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POTENTIAL FOR ANAEROBIC DIGESTION (AD) TECHNOLOGY TO TREAT ORGANIC SOLID WASTE AT COMMUNITY LEVEL: A CASE STUDY IN GONGO LA MBOTO, DAR ES SALAAM TANZANIA

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ABSTRACT
This paper looks at the potential of anaerobic digestion technology to treat Organic Fraction of Municipal Solid Wastes (OFMSW) in Gongo la Mboto in Dar es Salaam city. The study evaluates municipal solid waste generation, and composition, at transfer station level. Composition analysis of waste determined the relative amount of (OFMSW). For composition analysis of waste standard method ASTM-D5231-92 was used. 100 kg of sample was subjected to reduction of the sample using quartering technique. Then the reduced sample was sorted out manually into following categories: food waste, plastics, paper, tin cans, and metals, rubber and glass. Subsequently, the weight of each component were measured and recorded. Other parameters which were evaluated are moisture content of organic fraction, and volume of the digester. The results show that on average 34.39tons/day ton of solid waste is generated/day giving a per capita generation rate of 0.6kg/capita/day based on population of 57312. Results of waste composition analysis was as follows: food waste accounts for 39%, metals13.6%, wood 10.4%, plastics 9.4%, tin cans 8.4%, paper 7.8%, rubber 6.2% and glass 5%. Analysis indicated 78.3% moisture content of OFMSW. Amount of OFMSW generated was 13.41tons/day. Anaerobic digester of 761 m^3 volume was estimated. The study findings indicates that since OFMSW is high, anaerobic digestion could be an appealing option for converting raw solid organic wastes into biogas, which may play a critical role in meeting the world's ever-increasing energy requirements in the future.
Keywords: Organic, anaerobic, digestion, municipal, solid waste

INTRODUCTION
Solid waste management is an important environmental issue in urban areas. Rapid urbanization and change of lifestyle has increased generation of Municipal Solid Waste (MSW) leading to various problems in waste disposal. Municipal Solid Waste (MSW) contains organic as well as inorganic matter. As reported by Giavini and Van den Berg

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(2017) low-income countries are known to have the highest proportion of organic waste, which can range from 40-65% of the total waste stream. Due to its simplicity and financial reason, solid waste disposal on sanitary landfill has been the common practice for many decades. However, a study of Eriksson *et al.*,(2005) shows that burying organic fraction of municipal solid waste together with other fractions implied extra cost for leachate treatment, low biogas quality and quantity, and high post closure care. Increased environmental awareness and concerns over direct landfilling have stimulated new approaches for solid waste treatment before disposal. The aim of the paper investigate the potential of anaerobic digestion technology to treat Organic Fraction of Municipal Solid Wastes (OFMSW) in Gongo la Mboto in Dar es Salaam city. The objective is to evaluate municipal solid waste generation, and composition, at transfer station level.

REVIEW OF ORGANIC FRACTION OF MUNICIPAL SOLID WASTES (OFMSW)

Various alternatives are available for pretreatment of Organic Fraction of Municipal Solid Wastes (OFMSW) before disposal namely, biological, physical and chemical processes. Biological processes like Anaerobic Digestion (AD) and composting provide advantages due to its natural treatment process over other technologies. Anaerobic digestion (AD) is the natural process that breaks down organic matter in the absence of oxygen to release a gas known as biogas, leaving an organic residue called digestate (Nayono, 2010). According to Rapport et al., (2008) AD systems are employed for organic solid waste degradation, and are used in engineered anaerobic digesters to treat organic waste prior to disposal. AD processes can be single step processes where all the waste is placed into a single digestion stage/tank or multiple step processes. Multiple step processes optimize the breakdown of complex organic material into soluble compounds. This is followed by a high-rate AD process for biogas production. This process may take place in a number of vessels, normally two are employed, one as a separate hydrolysis vessel and the second as a digester (DEFRA, 2005)**.**

The digestion process takes place in sealed tanks (digesters) that are usually mixed thoroughly to maximize contact between microbes and waste. According to Giavini and Van den Berg (2017) there are three main types of anaerobic digesters that have been implemented in developing countries, namely; the fixed-dome digester, the floating-drum digester, and the tubular digester. All of them are wet digestion systems operated in continuous mode under mesophilic conditions (30-40°C). The basic features of this solution include the fact of being inexpensive, mostly built with locally available material, easy to handle, do not have many moving parts, hence they are less prone to failure.

