Municipal Solid Waste from Landfills a Solution to Energy Crisis in South Africa

O.R Dada and C. Mbohwa

***Abstract*— There is a growing interest in the management of municipal solid waste globally, and South Africa is also not relenting in its effort to turning wastes from landfill into resourceful materials or energy because of the environmental issues and job opportunities that arises from the wastes generated from household to industrial by-products. Due to the escalating increase in the cost of dumping wastes into landfills and depletion of land spaces despite the popular global campaign of waste reduction, re-use and recycling there is still a rapid increase in the tonnage of wastes that is being produced on daily basis from all works of life which results in huge quantity of waste that is disposed to landfills. This calls for an urgent need to look into possible ways of managing wastes better in such a manner that it contributes and promotes sustainable socio - economic development of the nation.**

This research paper focuses on the type of waste generated from the City of Johannesburg, the potential biomethane that could be produced from the organic wastes, waste collection methods around the city before disposal on landfills within the City of Johannesburg and investigation of energy generation from waste as a better waste management technique. Robinson deep landfill which is one of the biggest landfill site within the city in terms of capacity is located in the South of Johannesburg. This landfill is a potential site for the establishment of a biogas plant where landfill wastes is expected to be used as feedstocks for the production of biogas. The biogas produced will be further upgraded to biomethane for powering the City of Johannesburg metro buses.

***Index Terms*—, Biogas, Landfill, Sustainable development, Wastes**

I. Introduction

WASTE generated by human activities is of various types and it differs from one sector to another. As long as human beings continues to carry out their activities on the surface of the earth waste production is inevitable. People from all facets of life deal with different materials on daily basis and they discard materials that seems to be useless or old and some of which ends up on landfill sites. Even though environmental specialists are emphasizing on the need to minimize (Reduce), Re-use and Recycle wastes, it has been observed it cannot be completely eliminated therefore, it is very important to look into how best to produce an economical substance or commodity that is viable from wastes that ends up on various landfills within South African. On annual basis, South Africans generate about 108 million tonnes of waste is materials and majority of which is being dumped on landfill sites. Gauteng province of South Africa contributes about 45% of the country municipal solid waste amounting to about 59million tons a year [1] and by 2022 it is envisaged that there will not be space to dispose waste on landfills hence efforts are being put in place to ensure 75% of the waste will be diverted into recyclable materials from landfills [2]. It was also revealed that the waste generated annually in South Africa is worth about R17 billion [1] hence we cannot afford to let this huge amount of money go down the drain. Due to the growing population of Gauteng as a result of urbanization and increase in birth rate waste generated within the City of Johannesburg is expected to be on a rapid increase and because dumping of wastes into landfills seems to be the quickest way of disposing wastes therefore, reliance on this natural resources will be on the rise even though there is a decline in the capacity of the landfills as a result the need to urgently look into biogas production from landfill waste as a way of tackling waste management crisis.

Manuscript received July 19, 2016; revised August 6, 2016. This work was supported in part by the City of Johannesburg South Africa.

O.R Dada is with the department of Mechanical Engineering, University of Johannesburg, Auckland Park, South Africa. (+278027963969; e-mail: odada@uj.ac.za)

C. Mbohwa is with University of Johannesburg, Doornfontein, 2028 South Africa. He is the Vice Dean of Postgraduate Studies Research and Innovation Faculty of Engineering and the Built Environment (e-mail: cmbohwa@uj.ac.za).

II. Waste Collection Categorization

In South Africa, waste management and classification is guided by the Waste Act (Act No.59,2008) [3] which was established by the Department of Environmental Affairs. Every province and municipality has the right to register a waste management firm that helps to collect household waste and other waste from different sources thereby giving them the ability to dispose the waste collected on registered and designated landfills. Since 45% of the waste generated in South Africa annually is from Gauteng province and Johannesburg contributing about 60 % of the waste [2] it is of a necessity that a biogas plant is established at the city center close to the major landfill of the city where all waste dump trucks can easily access for waste disposal. There are several companies that handles and manages wastes within the city although, some are specific on the type of waste they collect. Wastes collected within the City of Johannesburg can be broadly classified into (i) Round Collected Refuse (RCR) (ii) Dailies.

A. Round Collected Refuse

These are waste collected from shops, restaurants and houses within the City by compressed trucks and disposed on landfills as seen in Fig 1. These wastes can be further

grouped into the following: Organic waste, Paper and Paperboard, Glass, Metals, Plastics and unclassified wastes. Unclassified wastes include the mixture of many components or materials mashed as a result of the compaction of the wastes by the waste trucks. These includes: Special care wastes, textiles, fabrics, leather and many more.

