Solid Waste Quantification for the University of Johannesburg's Waste to Energy Project

Rebecca Sebola, Lebogang Mokgatle, Akinwale Aboyade and Edison Muzenda

Abstract—Economic growth, urbanization and industrialization of African cities has caused rapid increase in volume and types of municipal solid waste (MSW) and hazardous waste. The inefficient collection, management, disposal and reuse of MSW has impeded the deployment of this waste resource into energy aside the heterogeneity problem associated with it. In addressing these challenges, the South Africa Energy Development Institute (SANEDI) in partnership with the University of Johannesburg is conducting a research into the deployment of waste into energy for use as vehicular fuel. As part of this project, waste quantification was carried out at Doornfontein campus (DFC), University of Johannesburg (UJ). This study investigated the amount of bio-waste generated in UJ DFC by quantifying the entire general and garden waste stream on campus and determining its composition. 310kg of waste is averagely generated on daily basis of which 82.34% are bio-degradable.

Keywords— Municipal solid waste, waste to energy, waste composition, waste generation

I. INTRODUCTION

WASTE management policies and legislation in countries around the world increasingly call for a reduction in the quantity of biodegradable waste that is landfilled [1]. The main reasons behind these policies can be summarized as follows; (i) the exhaustion of the existing landfill sites, (ii) continuous complaints from the people living in the vicinity of landfills, (iii) reducing the environmental impact of landfills, and (iv) utilization of this highly valuable resource [2]. Recovering energy from waste is the fourth priority of the waste management hierarchy (after reduce, reuse, and recycling). Energy recovery achieves multiple benefits: it leads to renewable energy production and according to the Energy Recovery Fact Sheet [3], reduces waste landfilled by nearly 60% to 90%, depending on the waste composition. The cost of transportation of waste to far-away landfill sites also gets reduced proportionally to the waste quantity reduction, and even more importantly, energy recovery can lead to the reduction in environmental pollution and methane emissions emanating from landfills. Methane is a greenhouse gas with 21 times the global warming potential of carbon dioxide.

The Process, Energy and Environmental Technology Station (PEETS) is undertaking a study to generate biogas from solid waste generated at the University of Johannesburg's Doornfontein Campus (UJ, DFC). The study forms part of the South African National Energy Development Institute (SANEDI) funded project to investigate the feasibility of converting bio-waste to vehicular fuel in the form of compressed biogas (CBG). Among the steps towards planning and implementing the aforementioned UJ, DFC waste-to-energy project was the assessment of quantities and composition of solid waste available at the DFC campus. This paper presents the approach and preliminary result of the exercise.

By 2020, more than 50% of the population in Sub-Sahara Africa will be living in urban cities which will likely raise the rate of production of waste by as much as 1kg per capita [4]. In Zimbabwe, solid waste generation is on average of 0.7kg/day per capita, in Tanzania it is 1/day per capita and 1.1k/day per capita of mixed MSW in Mauritius [4]. Most of this waste contains large proportion of organic matter [4]. Government agencies and other parastals are making considerable effort in tackling waste related problems yet there are still major gaps to be filled especially in the area of solid waste sorting. The World Bank reported that in developing countries, it is common for municipalities to spend 20-50% of their available budget on solid waste management even though 30-60% of all the urban solid waste remain uncollected [5]. In South Africa, waste collection has been tackled to an extent by the creation of South Africa Waste Information System (SAWIS) to provide public with access to information on waste collected, recycled, treated, landfilled and waste exported out of South Africa but the conversion of waste to energy is still yet to be fully implemented [6]. In 2011, 108 million tonnes of waste was generated in South Africa of which 98 million tonnes was disposed at landfill [6]. 59 million tonnes was general waste, 48 million tonnes was unclassified and the remaining 1 million tonnes was hazardous waste. It was reported that only 10% of all the waste generated in 2011 was recycled [6]. With the diminishing landfill space it has become imperative to find other option to manage these wastes especially those that can be converted into a resource.