As stated by Mata-Avarez (2003) anaerobic digestion (AD) has unique and integrative potential, simultaneously acting as a waste treatment and resource recovery process. AD also showed an excellent Life Cycle Analysis (LCA) performance as compared to other

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treatment technologies like composting or incineration as it can improve the energy balance. In addition, the residues are stable compost potential for agricultural purpose (Torres-Castillo et al., 1995). Compared to composting, anaerobic digestion of OFMSW has several advantages, such as better handling of wet waste, the possibility of energy recovery in the form of methane, digestion installations are technologically simple with low energy and space requirements, and less emission of bad odor and greenhouse gasses (Nayono, 2010).

Therefore, anaerobic digestion of bio-degradable solid wastes can be considered an alternative option to improve the environment condition caused by organic solid waste and at the same time taking an advantage as an environmentally friendly resource of energy.

The current study was carried out in Gongo la Mboto ward in Dar es Salaam city to find out the potential of Anaerobic Digestion (AD) technology to treat OFMSW (organic fraction of municipal solid waste). Gongo la Mboto ward was selected as a study area based on the fact that earlier effort to treat organic waste by implementing small composting project was not successful. The project was not effective due to factors such as the low efficiency of the plant, or the piling up of the residual waste, which was not transported to dumpsite and left at the site. Therefore, the main objective of this study was to find out the potential for use of AD technology to treat OFMSW (organic fraction of municipal solid waste) in Gongo la Mboto as a viable option in the near future. In order to reach the objective of the study, the organic fraction of waste was estimated by carrying out composition analysis of commingled waste. Moisture content of the organic fraction was determined as well, finally the volume of the anaerobic digester required to treat organic waste generated in Gongo la Mboto was determined.

Solid waste management in Gongo la Mboto

According to the ward officer, Gongo la Mboto ward was estimated to generate about 35 to 50 tons of waste per day by the year 2017. This amount was produced in residential areas, commercial, and small market. Unfortunately only a fraction of the waste generated can efficiently be collected. The ward officer reported that about 25% to 35% of the solid waste generated per day was managed (i.e. collected, stored, and transported to the landfill or recycled). Remaining portion of solid waste that is not collected is dumped on land in a more or less uncontrolled manner. These dumps make very uneconomical use of the available space, allow free access to waste pickers, animals and flies and often produce unpleasant and hazardous smoke from slow-burning fires. As a strategy of managing organic waste Bremen Overseas Research and Development Institute (BORDA) implemented composting according to the DESWAM (Decentralized Solid Waste Management) approach in the Gongo la Mboto sub-ward of the Gongo la Mboto ward in Dar es Salaam.. However, due to the low efficiency of the plant and the low level of cooperation by the municipality

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the leftover waste was left at the site and BORDA eventually handed the project back to the municipality.

2. RESEARCH METHODOLOGY

2.1 Research area

Gongo la Mboto is located in Ilala municipality in Dar es Salaam city. Ilala is a municipality in Dar es Salaam, Tanzania, the others being Temeke to the South, Kinondoni to the North, Ubungo to the West, and Kigamboni to the East Gongo la Mboto ward comprises four sub-wards namely, Ulongoni A, Ulongoni B, Gongo la Mboto and Gurukakwalala with the total population of 57312 according to the 2012 Population and Housing Census Report NBS, 2012). Figure 1 shows a map of Gongo la Mboto ward.

