Spatiotemporal Analysis of Municipal Solid Wastes Generation in a University Campus

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Abstract
Solid waste generation and characterization is a critical first step towards developing successful and effective planning of waste management strategies and services. In 2012 sandcrete block fenced dumpsites (SBFD) were constructed in the University of Lagos, Nigeria to control indiscriminate dumping of waste and to generate data for sustainable campus waste management strategies, Relevant data for analysis were collected from the dumpsites between 2013 and 2014. In this paper, the Volume to Weight (VtW) conversion factor has been used to estimate the quantum of wastes (by weight) generated annually. MS Excel 2010 was deployed to statistically evaluate and characterize the municipal waste on sectoral (activity-based) and temporal basis. The temporal distributions for each activity sector were determined on calendar months basis. The estimated average annual total solid waste generated in the University was 13,161.4 tons. The annual sectoral averages were Hostels (2,209 tons (16.78%)), Academic Buildings (2,185.5 tons (16.61%)), Administrative Buildings (1638.4 tons (12.43%)), Commercial Outlets (3,121 tons (23.43%)), Residential Buildings (3,235.5 tons (24.58%)) and Communal areas (774 tons (5.90%)). The results for each activity-based sector were further characterized. The result of the characterization was found to be influenced by the activities of each sector. The temporal distributions also reflected the nature of activities in each sector.

Keywords: *University of Lagos, municipal solid waste, waste characterization, sandcrete block fenced dumpsites, temporal distribution*

1.0 INTRODUCTION

Managing solid waste is one of the most essential services which often become overwhelming due to rapid urbanization along with changes in the waste quantity and composition. Quantity and composition vary from place to place making waste management system location specific (Das and Bhattacharyya, 2013, Bowan and Tierobaar, 2014). Solid Waste characterization and quantification is the first step in developing a strategic, efficient and sustainable Waste Management option for a community (Oyelola and Babatunde, 2008, Adeniran *et al*., 2017, Kianoosh and Leslie, 2017). Characterization of municipal solid wastes is simply a descriptive means of identifying the various constituent of the waste stream in terms of quantity and quality generation taking into account location as well as seasons in which these wastes are generated (Tonjes and Greene, 2012). The composition and characteristics of municipal solid waste are influenced by certain factors, which include the area (residential, commercial, etc.), the economic level (differences between high and low income areas), the season and weather (differences in the amount of population during the year, tourist places) and culture of people living or doing business in the area (Bichi and Amatobi, 2013). Characterization of municipal solid waste helps in determining the types of waste generated in a particular location at a particular time of the year. Characterization is also important to determine its possible environmental impacts on nature as well as on society (Rishi *et al*., 2015).

Universities are expected to be the light house to beam light of development to the rest of community. Universities have the moral and ethical obligation to act responsibly towards the environment; they would be expected to be leaders in the movement for environmental protection. Through their expertise, they have the capacity to increase awareness, knowledge, technology and tools necessary to promote and sustain best practices within and around the community in which they are located (Coker *et al*., 2016). In addition to setting standards for the benefits that the appropriate waste management would bring to the institutions such as reduction of the financial resources on waste management they would also set an example to the students and the community.
Research works on municipal solid waste management (MSWM) in universities across Africa are gradually on the increase. Works on different aspects of MSWM in African colleges and universities have been reported by Ikudayisi and Aribisala (2012), Okeniyi and Anwan (2012), Amori *et al*. (2013), Sebola *et al*. (2014), Mengesha and Dessalegn (2014), Coker *et al*. (2016), Adeniran *et al*., (2017) and Ifegbesan *et al*. (2017). In the University of Lagos, Nigeria (Unilag), uncontrolled disposal of different types of waste on open sites was a great threat to the University environment and groundwater prior to the coordinated campus waste management initiatives. The concept of organized and sustainable solid waste management started in Unilag in 2012 with the construction of forty-six (46) sandcrete block fenced dumpsites (SBFD) for ease of waste collection; to mitigate the reported ground water pollution; and to generate data for the establishment of an efficient and sustainable solid waste management policy. The SBFD were designed and deployed considering activity-based sectors on campus. This paper aimed at the evaluation and analysis of the wastes data collected from the SBFD during years 2013 and 2014 in furtherance of the establishment of zero waste policy for the University.

