Utilization of Organic Fraction of Municipal Solid Waste (OFMSW) as Compost: A Case Study of Florida, South Africa

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Abstract— *Abstract*— **Composting of municipal solid waste is one of the means of diverting organic waste from the waste streams thus eliminating the use of landfills. This process will ensure availability of cheaper materials which can enhance soil fertility thus leading to reduction of pollution and increasing life span of the landfill site. Availability of reliable data on waste composition and characterization studies will be invaluable to policy makers for formulation of policy on proper waste management. Also, quantification and characterization of municipal solid waste (MSW) are vital tools for decision making for adequate planning on sustainable solid waste management (SSWM). The objective of this paper is to evaluate the physical composition of the various waste components and the chemical composition of the organic fraction of municipal solid waste (OFMSW) that originate from Florida that are disposed at the Marie Louise landfill site (LS) in order to make a proposition on the complete diversion of the organic fraction of municipal solid waste (OFMSW) from going to the landfill. A composition study was conducted during the winter in June 2016 at the site. From the results, organic was 11% for Dailies and 27% for Round collected refuse (RCR) collection services. Food waste sample was taken from the site to the testing facility and was analyzed for both the elemental and proximate analysis. From the elemental analysis; carbon was found to be 45.03%, hydrogen 6.20%, nitrogen 1.90%, oxygen 41.16%, the C: N ratio was 22.74 and from the proximate analysis; moisture content was 63.47%, ash 5.56%, volatile matter 22.63%, fixed carbon 8.77% and the empirical formula developed was $C_{28}H_{46}NO_{19}$.**

Index Terms— Florida, composting, municipal solid waste, organic waste.

I. Introduction

All over the world, people treat food as a disposable item. About 1.7 and 2.6 billion kilograms of food waste was generated in 2012 somewhere around the world [1]. About 25% to 50% of all food meant for consumption is regarded as waste [1, 2]. Economic growth, improvement in the living standard and rapid urbanization contribute to the acute generation of municipal solid waste (MSW) [3]. MSW, under which food waste falls is not well managed in many developing countries (DCs) with regards to its collection, storage and disposal. This is posing great threat to the environment and the health of the general public [4]. In most cities in the DCs, waste management (WM) gets little or no attention which leads to illegal dumping of waste by the populace which eventually results to heaps of wastes around the urban centres [5]. Presently, the management of the organic fraction of municipal solid waste (OFMSW) is one of the environmental challenges confronting DCs as a result of its severe generation which ultimately results in pollution [6].

Composting of MSW has been considered as the best recycling method to divert organic wastes from being landfilled. The use of compost made from MSW in agriculture as fertilizer and as soil enrichment is currently gaining attention [7]. When bacteria convert the OFMSW in the presence of oxygen, moisture and high temperature, the process is referred to as composting and the resulting products is known as compost. The use of compost is attractive due to its usage in agriculture, odourless nature and absence of pathogens [8]. There are many environmental benefits of diverting organic waste from the waste streams. The benefits include; reduction of methane emissions, reduction in the amount of leachate generated, production of soil enrichment and source of renewable energy [9].

Study has shown that in 2006, the estimated quantity of MSW generated was 2.02 billion tones which was about 7% per year since 2003 and between 2007 and 2011, the total quantity of wastes generated globally has risen by 37.3% which has been estimated to be about 8% increase every year [10]. The amount of MSW generation has been projected to about 9.5 billion tones by the year 2050 [11]. To effectively managed the MSW, data on the quantity and composition of the waste streams are required in order for policy makers to make informed decision on a proper waste management program [12]. Reliable data on waste composition study that will guide policy makers in the formulation of policy or when making informed decisions on proper waste management planning are lacking in many countries of the world. Hence, composition and characterization determination of municipal solid waste

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(MSW) become very vital as a baseline through which adequate planning on sustainable solid waste management (SSWM) can be achieved [13] , [14]. The amount of MSW generated is a function of several factors like consumption habits, living standard of the people, extent of commercial activities and changes in seasons or seasonal variation [8].

As MSW generated on daily basis increases, it is important to have detailed and current information on the quantification, composition and characterization of solid waste disposed to the landfill sites. However, this information is often not available in many DCs and where it is available, it is usually unreliable because it is often based on assumptions [15]. Also, studies on waste composition are not available in most of the developing countries owing to lack of funding and technical know-how. Waste composition study consumes a lot of human and financial resources, however, it is worthwhile since it assists in evaluating the composition and the amount of waste generated in a city [15] , [16]. The composition and characterization of MSW become very important in order to evaluate potential materials that can be recovered from the waste streams, determine the origin of various waste streams, speed up plans for the design of recycling equipment, evaluate the physical, chemical and heating value of MSW and ensure that the municipality is complying with both the national and international standards [17].