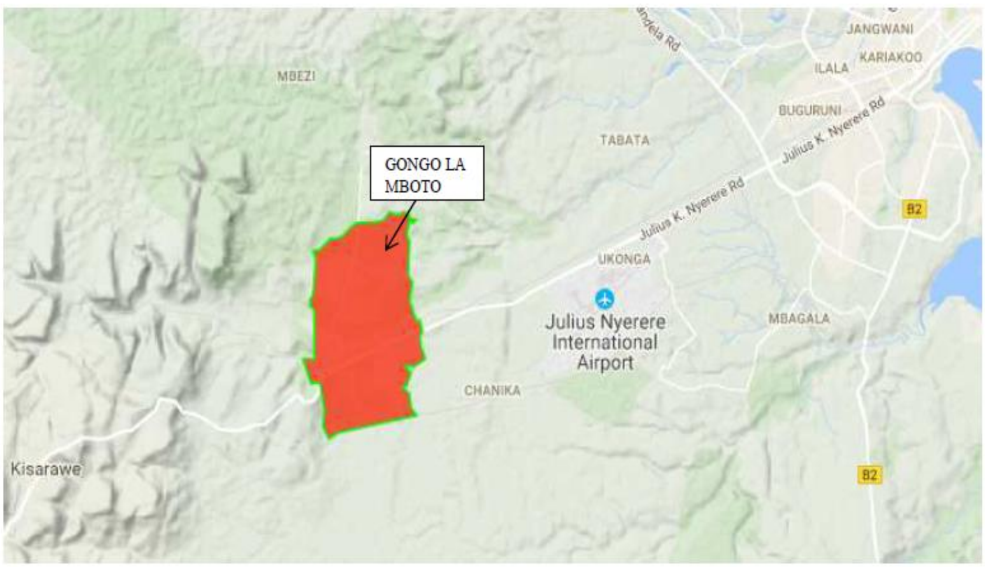

Figure 1: A map of Gongo la Mboto ward
(Source: Google Earth)

2.2. Population size at Gongo la Mboto ward

Table 1 presents the population of Gongo la Mboto sub-wards, namely, Ulongoni, Gongo la Mboto and Guruka Kwalala. The total population and number of households in Gongo la Mboto ward are 57312 and 14349 respectively (NBS, 2012).

Table 1. Population and number of households in Gongo la Mboto ward

STREET NAME	POPULATION	No. of Households
Ulongoni	27624	6680
Gongo la Mboto	17520	4543
Guruka Kwalala	12168	3126
Total	57312	14349

(Source: NBS, 2012)

2.3 Preparation of solid waste sample

Solid waste used in this study was collected from three (3) sub-wards of Gongo la Mboto. In this study solid waste samples were taken from trucks delivering waste to transfer stations from residential, commercial, and small markets. The amount of solid waste generated was determined, and then representative waste sample was manually segregated to retain the organic fraction by carrying out solid waste composition analysis. From the sample moisture Content (MC) of OFMSW was analyzed by following ASTM standards (1993).

The materials used for the measurement of waste were: portable weighing balances with a capacity of 50 kg and 100 kg, and plastic bags with a volume of 10 litres for weighing the waste. Other facilities were forks, gloves, and facemasks for protection.

2.4 Determination of rate of solid waste generation

The per capita per day generation rate was calculated from the daily generated quantity of waste. Based on the total weight of waste generated in a day and the total population of the Gongo la Mboto ward where the waste is generated, the per capita generation of solid waste was determined.

PCG = (Waste generated / day) / (Population (Kg/ day/ person)

Where,

PCG is the per capita waste generation

2.5 Estimating the composition of solid waste

On the basis of physical composition, the samples were divided into 9 physical components as listed in Table 2. The aim of carrying out waste composition analysis was to obtain the fraction of organic waste because anaerobic digestion can only act on biodegradable materials. For composition analysis of the solid waste standard method ASTM-D5231-92 was used. This method requires a representative sample of 100-200 kg from a week-day collection route in waste collection areas. Representative solid waste samples of 100kg were

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obtained from waste collection point (transfer station) for determination of solid waste characteristics. The sampling point was identified in consultation with ward authorities responsible for solid waste management to obtain a representative sample. Assessing waste quantity and composition in this way has been shown to capture the high spatial variation of waste (Mbue et al., 2015), thereby yielding more reliable and representative data.

To prepare homogeneous and representative sample, the waste sample of 100kg was mixed thoroughly and divided into 4 piles (quartering technique) of same volume followed by removal of two parts of waste at diagonal opposite ends and mixing the remaining amount. Once the representative sample was prepared it was weighed. Then the reduced sample was sorted out manually into various components. Subsequently, the weight of each component were measured and recorded.

In order to find out the percentage of organic components (i.e. food waste) of MSW, waste was manually sorted. Then the percentage by weight of each waste component was calculated by using physical balance. Afterwards the inorganic waste components (i.e. plastics, paper, tin cans, metals, rubber and glass) were discarded. Information and data on the organic fraction of solid wastes was important because it is a substrate of anaerobic digestion. The composition ratio of each waste in (%), was calculated as follows: Weight of each weight composition (kg)/ Total amount of each waste composition (kg) ×100

2.6 Determination of organic waste daily produced

The amount of organic waste (food waste) produced daily was obtained from determination of individual component of solid waste through manual sorting. A percentage composition by mass of organic waste obtained from sorting a representative solid waste were multiply by amount of solid waste daily produced to estimate the amount of organic waste produced daily.