2.0 MATERIALS AND METHOD

2.1 Study Area

University of Lagos is a Federal Government owned University founded in 1962 and has three campuses. The main campus is at Akoka, University of Radiography, Yaba and the College of Medicine in Idi-Araba, all in the Mainland of Lagos. This research work was carried out at the main campus of the University which is largely surrounded by the scenic view of the Lagos lagoon on 345 hectares of land in the North Eastern part of Yaba. It is on Latitude 6.5167^0 N and Longitude 3.3861^{0}E. The University has grown from a paltry 131 students in 1962 to over 45,000 as at 2015 made up of both postgraduate and undergraduate students. The University now has total staff strength of 3,365 made up of 1,386 Administrative and Technical Staff, 1,164 Junior staff and 815 Academic Staff. The University has nine faculties with a total of 117 programmes in Arts, Business Administration, Education, Engineering, Environmental Sciences, Law, Pharmacy, Sciences and Social Sciences. Other organs of the University to enhance academic works, research, human capital resources for community development include Human Resources Institute, Entrepreneurship Centre, Institute of Marine Studies, Institute for Continuous Education, Confucius Institute., Research and Innovation Centre and International partnership and Relation Office (Kadri and Associates, 2016).

2.2 Sandcrete Block Fenced Dumpsites (SBFD)

2.2.1 Design

Each of the SBFD has a volume 7.78m^3. The plan and elevation of a typical SBFD are shown in Figures 1(a) and (1b). The 3-D design of the SBFD is as shown in Figure 1(c). A typical SBFD in operation is shown in Figure 1(d).

