

Physicochemical characteristics and Biodegradability of organic fraction of solid wastes generated in Eldoret Municipality, Kenya.

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Abstract

This study was designed to characterise and assess the biodegradability of the organic portion of the waste from a fast growing agricultural urban centre, Eldoret, in North Rift of Kenya. This is because new strategies for waste management are aimed at integrating mechanical, thermal and biological processing for energy and reduction of the volume of waste to be disposed. Therefore biological methods are designed to degrade organic carbon of MSW under controlled conditions to produce desired quality for final disposal should take into account, the proportions and characteristics of the components as a factor that would influence the biodegradability of the wastes. The study was carried out in Eldoret municipality, a fast expanding urban setting in Western Kenya that serves as an administrative centre of Uasin Gishu County. Waste samples were collected on delivery at dumpsite and categorised by source of waste based on the economic status of the households. Waste composition, proximate analysis for crude nutrients, volatile solids and biochemical gas potential of the waste were carried out to estimate the physicochemical and biodegradability characteristics of the waste. Results showed that putrescible/organic material constituted the largest component of the waste irrespective of the source. Its moisture content was expectedly high (> 50%). The organic fraction contains high levels of crude nutrients that can support microbial activities thus biodegradability. This was supported by the volatile solids profiles and the biochemical gas potential. Statistically, biodegradability of wastes from central business district was significantly ($p < 0.05$) more degradable than from residential areas. This was attributable to the high organic carbon content.

Key words: Municipal solid waste, Biodegradability, organic, physicochemical characteristics

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Introduction

Municipal solid waste (MSW) comprises of combined domestic, commercial and industrial waste generated in a given municipality or locality (Fobil, 2005; Kothari, *et al.*, 2010). Due to increase in population and changes in lifestyles, there is an increased generation of wastes (Sintana and

Tchobanoglous, 2012). It is estimated that the current global municipal solid wastes generation stands at 1.3 billion tonnes per year and are expected to increase to approximately 2.2 billion tonnes per year by 2025 (World Bank, 2012; Sintana and Tchobanoglous, 2012). The integrated solutions to problems of the waste management in the modern era involving mechanical, thermal and

biological processing are often aimed at recovering materials, producing energy and minimizing the amount of waste to be disposed (Voelker, 1997).

Biologically, breakdown of degradable organic carbon of MSW under controlled conditions, produces desired quality for disposal. In the process, methanogenic activities are enhanced with gas generation and the waste sanitized before disposal (Zach *et al.*, 2000). However biodegradability of wastes is dependent on the organic carbon that is accessible to biochemical decomposition and properties of other components of the waste (It is a complex function of the elemental composition of the waste) which varies with sources and handling practices (Kathiravale *et al.*, 2003). This paper presents the solid waste characteristics and biodegradability of the organic portion of the waste from a fast growing agricultural urban centre (Eldoret) in North Rift of Kenya.

1999 and 2009) in Western Kenya that serves as an administrative centre of Uasin Gishu County. It lies at 0.°31N, 35°16E and at an elevation varying from about 2100 to more than 2700 metres above sea level. Eldoret has a cold and wet tropical climate with total annual rainfall of 1103 mm with bimodal rainfall pattern with long rains coming between March and June while the short rains normally occurring from August to early part of October (TUDelft, 2004). The town has large agricultural produce retail market and several commercial outlets, health and educational facilities. The Central Business District (CBD) is surrounded by several residential areas catering for residents of different economic status. The town is served by a single major dumpsite located on the south western, approximately four kilometres from the Central Business District at an abandoned quarry, 0.057155°N. 36.09419079°E

Materials and Methods

Study site and Waste disposal practice

This study was carried out in Eldoret municipality (Figure 1), a fast expanding urban setting (GoK