Anaerobic digestion (AD) is one promising technology option for recovering energy from municipal solid waste. It is already a common alternative method for the treatment sewage and manure. Since food waste has the advantage of high organic content compared with sewage or manure, AD is now increasingly considered as a viable alternative for

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recovering energy from the organic fraction of municipal solid waste, which usually has food waste as a main component. AD utilizes the biological processes of many classes of bacteria and generally consists of four steps: hydrolysis, acidogenesis, acetogenesis, and methanogenesis [7], [8], [9], [10]. 100 tonne of raw MSW with 50-60% organic matter can generate about 1-1.5MW power depending upon the waste characteristics [3].

II. WASTE CLASSIFICATION ACCORDING TO SAWIS

According to the National Environmental Management Waste Act (RSA, 2009), waste is defined as any substance whether or not that substance can be reduced, re-used, recycled and recovered. It was further stated that a by-product of a process that is a raw material for another process is not a waste. Also any portion of waste once re-used recycled and recovered ceases to be a waste. The department of environmental affairs gazetted waste classification regulation in 2012 which classified waste into two major classes; General waste and Hazardous waste [11]. General waste is waste that does not pose an immediate hazard or threat to health or the environment while hazardous wastes are waste that contains organic or inorganic chemical elements or compounds that may owing to the inherent physical, chemical or toxicological characteristics of that waste, have detrimental impact on health and the environment [11]. Table I gives a list of various waste under each classes.

TABLE I
WASTE CLASSIFICATION [6]

Code	General waste	Code	Hazardous waste
GW01	Municipal waste	HW01	Gaseous waste
GW10	Commercial and industrial waste	HW02	Mercury containing waste
GW13	Brine	HW03	Batteries
GW14	Fly ash and dust from miscellaneous filter sources	HW04	POP Waste
GW15	Bottom ash	HW05	Inorganic waste
GW16	Slag	HW06	Asbestos containing waste
GW17	Mineral waste	HW07	Waste Oils
GW18	Waste of Electric and Electronic Equipment (WEEE)	HW08	Organic halogenated and /or sulphur containing solvents
GW20	Organic waste	HW09	Organic halogenated and/or sulphur containing waste
GW21	Sewage sludge	HW10	Organic solvents without halogens and sulphur
GW30	Construction and demolition waste	HW11	Other organic waste without halogen or sulphur
GW50	Paper	HW12	Tarry and Bituminous waste
GW51	Plastic	HW13	Brine
GW52	Glass	HW14	Fly ash and dust from miscellaneous filter sources
GW53	Metals	HW15	Bottom ash
GW54	Tyres	HW17	Mineral waste
GW99	Other	HW18	Waste of Electric and Electronic Equipment
		HW19	Health Care Risk Waste
		HW20	Sewage sludge
		HW99	Miscellaneous

Wang et al., 2004, described waste quantification as a method used to determine the types of materials being discarded in a waste stream and in what proportion they are discarded. It is a way of sorting different kinds of waste produced according to specific categories [7]. After waste quantification process has been completed, the waste characterization which is to study the chemical composition of the waste can be carried out.

III. DESCRIPTION OF EXISTING WASTE MANAGEMENT SYSTEM

The University of Johannesburg's Doornfontein Campus is located in the central business district of Johannesburg, the economic nerve center of South Africa. The campus has an approximate population of 8000 students. 640 of these students live within the four residences on campus namely Aurum, Jeunesse, Dale Lace and Rolane Court while 1109 students live at off-campus residences namely Sive Beek, Robin Crest, Habitat and Sun Valley. These seven residences excluding 'Habitat' (whose waste is collected by Gauteng municipality) and the Students' Centre are very likely major sources of the campus's biodegradable waste which is our major concern as feedstock to the planned bio-digester. The campus has an existing waste management system in which all general waste (non-hazardous) and garden waste produced around the campus is collected and sent to a Waste Transfer Station (WTS) and a Garden Waste Storage (GWS) site, respectively (see fig. 1). Chemical and other hazardous wastes are handled by specialist contractors and do not form any part of this study. Separate contractors handle the garden and general waste. The GWS is a temporary collection point for all gardening and landscaping waste before their subsequent weekly movement to a private composting site located in the Germiston area of Johannesburg. The contractor collects and delivers all general waste to the Waste Recycling Station depicted in fig. 1 for hand sorting into recyclables (paper, recyclable plastic, and metals) and non-recyclables (e.g. food waste, polystyrene and others). The former is transported to recycling facilities whilst the latter (non-recyclables) are sent to landfills. Whilst the weight of recyclables was recorded at the WTS, non-recyclables (which include bio-degradables) were not weighed before being transported to landfills, hence no record of their quantities could be obtained. The case was similar for garden waste.