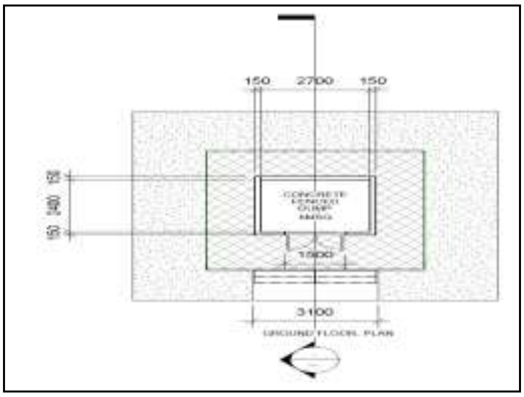


Figure 1(a): Plan of the SBFD

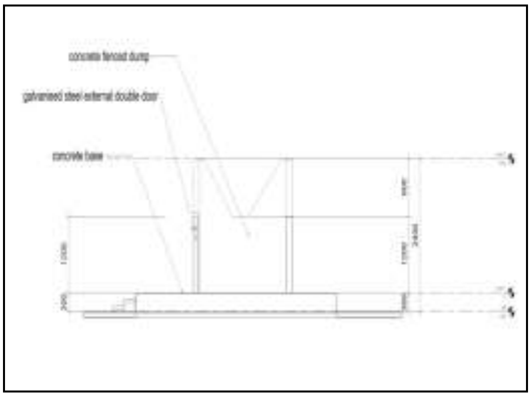


Figure 1(b): Elevation of the SBFD

Figure 1(c): 3-D Design of the SBFD

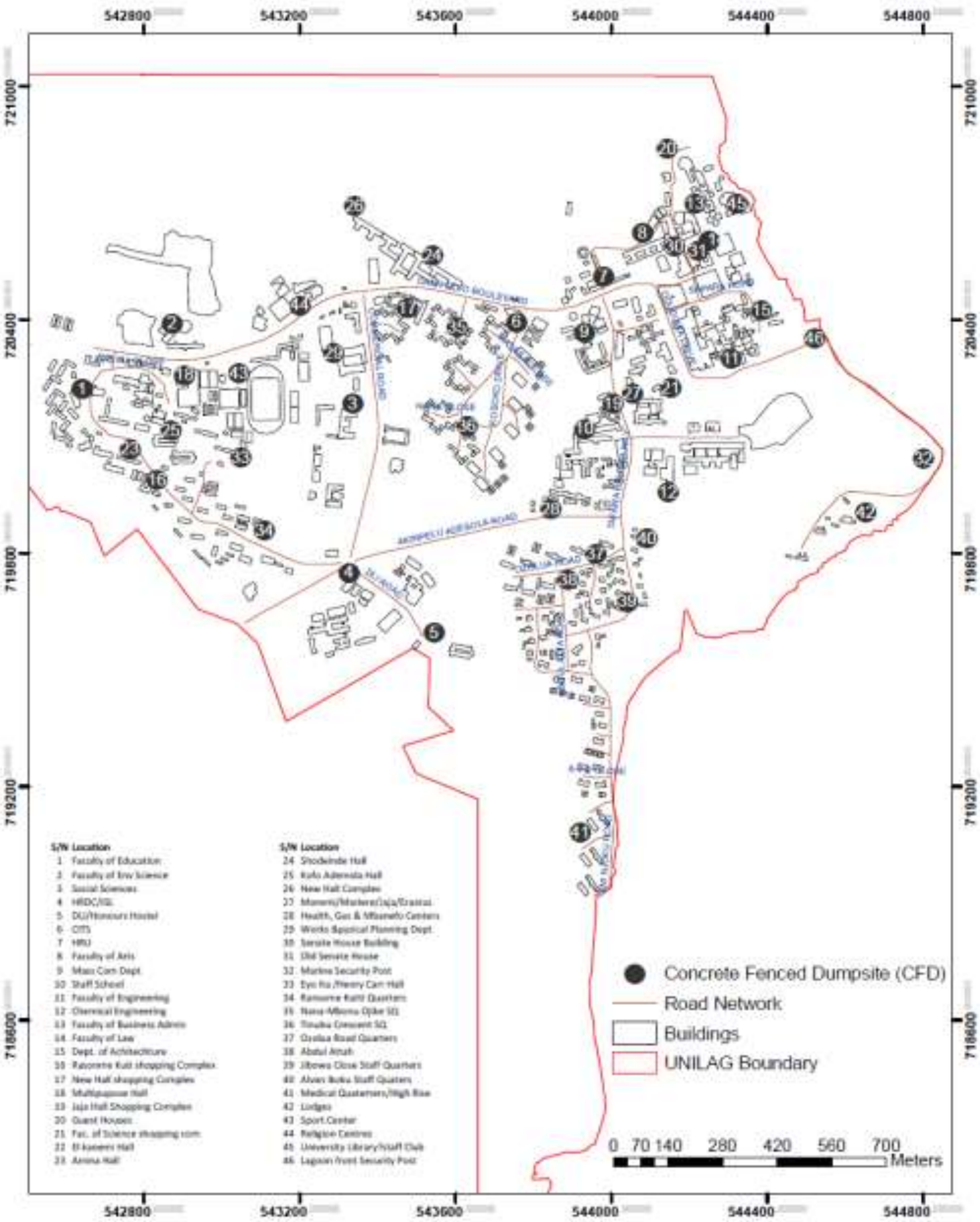
Figure 1(d): Typical SBFD in operation

2.2.2 Locations and Sectoral Distribution

The locations of the forty-six (46) SBFD constructed between 2011 and 2012, for the purposes of pilot study and for controlled waste collection and disposal are as in Figure 2. The 46 collection points were categorized into Hostels, Academic Buildings, Commercial outlets, Administrative Buildings, Residential Buildings, and communal sectors. The distribution of the SBFD across the sectors and distributed as shown in Table 1.