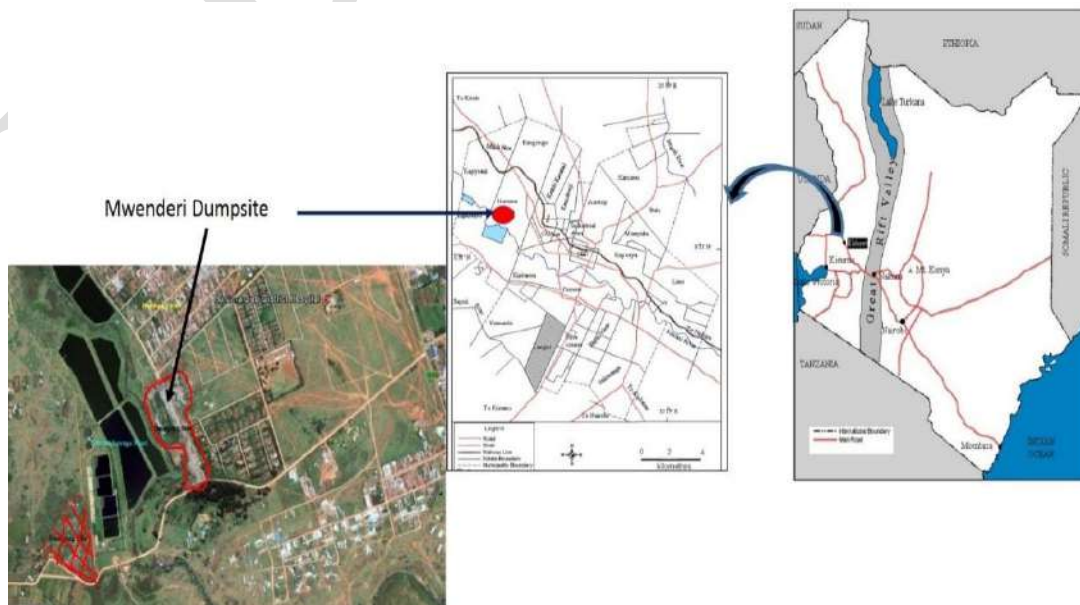


Figure 1: Location of the study site.

Waste sample collection

The study proceeded through two consecutive phases namely pre-sampling phase and sampling phase. Pre-sampling phase involved literature search and survey through interviews and reconnaissance visit to establish the type of waste and management practices at critical points in waste management including ; storage at the source, collection sites, transportation and delivery at the dumpsite. The respondents during the pre-sampling phase included municipal council officials, private waste handling companies, waste handlers and the dumpsite management staff. The outcome from the survey informed the study on the waste sampling procedures described below.

Waste characterization

Waste characterisation was undertaken at the dump site in accordance with standard procedures (ASTM, 2008; UNEP/IETC, 2009). Upon the arrival at the dumpsite the waste consignment was first separated into residential and non-residential (CBD) wastes. The residential waste was further separated based on the socio-economic status of the households in the estate of origin. Consequently the wastes were categorised as from High, Middle and Low income households.

Material based categorization of the components approach developed by Burnley (2007) was used to characterize the wastes as follows: Waste batches were delivered either in dedicated bags or truck full of mixed wastes from a single estate. Six bags from each delivered batch (identified by the date and origin) at the dumpsite were randomly picked as they were offloaded from trucks. The content of the six bags were emptied on polythene sheeting and thoroughly mixed before a sub sample of 100 kg was taken and transferred to another plastic sheeting. For the mixed wastes, 20 litres plastic buckets were used to collect the samples as wastes was offloaded. As for the waste in dedicated bags, waste from the 6 buckets were

mixed on plastic sheeting and a sub sample of 100 kgs was taken from each batch. The sub samples were separately weighed and segregated based on predesigned 8 character component template into putrescible organic waste (kitchen waste, fruit and vegetable peels, yard waste), textile/clothes, paper, plastic/polythene bags, Glass, Metal, Ash and clinical (hazardous) wastes. The components were separately weighed to determine their weights and the percentage of the total weight of the sub-sample computed. A further 2 kg from each sub sample consisting of putrescible components considered degradable, were then taken and thoroughly mixed and collected in polythene bags and taken to the laboratory for proximate, and biodegradability tests.

Proximate analysis

Moisture content of triplicate samples was determined by modified Standard Method 2540-B (APHA 1992). Each sample of solid waste was dried in an aluminum pan at 105⁰C to a constant weight after cooling under desiccation. Moisture content was determined by weight loss from the original sample and expressed as a percent. Crude fibre was estimated by Van Soest "Detergent Fiber" determination. Crude protein content was estimated by Kjeldahl Nitrogen.

Leachate Samples

Stagnant pools of leachate flowing from the dumpsite were collected in plastic voltic bottles that had been pre cleaned with concentrated nitric acid and finally rinsed in distilled water. Approximately 100 ml of leachate was collected at several points along the gradient as it flowed towards the river. The samples were transported to the laboratory on ice in an ice box and refrigerated at 4⁰C until used as inoculant.

Biodegradability tests

Biodegradability of the waste was estimated from the volatile solids and by gas production potential by means of a water displacement method.