Feedstock composition is one of the major factors that affect the production of biogas. When designing and operating an anaerobic digester, the quantity and characteristics of the feedstock are important and need to be assessed. Waste can be classified in different ways, according to origin and/or type [12]. Domestic and household waste comes mainly from residential areas and may include foodstuffs, garden waste, old clothing, packaging materials such as glass, paper and cardboard, plastics, and, in certain cases, ash. Industrial waste is generated by the manufacturing or industrial processes [5]. Kelley et al., 2000, describe residential waste as waste that emanates from premises used wholly or mainly for residential purposes and may include recyclable materials and non-recyclable material, but excludes hazardous waste [13]. Most of the residential waste generated at the residences and the student centre contain organic waste for example kitchen waste, recyclable waste which include plastics, paper, glass, cans and non-recyclables which include electronic waste like batteries, damage electrical equipments. Other non-hazardous waste generated within campus is construction and demolition waste which include rubbles, asbestos and dry wood. These are properly handled by the contractor in charge of such renovation within campus. Therefore, to quantify bio-degradable waste generated on campus, it was necessary to conduct a waste measurement field exercise, the approach and results of which are presented in the following sections.

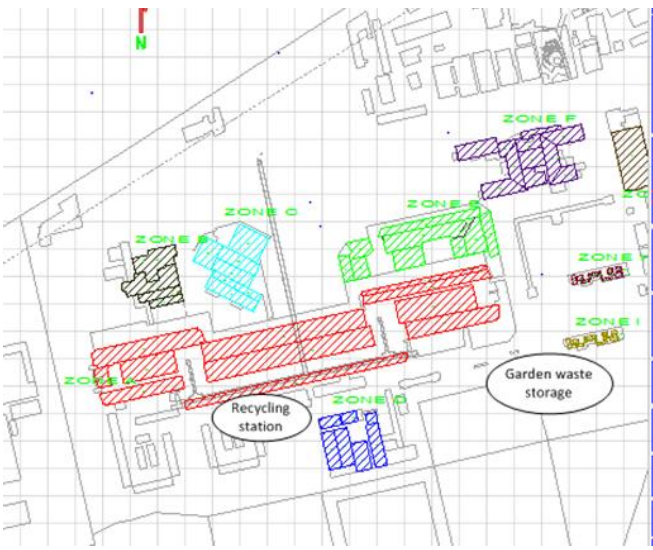

Fig. 1 UJ DFC campus map

IV. METHOD

There are a number of possible approaches to quantifying waste according to literature. A United Nation Environmental Programme (UNEP), 2009 report mentions the following options: (i) Measurement at the point of generation, (ii) by examination of records at the point of generation, (iii) through use of vehicle survey and (iv) by examination of records at the disposal facility [5]. The report goes on to mention that measurement at point of generation was found to be the one that can give the most accurate results [5], [14]. This method involves visiting the points where waste is generated and determination by measurement or observing the amount of waste disposed during a given period of time. The four aforementioned approaches were considered for this study. Option (ii), (iii), and (iv) had to be discarded outright due to the aforementioned lack of data records at UJ DFC, neither was there a disposal facility. Option (i), was deemed to be too time consuming and expensive, so a fifth approach was adopted; measurement at points of collection with respect to the WTS and the GWS. The description of this approach is provided in the following section.