2.7 Determination of Moisture content of organic solid waste

Moisture content is defined as the ratio of the weight of water (wet weight - dry weight) to the total weight of the wet waste. In this study the MC of solid wastes was determined in homogenized samples in accordance with the ASTMD 3173 standard. Samples of organic waste were first weighted in porcelain cups and dried in an oven at 105ºC for 24 hours. Then weights after heating were also recorded. The moisture content percentage was determined as a percentage loss in weight before as well as after drying by using equation:

Moisture Content (%) = (Wet weight – Dry weight)/Wet weight x 100 m1

M (%) = (w– d)/w x 100 m1

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Where,
M = moisture content, %
W = initial weight of the sample as delivered, kg
D = weight of sample after drying at 105^0C

3. RESULTS AND DISCUSSION

3.1 Composition of solid waste in Gongo la Mboto

Table 2 shows the average percentages of solid waste constituents found in solid waste in studied area, Nine, (9) different fractions of waste have been segregated in the collected sample. The major one is food waste which accounts for 39%, followed by ferrous and non-ferrous metals13.6%, wood 10.4%, plastics 9.4%, tin cans 8.4%, paper 7.8%. Rubber and glass were found at relatively lower percentages of 6.2% and 5% respectively. The results clearly indicate that the composition of organic waste is dominated by food waste (mixed). It mainly includes leftover food residue, vegetable waste, leaves and decayed vegetables. Tchobanoglous (1993) and Wakjira (2007) are previous studies which reported that large portion of solid waste in developing countries is food waste.

Table 2: Waste Composition for Gongo la Mboto Ward

Category	Food Wastes	Paper	Plastics	Rubber	Wood	Glass	Tin/ Cans	Metals	**Total**
Weight%	**39**	7.8	9.4	6.2	10.4	5.0	8.6	13.6	100

As waste comprised a high food waste fraction which was organic in nature, there are two main reflections: First and foremost this is an indication of anaerobic digestion and composting possibilities, as the transformation of this material into manure could reduce the volume of waste required to be transported to the dumpsite. Secondly, when this kind of waste is not collected, a foul smell is emanated due to its high decomposition rate, taking into consideration that the study ward is found in a very hot climate.; and thirdly, emission of methane which is a major greenhouse gas due to anaerobic decomposition in the dump sites.

3.2 Amount of Solid Waste Generated

The per capita waste (per person) was calculated by dividing the total waste generated by the Gongo la Mboto ward total population. The average per capital waste generation rate was found to be 0.6 kg per person per day. This finding is comparable with earlier study done by BORDA on the amount of waste generated by households in Kinondoni municipality which resulted in 0.644 kg per capita per day (average) waste generation of which more than half

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consists of organic material. This value in comparison is within the generation rate reported in other developing countries. Therefore, total amount of waste generated in Gongo la Mboto ward = 0.6(kg/person / day) x 57312)/1000 = 34.39tons/day.

3.3 Amount of Organic Waste Generated daily

From percentage composition by mass of representative solid waste sample Food waste =39% (see. table 2). To estimate amount of organic waste produced daily = 39% of total amount of waste generated.

Therefore, the amount of organic waste (food waste) = 0.39 x 34.39 tons/day = 13.41tons/day. The amount of organic waste generated daily was used to determine the plant capacity. Wastes from vegetable/ fruit yards and markets, agricultural and food processing units etc. contain high concentration of bio-degradable matter and are suitable for energy recovery through anaerobic de-composition

3.4 Moisture Content of organic waste

Moisture is important for the activity of microbes because it increases the rate of metabolism. A typical range of moisture content is 20 to 40%, representing the extremes of wastes in an arid climate and in the wet season of a region of high precipitation. However, values greater than 40% are not common. The percentage of moisture content in organic food waste turned out to be 78.3%. The recorded value wet weight was 106 g and dry weight was 23 g. High moisture content causes biodegradable waste fractions to decompose more rapidly than in dry conditions.

It has been reported that high moisture contents usually facilitate the anaerobic digestion the highest methane production rates occur at 60–80% of humidity (Khalid *et.al* 2011).