This paper attempts to evaluate the physical composition and chemical characteristics of the OFMSW generated in Florida, Gauteng region in South Africa as a baseline to propose complete diversion of the OFMSW from the waste streams.

II. DESCRIPTION OF THE STUDY AREA

Florida shares it existence from the birth of Roodepoort. The township began to take shape in around 1888. A surveyor, William Pritchard came searching for gold in around 1884 and in 1886, mining of gold was declared public. William Pritchard had initially surveyed Roodepoort but was excited by the superfluity of flowers in a particular valley in that area and then decided to call the valley Florida, the name given to flowers in Spanish. It was mainly accommodating the heads of the mines who were mostly whites. The other employees who were the miners were largely Africans and Coloured races. They lived in surrounding areas like Roodepoort and Maraisburg. Florida later became a home for the workers of railway. It was exclusively dominated by the White which made the apartheid to be very high. After South Africa gained independence in 1994, there was a significant racial change which led to the influx of Coloured to Florida. Currently, the population of Florida is between 40 to 50% Coloured and the African is about 10%. The major types of housing in Florida comprise of free-standing and flats [18].

III. SOLID WASTE COMPOSITION

The composition of MSW usually shows the physical and chemical features of solid waste [19]. A crucial factor to designing the solid waste management (SWM) of a city is its composition [20]. To achieve effective solid waste management SWM), reliable data on waste composition is very crucial in order to be to recoup resources from the waste streams [21]. Many nations of the world have been required to meet up with the target of resource recovery rather than landfilling of organic waste, details on waste composition of MSW is the way out [22]. The composition of solid waste is determined by culture, improvement in the standard of living, climatic changes and sources of energy. The degree of waste collection is also dependent on the composition of the waste generated [23].

IV. CHEMICAL COMPOSITION OF SOLID WASTE

The focus of this section is the evaluation of the elemental constituents and characteristics of the OFMSW. The elemental composition also known as ultimate analysis includes carbon (C), hydrogen (H), oxygen (O), nitrogen (n) and sulphur (S). The characteristics of the OFMSW also referred to as the proximate analysis includes the moisture content, volatile matter, ash content and fixed carbon [24, 25].

i. Moisture content (MC)

The percent moisture was determined by preparing 5 samples of 10g each of the food waste were prepared. The 5 samples were for 5 repetitions in order to determine the average. The samples were homogenized since waste is always heterogeneous. Homogenizing is simply breaking or reducing the particle sizes. The samples were weighed in 5 dishes and were dried in an oven at a temperature of 105°C according to ASTM D3173. The samples were sieved using Filtra Sieve Shaker. The percentages of the moisture content were then calculated as a percentage weight loss before and after drying as shown in Equation I [26].

$$\% Moisture = \frac{E - F}{E} \times 100\% \qquad (1)$$

Where E is the weight of wet sample and F is the weight of dry sample

ii. Volatile matter (VM)

To determine the volatile matter (VM) content, the method of ignition was utilized in which the sample was ignited at 950°C. The samples used to determine moisture content were utilized. The samples were place in 5 crucibles, were weighed and heated in a muffle furnace for a period of 7 minutes at a temperature of 950°C according to ASTM D3175. The crucibles were removed from the furnace and were made to cool and weighted as soon as they were cold. Volatile matter was then determined as the difference between weight loss in percent and the percentage moisture as shown in Equation II and Equation III [27].

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$$\% \, loss \, in \, weight = \frac{X - Y}{X} \times 100\% \quad (2)$$

Where X is the weight of sample before heating and Y is the weight of sample after heating

$$\% \, VM = \% \, weight \, loss - \% \, MC \quad (3)$$

iii. Ash

To determine the ash, samples from moisture content analysis were weighed. After weighing, they were placed in an oven and were heated to a temperature of about 750 ^{0}C for 1 hour in agreement with ASTM D3174. Samples were then removed from the oven and allow cooling and then weighed. The percentage ash is given by Equation IV [28].

$$\% \, Ash = \frac{K - L}{M} \times 100\% \quad (4)$$

Where K is the weight of crucible + cover + ash, L is the weight of empty crucible + cover and M is the weight of sample.

iv. Fixed Carbon (FC)

Fixed carbon (FC) is calculated by summing up of % moisture content, % volatile matter and % ash and the total sum is taken away from 100. This is given by this relation in Equation V [4].