A. *Material and Separation Procedure*

Fig. 2 depicts the overall approach employed for waste quantification exercise. Garden waste collected in the GWS was separated into compostable and non-compostable waste by hand sorting. Refuse bags were used to collect all compostable waste which were then weighed to find the total compostable garden waste for that day. Non-compostable garden waste was collected in refuse bins and weighed.

Quantification of general waste was done during the sorting process that normally takes place at the WTS. All waste brought to the centre by the collectors were weighed before the workers separated the recyclables. After this was done, the non-recyclables left were also weighed and then hand sorted into food waste, other bio-degradable, polystyrene and non-categorised before being dumped in the skips which would later be emptied and transported to landfills.

To ensure safety of personnel and students involved in the exercise, Personal Protective Equipment (PPE) was used. The PPE include gloves, safety boots, overalls and masks. Small bins and refuse bags were used to categorize waste and a platform floor scale with the weighing capacity of 30-90 kg was used to weigh all the waste after hand sorting. Brooms and rake were used to assemble garden waste discarded behind Aurum residence. Shovels and refuse bags were used to categorize garden waste into compost and non-compost.

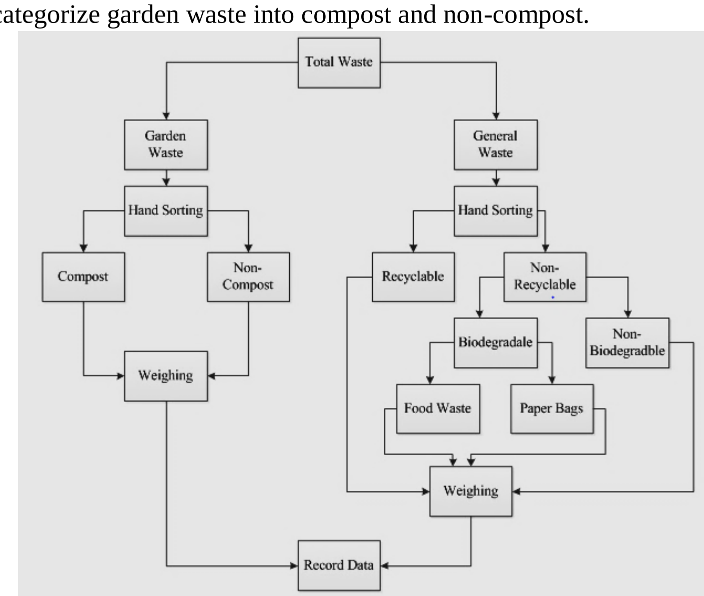

Fig. 1 Waste characterization flow diagram

V. RESULTS AND DISCUSSIONS

After the first stage quantification exercise, approximately 310kg of waste (general and garden) were been generated on campus on daily basis. The bulk (65.21% on average) of which was general waste. Table II and III shows the data for waste generated on campus. Table II gives the average general waste per day of collection over a period of five weeks while table III gives the garden waste per week of collection over a period of five weeks. After separation of recyclables, the average amount of biodegradable general waste produced is 156.46kg/day from table II. In Table III, the compostable waste generated accounted for 32% of the total waste generated on campus.

TABLE II

AVERAGE GENERAL WASTE COLLECTED PER DAY OVER FIVE WEEKS

Categories	**Type of Waste**	**Mass per day(kg)**							**Average Mass (kg)**	**Composition (%)**	**Standard Deviation**
Collection days		1	2	3	4	5	6	7			
General	Food	137.10	160.20	142.68	178.22	110.70	103.60	106.10	134.09	67.36	28.79
	Other biodegradable	5.10	4.85	3.88	3.77	46.70	51.90	40.40	22.37	11.24	5.76
	Polystyrene	3.60	3.63	3.20	4.00	2.10	2.40	4.35	3.33	1.67	0.82
	Non-categorized	40.20	36.79	38.65	34.78	35.67	42.05	46.70	39.26	19.73	4.15
Total		186.00	205.47	188.41	220.77	195.17	199.95	197.55	199.05	100.00	11.65

