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Waste Quantification at the Johannesburg Market for the City of Johannesburg Waste to Energy Programme

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Abstract— **The City of Johannesburg, a world class African city is looking to improve air quality, cut down on greenhouse gas emissions and generate alternative sources of fuel by creating an effective management system for the enormous amount of waste generated within the city. The structures put in place would not only cut down dependence on landfills but provide fuel to power the city's metro buses and in the nearest future generate electricity. This paper focuses on the quantification exercise at the Johannesburg Market which has the potential to generate about 28, 486 GJ of energy per year from the anaerobic digestion of fruit and vegetable waste which accounts for 93% of the total waste generated at the market.**

Index Terms— **Greenhouse gas, Waste, Fuel, Quantification**

I. Introduction

As the world population continues to increase geometrically, a corresponding impact is seen in waste generation which necessitates the need for more effective ways to manage this seeming menace [1]. Landfills have been the most popular method of waste disposal across the world. However, in recent years, there have been clamour for alternative waste management systems as landfills are now seen as short term solutions due to their negative impact on the environment and human health. At Landfills, human waste is compacted and buried underneath the soil which caused decomposition of the waste [1]. Most modern landfills, even with the latest technological advancements and effective management still yield harmful leachates and landfill emissions which irritate the human respiratory system and contribute to greenhouse effect. Also of concern is the relatively short lifespan of working landfills which is determined by various factors such as rate of delivery, depth of fill, operating practice, soil properties, topographic information, characteristics of the solid waste and recovery of capital investment to name a few [2].

In Johannesburg, the four major landfill sites have a life span of less than 16 years each before they are decommissioned, meaning other environmentally friendly waste management systems must be explored to exploit the waste generated in the city [3]. If this is not done, other useful arable lands might be converted to less productive landfill sites. Another point of note is that landfills continue to generate methane, a 21 times more potent greenhouse gas than carbon dioxide and they continue to generate methane for 30 to 50 years even after which they have been decommissioned [4].

The quest to turn to alternative forms of waste management by the City of Johannesburg (COJ), would not only be looking cutting down on the use of landfills but developing systems that would render the waste innocuous while also creating utilization pathways for the wastes for more productive outputs. The aim is for the waste generated within the city is to facilitate them into products that would drive the economy of the city and empower its people [5].

Recently, COJ effectively set up structures through its waste management framework to ensure greenhouse gas emissions reduction (from waste) by encouraging recycling and energy recovery from waste to propel development in a city which is the financial and commercial nerve center of South Africa. The waste is to be further processed into a green fuel called biogas to supplement fuel and electricity generated from fossil sources. The green fuel is to be gradually integrated into the industrial and transport sector where petrol, diesel and natural gas are the conventional fuels [5]. These sectors consume the major percentage of the nation's energy resources and contribute to making South Africa one of the counties with the highest carbon dioxide emissions per capita in the world and definitely the highest in Africa [6]. Biogas combustion and utilization could cut well-to-wheel carbon dioxide emissions by more than 50% [7] .

Key to the city's waste management goal is to educate the populace, with added incentives aimed and encouraging the reduction, reuse, sorting and recycling of waste generated

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with the first three being done at household levels. The city is also in the process of developing data on the waste generated in the city and how the quantities reached may be efficiently utilized to source energy [8].

The City of Johannesburg with respect to the afore mentioned partnered with The University of Johannesburg to assist with the waste quantification exercise in different areas of the metropolis while employing anaerobic digestion to generate biogas through a pilot plant to initially power some of its metro buses and in future generate electricity [9].

This paper will highlight the waste quantification exercise done at the Johannesburg Market. The waste produced at the fruit and vegetable market is dumped daily at the close landfills. This exercise was done to primarily obtain the quantity of waste produced and secondarily to project the energy estimate that could be recovered annually from the organic fraction of the waste generated at the market.

It is important to state that as at the time of writing this paper, the project is still on-going and there are plans to also quantify the waste generated during other seasons as this was carried out during summer. Summer records the highest temperatures for the year and the warm temperatures promotes bacteria development which also quickens the destruction of fruits and vegetables. Hence, there is a high chance that more waste would be generated at the market during summer as compared to other seasons. The exercise took place from the 11^{th} to the 20^{th} of November, 2015 which included a 3-day site understudy (11^{th} to 13^{th}) and a 5-day (16th to 20^{th}) quantification period done in agreement with the management of the Johannesburg Market while adhering to set standards as a proof of concept study, neglecting slight variations that might affect the waste volume as a result of seasonal changes causing unavailability of some produce.