TABLE 1: DISTRIBUTION OF SBFD BY SECTORS

SN	Sectors	SBFD Location Nos	Total No
1	Hostels	1,16,21,23,24,26,27,33	8
2	Academic Buildings	2,3,5,6,8,9,11,12,25	9
3	Administrative Buildings	7,13,14,29,30,31	6
4	Commercial Buildings	10,15,18,19,20,22,34,45	8
5	Residential Buildings	4,17,35,36,37,38,39,40,41,42	10
6	Communal Areas	28,32,43,44,46	5
		Total	**46**



***F**igure 2: Location of the 46 SBFD on Unilag Campus (2013 – 2014)**

2.3 Sample Collection

2.3.1 Sampling Approach

The ASTM D5231-92 (Re-approved 2016) sampling method was used to determine number of samples to be used for each of the sectors identified. The numbers of samples required were statistically determined using the equation provided by ASTM D5231-92 (Equation 1.0).

$$n = \left(\frac{T^{*}S}{E\bar{x}}\right)^2 \quad (1)$$

Where:

T*= student's t-test for the desired confident level

S = estimated standard deviation

E = desired level of precision, and

$\bar{x}$ = estimated mean

2.3.2 Number of Samples per Sector

The numbers of samples (n) as calculated, using on Equation (1), are shown in Table 2 with the assumptions of 90% confident level, 10% precision level and corresponding student-t values. The various dominant wastes for each sector were determined from preliminary samplings and observations. The numbers of samples shown in Table 1 were collected weekly for 104 weeks (2013 to 2014) from the SBFD in each sector. An average of 40kg waste was collected per sampling. All samples collected were separately labelled and sorted with respect to each sector to avoid any mix up. The samples were analysed using MS Excel 2010.

Table 2: Number of Samples for Each Sector

	Dominant Waste Component	T*	S	E	$\bar{x}$	Calculated n'	Selected N
Hostels	Food waste	1.69	0.03	0.1	0.1	25.70	30
Academic Buildings	Paper	1.69	0.07	0.1	0.21	31.73	35
Administrative Buildings	Paper	1.69	0.07	0.1	0.21	28.92	30
Commercial Buildings	Food waste	1.69	0.03	0.1	0.1	25.70	30
Residential Buildings	Food waste	1.69	0.03	0.1	0.1	25.70	30
Communal Areas	Plastics	1.69	0.03	0.1	0.09	31.73	35

The volumes (V_m), for each month, were converted to weights using the USEPA (2016) Volume-to-Weight Conversion (USEPA_VtWC) factors for non-compacted bins.

2.4 Quantity of Waste Generation

The volumes of the waste collected monthly from each SBFD were determined from the number of evacuations and the capacity of the SBFD. To allow for human errors and waste left-over, a 90% volume capacity of the SBFD was used in computing quantity of waste evacuated.

$$V_m = v_m . n . N . \epsilon \qquad (2)$$

Where:

V_m = Estimated Monthly Volume
v_m = Volume of each SBFD = $7.78 m^3$
n = Number of trips per month
N = Number of SBFD in the Sector
ϵ = Error factor = 0.90

3.0 RESULTS AND DISCUSSION

3.1 Quantity of Waste Generation

The annual average for the municipal solid waste generated in Unilag over the two years study was 13,161 tons/year (36.06 tons/day). This is consistent with 32.2 tons/day obtained by Adeniran et al (2017) using a different waste collection approach for Unilag. The annual average waste generation by Residential, Commercial, Hostels, Academics, Administrative and

Communal sectors were 3,231 tons (24.59%), 3,117 tons (23.72%), 2,206 tons (16.79%), 2183 tons (16.61%), 807 tons (6.14%) and 771 tons (5.87%) respectively (Table 3). Figure 3 shows that the waste generations were Residential buildings (8.85 tons/day), Commercial outlets (8.54 tons/day), Hostels (6.04 tons/day), Academic buildings (5.98 tons/day), Administrative buildings (2.21 tons/day) and Communal areas (2.11 tons/day). The temporal trends of solid waste generation in the University were similar for the two years studied. Temporal trends (Figure 4) show two peak periods (i) April to June and (ii) September to November with high volume of waste generation. These peak periods are examination periods with influx of regular non-residential and the non-regular Distance Learning Institute students.