$$\% \, FC = 100 - \left(\begin{matrix} \% \, wt.MC + \% \, wt.VM \\ + \% \, wt.Ash \end{matrix} \right) \quad (5)$$

V. SAMPLING TECHNIQUE

Random selection of incoming compactor trucks from different locations applied in this study but trucks from Florida were mostly targeted in order to capture the average number of incoming compactor trucks from Florida on daily basis. This was achieved by recording details of each truckload of waste which includes the origin of the waste, date, time and the weather condition on the waste composition data sheet. A total of fifteen trucks were sampled from Florida for a period of 5 days. Representative samples of MSW were collected using this method. The truck loads of wastes were discharged and the site excavator was used for thoroughly mixing of the wastes, thereafter a sample of 100 kg was taken from the truckload [10, 29].

The representative sample was sorted into different classes with the help of five waste pickers/reclaimers at the site per day. The main category of the waste was grouped into seven classes and the seven classes were further divided into fifty-two sub-groups. Data were recorded by the researcher on the waste composition data sheet based on two of the services offered by Pikitup Johannesburg (SOC) Ltd (the municipality).

VI. EQUIPMENT AND MATERIALS

The equipment and materials used for the study consist of the following: A crane scale with a capacity of 500kg and was used for weighing of the waste samples. Heavy-duty tarps were spread on the ground and sorting exercise was carried out on them in order to prevent soil from contaminating the waste samples. Excavator was used for thoroughly mixing of the wastes before the representative samples were taken. Hand brooms were used to gather the residual waste samples after sorting them into different classes. Twenty refuse bin containers of 120 liters' capacity provided by the municipality and sixteen refuse bins of 140 liters' capacity provided by the Process, Energy and Environmental Technology Station already labelled according to each sub-group of waste components were used. Two traffic cones were used to demarcate the sampling and analysis areas to prevent moving trucks from coming into the sorting area. A large First Aid kit was provided by the University of Johannesburg to use to attend to any emergency or minor accident. Personal Protective Equipment was provided for the Researcher. This includes the over-all, gloves, rubber boots, disposable face masks, helmets and safety goggles. A liquid soap and disinfectant alongside washing-hand basins were all provided to be used for washing after each day activity.

Oven was used to dry the food waste sample. Roll crusher was used to crush the sample and pulverized machine was used to convert it to powder form. CHNS analyzer (used for analysis of carbon, hydrogen, nitrogen and sulphur) was used to analyze the food waste samples.

VII. RESULTS AND DISCUSSIONS ON WASTE COMPOSITION

The waste composition exercise was conducted at the Marie Louise landfill site (LS) from 6th to 10th of June 2016. Two of the services offered by Pikitup were investigated. The services are Dailies non-compacted waste collection services and Round collected refuse (RCR) collection services. The daily non-compacted waste originates from hotels, restaurants, fast food joints, butcher shops and street sweeping. They are collected daily in order to avoid offensive odour that may emanate as a result of its decay which can pose threat to the health of the general public. The RCR originates from households in formal residential areas and businesses and are routinely collected weekly. They are commonly stored and collected in a 240 liters' container. Sample of food waste was then taken to the laboratory for chemical analysis. Figure I and Figure II show the amount of organic wastes that are generated from Florida and are disposed at the Marie Louise LS. Table I and Table II show the percentage weight compositions of different classes of organic wastes and other waste components for both Dailies and RCR services.

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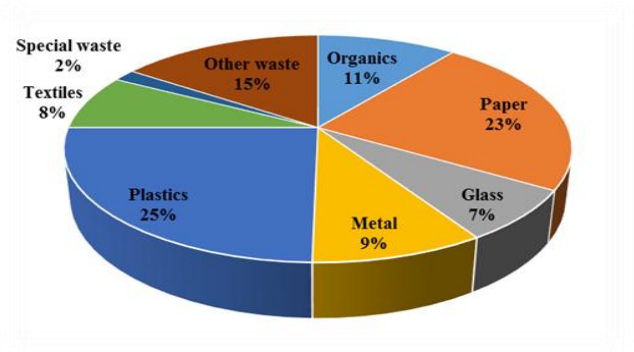