II. Joburg Market

Previously known as the Johannesburg Fresh Produce Market, this facility caters for the fruit and vegetable needs of dwellers in the metropolis and beyond. It is located 5km south of Johannesburg business district. It houses varieties of fresh agricultural produce served by about 5000 farmers across South Africa. An average of 10,000 buyers daily, make purchases from this market. It is the biggest fruit and vegetable market in South Africa with fruits, vegetables, potatoes and onion hubs spanning over 65,000m^2. All JM wastes are discarded at the waste transfer station in skips [10]. The 7 skips are emptied into trucks daily and driven to close landfills. The relatively hazardous nature of the waste generated necessitates special handling and swift disposal.

III. Methodology

The waste quantification study was done for 5 days by the University of Johannesburg Research Team. The ASTM D5231-92 standard for determining waste composition and sorting was followed [11]. 52 samples of 100kg each were randomly selected as the vehicles discharged the waste to the skips, providing 90% confidence levels. A strategic area was mapped out to sort the waste samples. The mapped area had tarpaulin sheets unto which the 100kg samples were discharge for manual sorting. A 500kg capacity scale was recalibrated for the exercise while 140 liter refuse bins were used to collect the sample and for sorting to different categories. Since we were interested in the useful organic content for energy generation, the categories were trimmed to six rather than the over 70 vegetable and fruit species available at the market. The sorting process was effectively done to ensure little or no particles were left on the tarpaulin or in the containers. Details of the samples and sorted waste streams were collated in our data sheets taking into account our tare and gross weights (the effect of the weight of the containers) and an overall average calculated to get the composition percentages. Fig. 1, and Fig. 2, shows part of the quantification activities at the market

Fig.1. Waste sorting

Fig. 2. Waste in skips

IV. Result

The organic contents of interest which would thrive efficiently in anaerobic conditions are the fruit and vegetable waste and they account for 93% of the total waste generated as seen in Fig. 4, and Fig. 5, showing the percentages without fruits and vegetables which could also be recycled. The total waste generated daily for the 5 days are shown in Fig. 3, with a daily average for the days pegged at about 49,896 kg. However, based on the available records, number of skips lifted from the market, loading rate, waste type and frequency of lifts of the rear end detachable truck. The waste generated daily throughout the year should be between 39 tons to 67 ton, with seasonal availability of some produce contributing to the quantity of waste generated at a given time.

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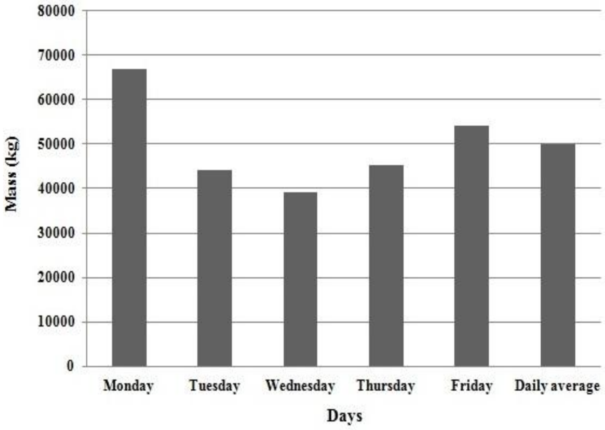