Table 3: Average of 24 Months Solid Wate Generation from Sbfd (Tons) by Sectors

Months	Hostel Buildings	Academic Buildings	Admin Buildings	Commercial Outlets	Residential Buildings	Communal Areas	Totals
January	103	98.5	132	259.5	234	37	**864**
February	174	169	144.4	260.5	235.5	57	**1040.4**
March	192	188	146	250	295	65	**1136**
April	237	231	147	261	290	72	**1238**
May	236	227	144	293	268	83	**1251**
June	210	209	135	243	273	73	**1143**
July	116	113	119	221	254	38	**861**
August	108	105	130	222	272	41	**878**
September	260	232	141	258	279	86	**1256**
October	255	297	132	281	274	105	**1344**
November	191	188	131	333	293	66	**1202**
December	127	128	135	239	268	51	**948**
Totals	**2209**	**2185.5**	**1636.4**	**3121**	**3235.5**	**774**	**13161.4**
Sector %	**16.78**	**16.61**	**12.43**	**23.71**	**24.58**	**5.90**	**100**

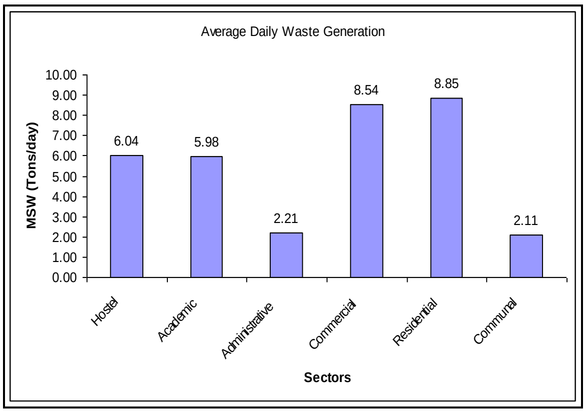


Figure 3: Sectoral Daily Waste Generation

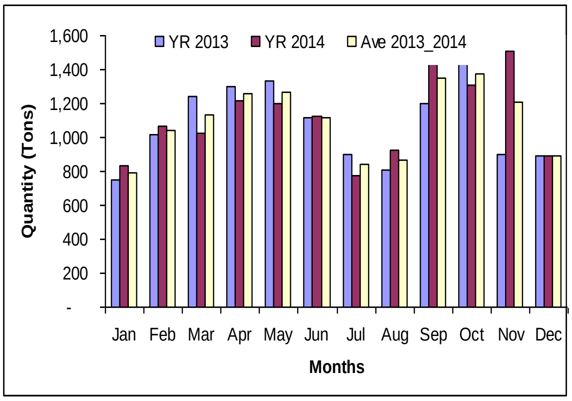


Figure 4: Temporal Waste Generation Trends

3.2 Waste Characterisation and Distribution

3.2.1 Overall Characterization and Distribution

Figure 5 gives the percentage (%) distribution of the waste generated on campus during the study period along sectoral (activities) divides. The characterization of the entire waste generated on the university campus is as shown in Figure 6. The characterization obtained in this study shows consistence in the trends of waste composition of the university as reported by Adeniran et al. (2017). However, e-waste that was rarely characterized by Adeniran et al. (2017) at 0% was found to be 3.33% in this study. Paper (19.67%) was found to be the largest contributor to MSW in Unilag. This was because sampling was done at the collection points (SBFD) as against sampling at the central dumping site. The present sample collection system from the SBFD also enhanced paper characterization before been corrupted by other wet wastes. It was now possible to detect medical wastes at the SBFD located near the Medical Centre and communal areas where medical devices and pharmacy items are generated along with other municipal waste.