Volatile Solids

The volatile solids procedure followed a modified version of Standard Methods APHA Method 2440-E. Samples were dried once again at 1050 C to a constant weight and held in a desiccator. Approximately two grams of dried MSW were placed in pre-weighed aluminum pans and inserted into a muffle furnace at 550°C for 20 minutes. Samples were removed and allowed to cool in a desiccator to a constant weight. The percent weight loss from ignition yields the total amount of volatile matter.

Gas production potential

The gas production potential was based on Mariotte principle (i.e., the volume of water displaced is equivalent to volume of biogas generated) as described by Itodo *et al.* (1992), Owens and Chynoweth (1993) and Stinson and Ham (1995). In brief, oven dried Solid waste samples were separately ground in a laboratory mill to pass through a 0.2mm sieve. Ten (10) grams of ground waste was suspended in 150 ml double distilled water and homogenized in a laboratory blender and transferred to the a 500 ml flat bottomed flask (reactor flask). The blender was rinsed once with 50 ml double distilled water and the rinse was added to the reactor flask to make a final waste suspension volume of 200ml.

The inoculant (from the leachate collected from the waste and previously maintained at 4°C) was prepared as described by Owen *et al.* (1979) and

added at 1 mL for every 4 ml of waste mixture to a final volume of 250 ml of mixture plus leachate inoculant. A temperature of 37° C was maintained by incubating the reactors in a temperature controlled shaking water bath for 20 days. The quantity of total gas produced was measured by fluid displacement on daily basis. A measuring cylinder at outlet of the aspirator bottles collected displaced water which measured the total gas at atmospheric temperatures and pressure.

Statistical analysis

Data was subjected to ANOVA using the procedure GLM (SAS institute, 2003). Percentage data for Moisture Volatile solids, Crude Fibre, Crude Fat and crude proteins was arcsine transformed before being subjected to ANOVA. Results of analysis were interpreted in their original scale of measurements (i.e. analysed information was transformed back to original scale (percentage) in which raw data was captured). All test were performed at a significant $\alpha = 0.05$.

RESULTS AND DISCUSSION

Waste Generation and storage systems

Waste is generated from residential (Estates) and the Central Business District which includes (Retail and wholesale outlets, restaurants and hotels, Academic institutions and open air markets and motor vehicle garage). As shown in Figure 2, Waste storage varied with the sources. In the high income and in some middle income households, the wastes are mostly stored in dedicated individual household waste containers (e.g. black polythene bags-left). Most middle and the Low income households make use of communal containers or informal piles. At the CBD, waste is either piled in an open yard (middle) or in skips (Right) awaiting collection.



Wastes in dedicated polythene bag awaiting collection



Waste heap at market centre



Waste skip at CBD

Figure 2. Waste storage/holding facilities before transportation to dumpsite

Composition of the municipal solid wastes

The waste composition of the sampled sites is shown in **Figure 3**. When all the sites were considered, the organic material represented the single largest component of the MSW stream from Eldoret municipality accounting for 51% by weight - followed by metal at 15%; Glass 14%; Ash 6%; Paper 5%; Plastics 5%; Special-care waste/Clinical 3% and textiles 1%..

Although the percent composition of the organic material did not differ significantly among the residential zones, the organic material in the waste from the CBD was observed to be significantly lower and unusually low compared to previous studies. It is possible that the organic matter from the CBD which predominantly is composed of food leftovers and discarded fruits are scavenged upon by humans and other animals before transportation to the dumpsite.

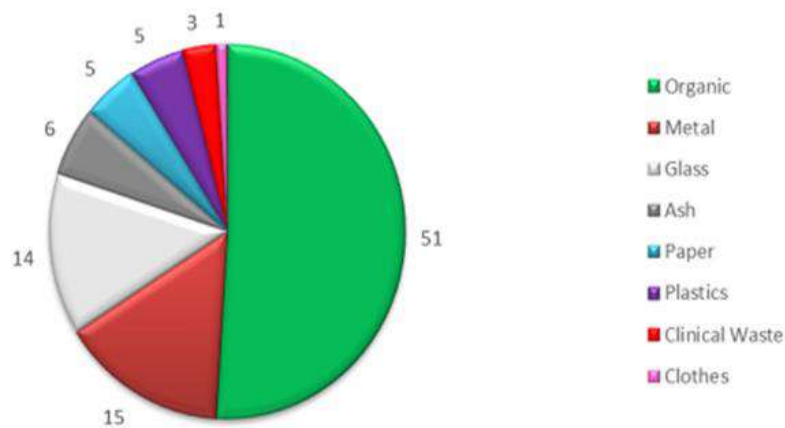


Figure 3. Average composition of MSW from Eldoret Town

The waste from the CBD had the highest percentage plastics followed by the medium population density zone. It was observed that the nature of plastics differed such that the latter zone waste contained thin plastic bags and the former being characterized by heavier plastic containers. This could be that in the high density zones packaging is increasingly of small quantity goods in thin plastic bags.