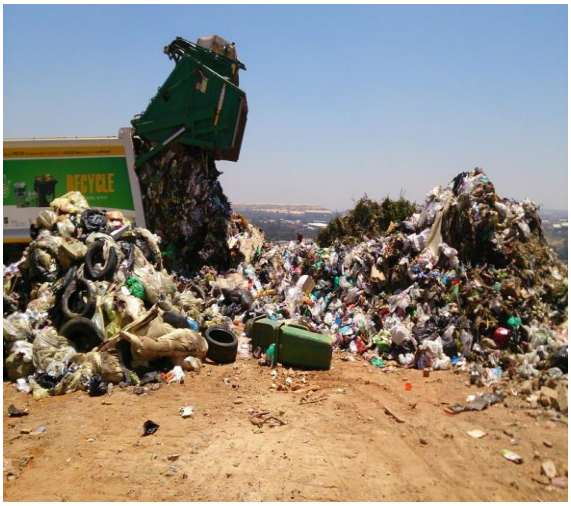

Fig. 1. Round Collected Refuse dumped on a landfill site.

B. Dailies

Dailies are otherwise known as non-compacted municipal solid wastes. These wastes are collected from various locations within the city by trucks or vans managed by waste management companies. They are wastes mostly collected from less dense populated areas and are usually stored in waste plastic bags awaiting to be picked up by waste vans as shown in Fig 2.

Non- compacted wastes are similar to wastes collected by round collected refuse trucks in terms of categorization so, they can be easily sorted and classified into organic wastes, paper and paper board, glass, tyres, plastics and metals.

Fig. 2. Dailies (Non-compacted) Waste dumped on a landfill.

III. LANDFILL BIOGAS FUTURE OF SOUTH AFRICA ENERGY SUPPLY

The generation of renewable energy from renewable resources or wastes is important due to the energy crisis the country is experiencing and also in order to create a more environmental friendly country by transiting from fossil fuels as a source of energy into non-fossil fuels (renewable energy). The main reasons why renewable energy is the most preferred alternative to fossil fuels globally is because of the increase in the concentrations of greenhouse gases (GHGs) in the atmosphere as a result of fossil fuel-derived CO_2 emissions and also political instability in the regions of the world that has been the major producers of the world's oil and gas. Studies has shown that bioenergy will contribute 10% to the world's future energy supply [4], [5] with biogas being expected to contribute 25% of the total bioenergy [6]. Although, there are various raw materials for the production of biogas such as: agricultural wastes, manure, plant materials, sewage, municipal waste and food wastes nevertheless, in one way or the other all these streams of raw materials which could be used as feedstocks for biogas production are still found on landfill sites. Landfill biogas is produced when wet organic waste is decomposed under anaerobic conditions. Anaerobic microbes are formed over time when wastes on landfills are covered and mechanically compressed thus, leading to the gradual building up of gases which could be captured and further processed in other to increase the percentage of methane contained in it. Prior to practical utilization of the biogas, it has to be dried (usually through application of cooling and condensation steps). Landfill biogas when upgraded will be most suitable for electricity production and utilization in transportation sector has a vehicular fuel.

IV. BIOGAS PRODUCTION FROM LANDFILL

One of the ways of producing biogas from landfill wastes is through anaerobic digestion of organic matters. This process is a biological process and it is strongly dependent on environmental conditions such as temperature, nutrients content, Carbon/Nitrogen ratio, Carbon /Phosphorous ratio, presence of inhibitors, substrate typology, microelements availability and particle sizes [7]. Other sources of wastes that can be used as feedstock for the production of biogas include: waste from sewage plants, industrial wastes and agricultural produce. Landfill wastes which is known to be rich in organic matters such as garden wastes and food wastes also has the potential of producing biogas whose methane concentration can be increased to about 95-97% when upgraded. Producing biogas by anaerobic digestion involves four (4) stages as shown in Fig 3.

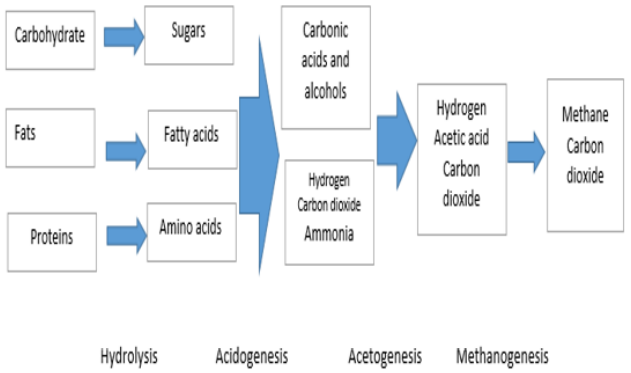

Fig. 3. The four stages of biogas process.