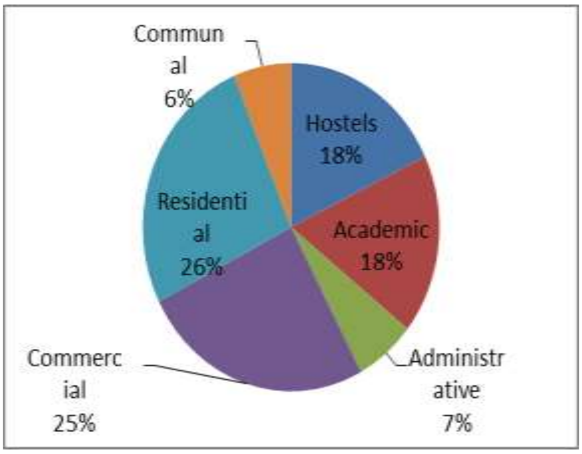


Figure 5: Unilag Sectoral % MSW Distribution

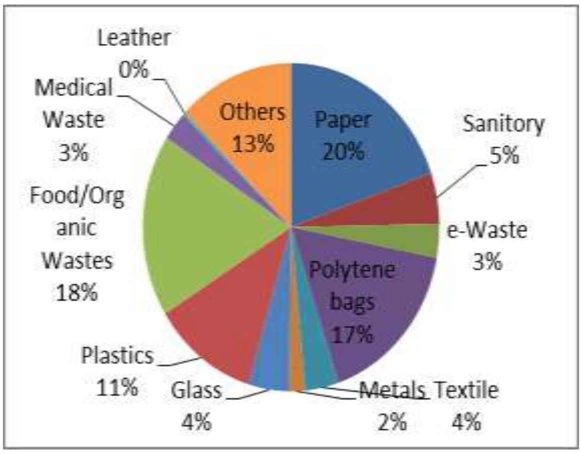


Figure 6: Overall Waste Characterization

3.2.2 Sectoral (Activity-Based) Waste Characterization

The results of the % characterization of waste reflect the nature of the activities being carried out by the sectors. Table 4 show the results the % waste characterization for each sector.

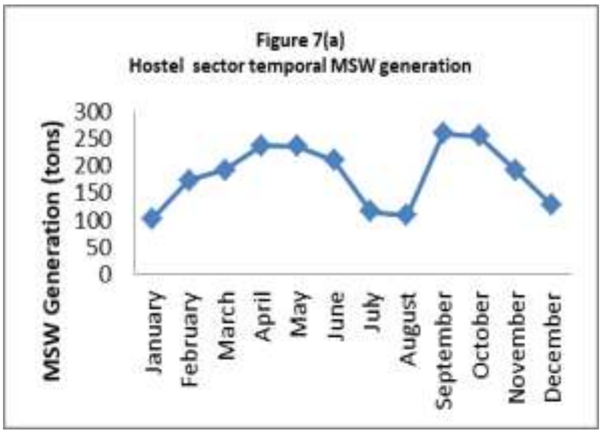
Table 4. Waste Characterization in Unilag by Activity Sectors