3.5 Determination of the volume of the digester

The following parameters are important in determining the anaerobic digester to treat organic waste of Gongo la Mboto:

Number of population at Gongo la Mboto Ward = 57312

Solid waste generation rate per day = 34.39 tons/day

Total amount of organic waste generated per day = 13.41tons/day

Moisture content of food waste = 73.8 %

3.5.1 *Volume of Digester*

Digester volume is given by:

Digester volume = Organic loading rate (daily input) x hydraulic retention

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3.5.2 *Hydraulic retention*

The Hydraulic Retention Time (HRT) is a measure to describe the average time that a certain substrate resides in a digester. According to Hartmann and Ahring (2006) the HRT for dry anaerobic digestion ranges between 14 and 30 days for food waste. In this study a retention time of 30 days was used.

The organic loading rate (OLR) is defined as the amount of organic matter that must be treated by a certain volume of anaerobic digester in a certain period of time.
Amount of organic waste generated daily = 13.41 tons/day' ≈ 14000 0kg/day

Taking hydraulic retention time for organic waste = 30 days
- Daily feed requires ratio of 1:1/2 of organic waste to water since MC of organic waste is > 50% (Oekotop, Sasse)
Therefore 14000kg of organic waste = 7 m^3 of water
- Daily feed = (14000/1000) + (0.5 x14) = 21 m^3
Digester Volume = 21m^3 x 30 = 630m^3

3.5.3 *Gas storage Volume*

Gas storage volume was calculated based on the equation given by (Seadi et al., 2013) as follows:
Gas storage Volume = 0.62 x Maximum gas daily production
Where,
Maximum gas daily produced = Mg x Sg
Where; Mg is Maximum daily input of organic waste = 14000 kg = 14 tons
Sg is Specific gas production (Based on Bolzonella, et al., (2004, Sg = 0.6),
Therefore, specific gas production for organic waste:
= 0.6 x amount of organic waste = 0.6 x 14 = 8.4
Maximum gas daily produced = 8.4 x (0.6 x30) (where 30 days = retention time)
8.4 x18m^3 = 151.2 m^3
Therefore, Gas storage Volume = 0.62 x 151.2m^3 = 93.72 m^3
Say 94 m^3

3.7.4 *Dead Volume*

The purpose of dead volume is to accommodate the floating layer on top of the slurry .when gas production is less than nominal or when there is a gas leakage. To prevent the higher slurry level to rise up to overflow level 5% addition is allowed for the Gas volume and digester volume.
Dead Volume = 5% (Gas volume + Digester volume)

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Gas volume + digester volume = $94m^3 + 630m^3 = 724\ m^3$
Therefore, Dead volume = $0.05 \times 724.72\ m^3 = 36.2\ m^3$

3.7.5 *Total Plant Volume*
The total plant volume is summation of Digester Volume + Gas storage + Volume + Dead Volume.
Total plant volume = $630\ m^3 + 94\ m^3 + 36.2\ m^3 = 760.2\ m^3$
Therefore; Total digester volume = $761\ m^3$

CONCLUSION

This study explores the anaerobic digestion technology (AD), as one of the main options for treating the organic fraction of municipal solid waste OFMSW in Gongo la Mboto Dar es Salaam city. It was estimated that approximately 34.39 tons per day of solid waste were generated in Gongo la Mboto ward in 2017. This represents a generation rate of 0.6 kg/cap/day based on a population of 57312. Sorted solid waste from residential, commercial and market place in Gongo la Mboto was found to have a high fraction of organic fraction (food waste) which accounts for 39% .i.e. 13.41 ton/day' ≈ 14000 kg/day of waste composition, and has a moisture content (MC) of 78.3%. This waste can be fed to the digester of capacity of 761 m^3. The calculated volume is an important parameter to consider when dimensioning the biogas system for organic waste produced in Gongo la Mboto ward. Recycling and energy recovery would be an appropriate option for the inorganic fraction of the waste stream, comprising paper, plastics, metals and glass.

However, a detailed feasibility study needs to be conducted to determine the economic and environmental competitiveness of anaerobic digestion technology, as one of the options for treating the biodegradable organic materials in Municipal Solid Waste (MSW). Wherever feasible, this option should be incorporated in the over-all scheme of solid waste management at municipal or city level.

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