TABLE III

AVERAGE GARDEN WASTE COLLECTED PER WEEK OVER FIVE WEEKS

Categories	**Type of Waste**	**Mass per week (kg)**					**Weekly Average Mass (kg)**	**Daily Average (kg)**	**Composition (%)**	**Standard Deviation**
Collection weeks		1	2	3	4	5				
Garden	Compost	555.50	742.93	823.94	626.78	708.80	691.59	98.80	92.68	103.89
	Non-compost	74.40	40.50	50.60	48.70	58.90	54.62	7.80	7.32	12.85
Total		629.90	783.43	874.54	675.48	767.70	746.21	106.6	100.00	95.98

Fig 3 shows the average distribution of general and garden wastes according to the classification described earlier. It shows that only 67% on average of the general waste collected from UJ, DFC were food waste and 11% was other biodegradables, which were normally sent to landfills.

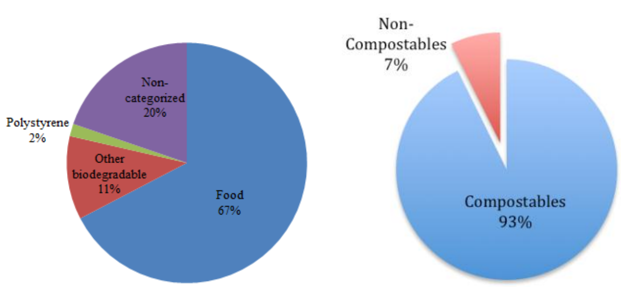

Fig. 2 Pie charts for general and garden waste

Day 1, 2, and 4 showed to have high percentages of food waste which results from the high population of students on campus. In contrast a low amount of 101.70, 103.60 and 106.10 kg/day was obtained from day 5, 6 and 7 respectively. This occurred due to the absence of students on campus for recess. Food waste and compost comprising 82.34% of the total waste generated are the most suitable feed stock that can be fed into a digester due to their high bio-degradability characteristic. 255.26kg which is the mass fraction of food waste and compost waste will yield approximately 94m^3 of biogas per day with an energy equivalent of 0.6MWh per day according to Nathan et. al. 2011. It is estimated that one tonne of food waste has the potential to produce 367m^3 of biogas and 1m^3 of biogas with 65% methane content will generate 6.25kWh energy [15]. Based on the sources of food and green wastes, it is expected that the bio-degradability of food waste will be relatively consistent throughout the year but the biodegradability of green waste could have seasonable variation. The results of this study on the green waste would well represent the characteristics of green waste in the summer and spring.

Seasonal variation contributes to the difference in the amount of waste produced; however general waste is affected by the number of people around campus because most waste is collected from the student residences. Less waste was collected during university holidays. Seasonal variation mainly affect the garden waste generation. Studies have shown that during rainy seasons more garden waste is generated [13]. In contrast, a minimum amount of waste is generated during winter. Further studies is recommended to quantify the amount of garden waste generated on campus per season. Apart from weather patterns, variations in waste can also be to cyclical nature of the university occupancy that is term time and holidays. Due to the variation in the quantities of certain types of solid wastes generated under varying seasons, special studies should be conducted to verify if this information will have a significant impact on the system.

VI. Conclusion

The study presented methods and initial results of the waste quantification exercise on UJ DFC campus. Reliable estimates of solid waste generation are very important for proper waste management planning and scaling of bio-digester. Recovering energy from waste does not only serve as a renewable energy but also reduce landfilling requirements such as land space, transportation cost etc. Waste was quantified using measurement at point of generation. Food waste, non-categorised waste, other biodegradables and polystyrenes were calculated to be 67%, 20%, 11% and 2% respectively. Furthermore compost was found to be the most produced than non-compost with 93%. Compost and food waste are the main ingredient which can be fed into an anaerobic digester for the production of biogas. Biogas produced can be used as fuel for kitchen activities at the student center and also to provide heat for the residences during winter. Due to seasonal variation of the quantity of compost available which forms a substantial part of the feed stock, further study is needed for characterizing the green waste generated during other seasons of the year.

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