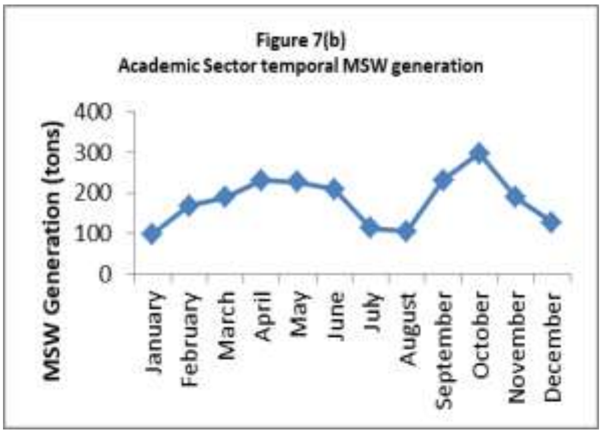
Waste Type	Hostel Buildings %	Academic Buildings %	Admin Buildings %	Commercial Outlets %	Residential Buildings %	Communal Areas %
Paper	16	31	27	25	16	9
Sanitary	5	7	9	0	9	0
e-Waste	1	8	6	4	0	1
Polytene bags	7	5	9	7	5	8
Textile	1	4	7	1	4	5
Metals	3	0	2	2	2	1
Glass	3	2	6	3	2	11
Plastics	21	14	11	22	7	36
Food/Organic	36	24	18	32	48	16
Medical Waste	3	0	0	2	0	12
Leather	1	0	0	1	0	0
Others	3	5	5	1	7	1
Total	100	100	100	100	100	100

In the academic sector (a mix of factulties and students), Paper and Food wastes were found to be the dominant (31%) and 24% respectively. In the Adminstrative sector, the waste generated reflected the sectoral activities with 27% paper, 18% Food wastes and 11% plastics. At the Academic and Administrative Units, papers disposed as wastes were captured before the activities of scavengers hence the significance level of paper observed during the study. The dominant waste types in the Hostels were Food/Organic waste (36%), Plastics (21%) and paper (16%). The Commercial sectors where food and other disposable itims are purchased, 32% Food, 25% paper (packagings) and 22% plastic wastes were generated. More Food wastes (48%) were generated in the Residential buldings. It is observed that in all the sectors, non-recylable wastes (Food and Organic wastes) constitute the major waste generated raging from 48% in the residential areas to 16% in the communal areas. Medical wastes constitute 3% of solid wastes in Hostels, 2% in Commercial outlets and 12% in Communal areas. The high percentage of medical wastes included wastes from the Medical Centre. The medical wastes in the Hostels and the Commercial outlets might be due to the sale of medical products in these sectors.

3.2.3 Sectoral (activity-Based) Waste Temporal Distribution

The monthly solid waste generated in each sector is as in Table 3. Figure 7(a-f) show the temporal distribution of MSW in the hostel, academic, administrative, commercial, residential and communal sectors of Unilag respectively. The temporal distribution of MSW revealed that Hostel, Academic and communal sectors exhibited similar trends with two peaks during the year. The trends for these sectors are in line with the academic calendar of the University. During the examination periods of May/June and September/October students influx and academic related activities on campus increase with the resultant increase in MSW generation in the hostel, academic and communal sectors (Figure 7(a), 7(b), 7(f)). As the population grows so does solid waste accumulation (Senzige and Makinde, 2016). The temporal distribution of MSW for Administrative, Commercial and Residential sectors reflected the relative steady nature of the activities in the sectors. Between December to February a sizeable proportion of resident staff prefer to take their vacation hence the relative low MSW generation during this period (Figure 7(c), 7(d), 7(e)).