Fig. 3. Quantity of waste generated for the sample days

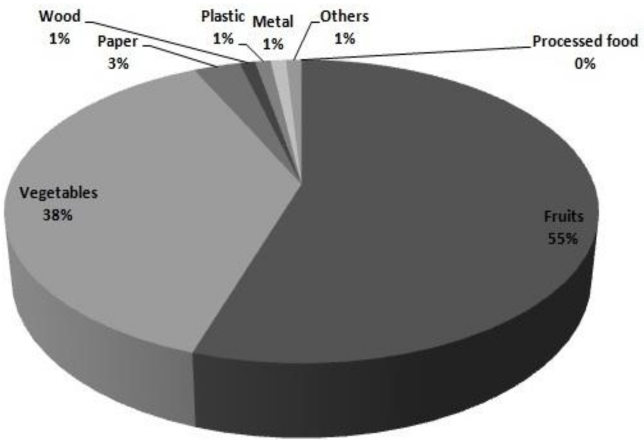

Fig. 4. Composition of Johannesburg Market Waste

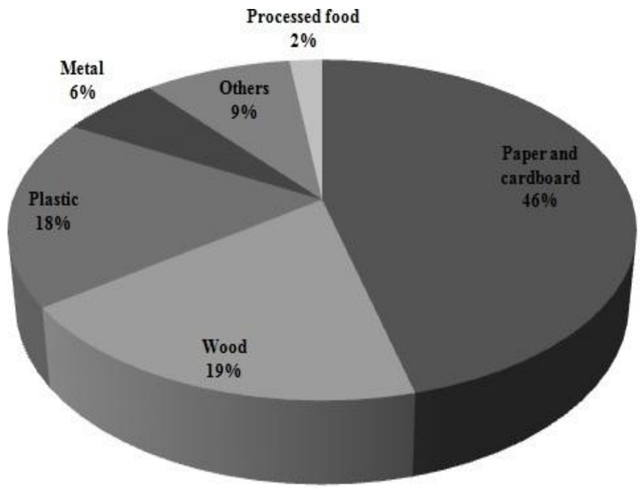

Fig. 5. Percentage distribution of waste streams aside fruits and vegetable

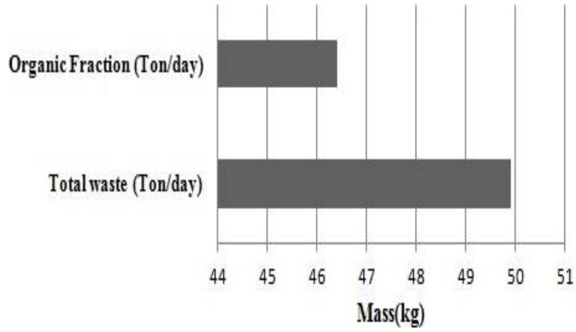

Fig. 6. Average total waste generated and the organic fraction to be used for energy recovery.

V. Energy Potential

The energy potential in this section was calculated according to the BC BioProducts Association Estimate taking into account the average daily waste collated during the 5-day exercise [12]. The energy equivalent expected is seen in the table and figures below when the fruit and vegetable portion of the waste is fed consistently for a year into a digester designed for its capacity.

TABLE 1
ENERGY EQUIVALENT FROM THE FRUIT AND VEGETABLE WASTE

Energy potential of organic waste	Quantity organic (tons/y)	Biogas (m3/y)	Energy (GJ/y)	Electricity* (kWh)
Fruits and Vegetables	16,936	1,318,806	28,486	3,165,134

TABLE 2
EQUIVALENT OF OTHER FUELS TO BIOGAS AND CO_2 REDUCTION*

Other fuel	Equivalent
Natural gas (m^3/y)	791,284
Diesel (l/y)	749,109
Petrol (l/y)	844,300
Electricity (MW)	0.36
CO_2 equivalent reduction (tCO_{2eq}/yr)	11,632

**Assuming biogas with 60% methane and 35% conversion efficeincy from methane to electricity*

**1 Nm^3 of biomethane equals 0.9467 l of diesel and 1.067 l of petrol*

VI. Conclusion

It was observed that a very large percentage of the waste generated at the JM is organic and can be fed directly into an anaerobic digester with minimum level of sorting that could be done manually and inexpensive. Energy can be produce from these wastes as indicated in the exercise, which may be used to supplement the electrical power and

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fuel need to run daily operations or sold to generate extra income. Utilizing the waste to generate energy cuts down the cost of transporting the waste to the landfills and if the generation process is maximized there would be no need to transport the waste as all the waste generated may be reused, recycled or used to generate energy. However, future works on other phases of this project would assess the waste generated across the 4 seasons as well as laboratory test waste characterization, looking at salient variables like pH, temperature, moisture content, waste particle size, CN ratio and density to find out how they affect the rate of degradation and how it may be co-digested to improve system efficiency for biogas production.

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