At hydrolysis stage which is the first process of organic waste decomposition, extracellular molecules such as carbohydrate, fats and proteins are broken down through the help of hydrolytic bacteria. At acidogenesis phase, hydrolytic bacteria begin the fermentation on carbohydrate as a result creating ammonia (NH_3), Carbon dioxide, Hydrogen sulphide (H_2S), Hydrogen (H_2), organic acids, shorter volatile fatty acids and low alcohols [8]. Following the acidogensis stage is the acetogenesis process where volatile fatty acids are synthesized and the advantage of this process is that it consumes hydrogen gas which helps to keep the concentration level very low. Finally, at methanogenesis stage methanogenic organisms (methanogens) convert the formed hydrogen and acetic acid to methane gas and carbon dioxide. At this stage waste stabilization is obtained as a result of the formation of methane gas and carbon dioxide. The pathway for the formation of the methane is expressed in the equation (1), (2) and (3).

$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O \quad (1)$$

$$2C_2H_5OH + CO_2 \rightarrow CH_4 + 2CH_3COOH \quad (2)$$

$$CH_3COOH \rightarrow CH_4 + CO_2 \quad (3)$$

V. WASTE TO ENERGY A BETTER APPROACH TO MSW MANAGEMENT

Apart from producing biogas from landfill wastes which could be used in boilers for the production of steam and heat, electricity production, replacement for natural gas by injection into gas grid when upgraded, replacement of liquefied natural gas for transport fuel usage, biogas produced from landfills has also been observed as one of the best solutions to managing municipal solid waste when compared to other traditional methods of waste management.

With the aim of protecting the environment, a feasibility study was done were four (4) waste management techniques namely: Anaerobic digestion, Incineration, Landfill and composting were considered and are given criterion rankings which was used to develop a priority matrix. All the matrix was synthesized by multiplying each criterion ranking by the priority vector and adding the resulting weights to get the overall priority vector. Using Analytic Hierarchy Process (AHP) based on four criteria such as: Environmental, Sociocultural, Technical and Economic and four waste management technique namely: Anaerobic digestion, Landfill, Incineration and Composting, weighted factor was obtained as presented in Table 1.

TABLE I
PRIORITY VECTOR OF THE CRITERIA

	Environmental	Sociocultural	Technical	Economical
Weighted factor	0.5527	0.2595	0.0538	0.1341

The result from Table I shows that environmental vector has the highest priority followed by sociocultural and economic factors while technicality is the least and when comparing this to the techniques for managing MSW especially waste that are rich in organic matter. Anaerobic digestion is the most acceptable followed by incineration and then composting while landfill is the most undesirable method of managing waste for the reason being that it is not environmental friendly neither is it economical.

VI. CONCLUSION

If waste management is to be given a serious attention by the government of South Africa and other developing countries at large, there is an urgent need to research and develop anaerobic digestion plants where biogas could be produced for electricity and transportation purposes for the benefit of the people and also to create a conducive and healthy environment for the citizens.

ACKNOWLEDGMENT

The authors wishes to thank the members of the UJ - COJ team as well as the staffs of Pikitup Johannesburg for their assistance during the landfill visits.

REFERENCES

[1] S.Jamal “Garbage we dump in landfills is worth billions”. South Africa, March 2015. http://www.timeslive.co.za/thetimes/2015/03/25/garbage-we-dump-in-landfills-is-worth-billions. [Accessed 30 May 2016]

[2] B. Ackroyd “Recycling the only solution to South Africa’s landfill shortage”. South Africa, June 2014. http://www.enca.com/south-africa/recycling-only-solution-south-africans-landfill-shortage, [Accessed 8 June 2016]

[3] Department of Environmental Affairs, *waste classification and management regulations, 2008.*

[4] P. Monarty, D. Honnery. What is the global potential for renewable energy? Renewable and sustainable Energy Reviews 2012; 16(1): 244-52, http://dx.doi.org/10.106/j.rser.2011.07.151

[5] A. Jess. What might be the energy demand and energy mix to reconcile the world’s pursuit of welfare and happiness with necessity to preserve the integrity of the biosphere? Energy policy 38(8):4663-78;2010.

[6] J. Holm-Nielsen, T. Al seadi, P. Oleskowicz-popiel. The future of anaerobic digestion and biogas utilization. Biresources Technology 2009; 100 (22): 5418-84.

[7] J. Mata-Alvarez, S. Mace, P. Liabres “Anaerobic digestion of organic solid waste. An overview of research achievements and perspectives. Bioresour Technol 74: 3-16; 2000

[8] S. Verma. Anaerobic Digestion of biodegradable organics in municipal solid wastes. Department of Earth and Environmental Engineering (Henry Krumb School of Mines). Columbia