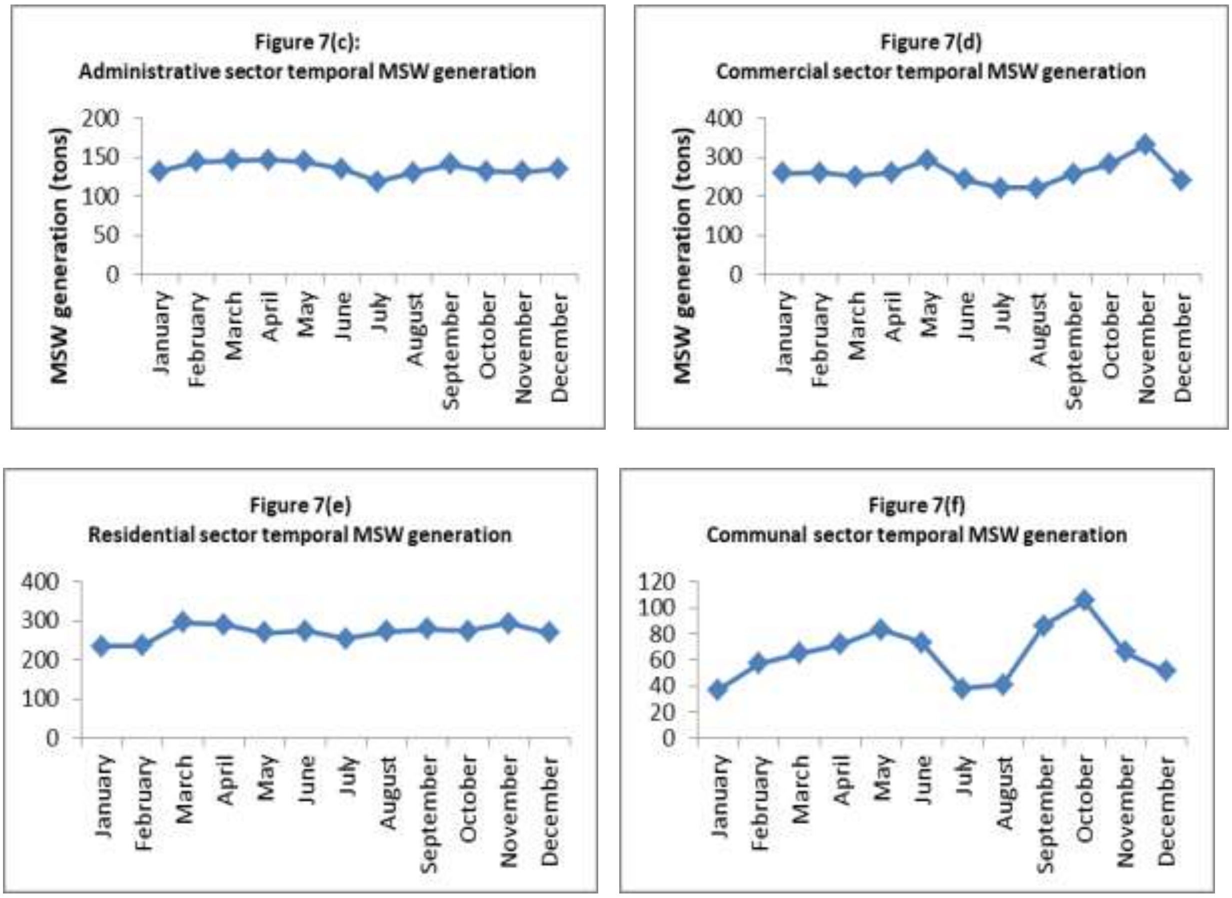


Figure 7: The temporal distribution MSW in Unilag

4. CONCLUSION

In order to establish a sustainable waste management strategy, waste distribution in terms of time and sectoral activities is of essence. In this study SBFDs located in proximity to activity sectors were used to analyse, characterise and evaluate spectoral and temporal distribution of solid waste generation in the Unilag. The sectoral and temporal distribution of waste reflected the activities in each sector. The result of the characterization was found to be influenced by the activities of each sector. The temporal distributions also reflected the nature of activities in each sector. Paper were found to constitute the highest proportion of the waste generated in Unilag (20%). The proportion of food and organic wastes was found to be high (18%). The locations of the SBFDs in close proximity to the sectors allowed for detailed characterization of the components of the waste generated. e-Waste which was not easily detected with generalised collection system were found to be 3.33% of the total waste generation. Medical wastes (3%) were found in Hostels, Commercial Outlets and Cummunal Areas. Adeauate attention should be taken when evacuating waste in these sectors. We conclude that anlysis based on a system of collection located in close proximity to activity sectors can be robust and afford very good insight into to the types and characteristic of the solid waste generation.

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