Fig. 1 Composition of Dailies non compacted waste from Florida

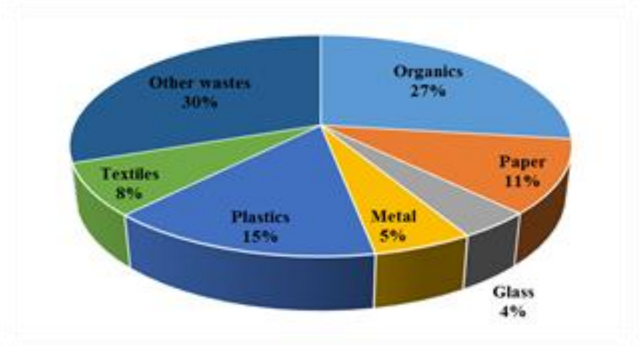

Fig. 2 Composition of RCR compacted waste from Florida

TABLE I
COMPOSITION OF MSW FROM DAILIES SERVICES

Component of Municipal Solid Waste	Composition (%)
Organic	
Food waste	2.9
Yard waste	2.4
Fruit and vegetable wastes	1.8
Composite organic waste	3.5
Total	10.6
Paper and paperboard	23.1
Glass	7.3
Metal	9.3
Plastics	24.7
Textile/Fabric/Leather	7.9
Special care waste	1.7
Other waste	15.4
Total	89.4
Grand Total	100

TABLE II
COMPOSITION OF MSW FROM RCR SERVICES

Component of Municipal Solid Waste	Composition (%)
Organic	
Food waste	11.9
Yard waste	13.4
Fruit and vegetable wastes	0.5
Composite organic waste	1.2
Total	27.0
Paper and paperboard	10.7
Glass	4.0
Metal	5.4
Plastics	14.9
Textile/Fabric/Leather	7.6
Other wastes	30.4
Total	73.0
Grand Total	100.0

From Figure I and Figure II, the amount of organic wastes generated were shown. For the dailies non compacted wastes, about 11% organic waste was generated and the RCR accounted for about 27% organic waste. All these organic wastes are being compacted with soil on daily basis. Resources can be recouped from these wastes in the form of compost and the compost can serve as soil enrichment. Also, when OFMSW is diverted from the waste streams, impact on the health of the general public will be drastically reduced, life of landfill site will be extended and quantity of leachate production will be reduced.

VIII. RESULTS AND DISCUSSIONS ON THE CHEMICAL COMPOSITION OF MUNICIPAL SOLID WASTE

The results of the elemental and proximate analysis of food waste were carried out according to ASTM standards as illustrated in Table III.

TABLE III
ELEMENTAL AND PROXIMATE ANALYSES

	Range	Average
Elemental analysis		
C (%)	44.95 - 45.10	45.03
H (%)	6.17 - 6.23	6.20
N (%)	1.95 - 2.01	1.98
S (%)	0	0
O (%)	40.78 - 41.54	41.16
C :N		22.74
Proximate analysis		
Ash (%)	5.39 - 5.88	5.56
Moisture (%)	62.55 - 65.48	63.47
Volatile matter (%)	21.77 - 22.86	22.63
Fixed carbon (%)	6.31 - 10.29	8.77

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The result of the analysis showed carbon to be 45.03%, hydrogen 6.20%, nitrogen 1.98%, oxygen 41.16%, there is no sulphur and the carbon to nitrogen (C: N) ratio was 22.74. This C:N is low compared to the best C:N ratio for the active composting which is between the range of 25:1 and 30:1 [9]. The C:N can be increased to the range of 25:1 and 30:1 by blending meat, fruits and vegetables with the feedstock and the C:N will increase to the range of 26 and 30 [30]. Also, the best moisture content when active composting process is taking place falls within the range of 55% and 65% [9]. The moisture content of the food waste sample used in this study was 63.47% which agrees with the optimal moisture content for active composting process. An empirical formula was developed. The estimated empirical formula was given as $\mathbf{C_{28}H_{46}NO_{19}}$.

IX. Conclusion

Food wastes from Florida will be a good source of compost having satisfied the condition of the moisture content of 63.47%. Though, the C: N ratio of 22.74 was low but it can be increased by blending meat, fruits and vegetables with the feedstocks. Thus, rather than sending food wastes to the landfill site, it should be composted and composting facilities can also be sited in the locality. It was observed that the Dailies non compacted waste collection services generated 11% organic waste and about 27% organic waste was generated by the RCR compacted collection services.

The dailies collection services generate more inorganic waste than organic since most people depend on packaged food items most especially as soon as the standard of living improves. For the RCR, organic waste occupied the second to the largest group. RCR generates more organic waste since most people prepare every of their basic meal. The food wastes are sent to the landfill site and are daily covered with the soil. These are resources that are being wasted. This is unsustainable but if the organic wastes can be recouped from the waste streams and converted to compost, several benefits accrued but this must start with source separation of wastes at household levels and commercial centres. The benefits include reduction of leachate production, reduction in methane generation which will automatically leads to reduction of greenhouse gases (GHG) emissions and availability of cheaper material which can serve as soil conditioner and the life of the landfill site will be extended.

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