The CBD had a predictably high percentage papers due to high generation by offices. In comparison to previous studies, percentage composition of paper in MSW upto 22.6% has been recorded. The lower percentage (12%) in this study may indicate that paper waste is picked directly by recyclers and is not available as part of the MSW. Indeed it was observed that paper from offices in the CBD was collected and send to Eldoret paper converters. The percentage composition of papers showed that the residential zones had the lowest percentage composition of paper. .At 3%, proportion of paper was lower than previously reported. Again this may be attributed to the difference in packaging between the zones.

Glass ad metals considered as inorganic components of the MSW constituted significant portion of the waste with the highest percentage

composition in the CBD of 25% and 18% for metal and glass, respectively. As a growing urban centre, construction work with the use of metals and glass is expectably high. On the other hand ash was highest in the high population density areas probably indicating that wood and other combustibles are the prime biomass for energy.

When compared with previous studies, the organic matter has always constituted over 50 % of the waste (Farid, 1985; Kibwage, 1996; JICA, 1998; Bahri, 2005; UNEP/CCN/NTT, 2009) its percentage significantly high in 80s’, a percentage reduction in late 90’s and a slight increase thereafter. Therefore, the high percentage of moisture in the current study is a simple evolving solid waste composition with fluctuating percentage composition probably due to decrease/increase in percentage other components other than actual per capita generation.

The averaged moisture contents and crude nutrient content MSW from the sampled zones are shown in **Table 1**. The moisture content of the organic fraction of the municipal solid waste ranged between 67.7 and 84.76 wt. %, which is more than 50 wt. % of the total weight of the sample

Table 1. Proximate composition of dumped municipal solid waste in Eldoret town.

Household Economic status	Parameter				
	Dry matter (%)	Energy Kcal/kg	Crude Fibre (%)	Crude Fat (%)	Crude Protein (%)
High	80.3 ^a	3559 ^a	8.8 ^a	10.1 ^a	23.3 ^a
Medium	72.77 ^b	3316.14 ^{ab}	8.9 ^a	6.9 ^b	22.0 ^b
Low	67.71 ^b	3172.43 ^b	9.1 ^a	5.5 ^b	22.5 ^a
CBD	84.76 ^a	2505 ^c	12.3 ^b	3.9 ^c	24.7 ^c

*Each column with different superscript letters is significantly different at p = 0.05

The high moisture content of the waste from the CBD and High economic status households is probably due to the mode of storage where the use of skips and dedicated waste bags that retain moisture as opposed to the medium and low economic households who store the waste in the open often hot and windy environment that would dehydrate the waste. The moisture content in Eldoret is therefore high, consistent with studies from other developing countries (Yousuf, 2007, Fobil *et al.*, 2005). The high moisture content of the organic fraction would be supportive of biodegradation. Moisture is essential for bacterial survival. Ideal moisture content for waste decomposition is one that approaches saturation. Biological reactions can be retarded if moisture content drops below 40 percent and stops when moisture content is below 20 percent

Laboratory biodegradability of municipal solid wastes was estimated by the use of biochemical gas potential and volatile solids. Volatile solids represent the portion of wastes that has the potential

to be converted into methane while biochemical gas potential is the gas production and used to estimate waste decay thus biodegradability. As shown in Figure 4, the volatile solids and the biochemical gas potential (BGP) exhibited the similar pattern and is a reflection of the content of the biodegradable carbon. Biodegradability of waste is a result of aerobic or anaerobic microbial activities and depends on composition and characteristics of crude ingredients (proteins, fat, carbohydrates and lignin among others) (Owens and Chynoweth, 1993). Biochemical methane potential determination of organic wastes process is therefore highly influenced by inherent substrate characteristics of organic matter. The above nutrients composition and availability of moisture in the waste explains the high gas potential. Waste from the CBD had the highest percentage of crude nutrients thus highest percentage of biochemical gas potential

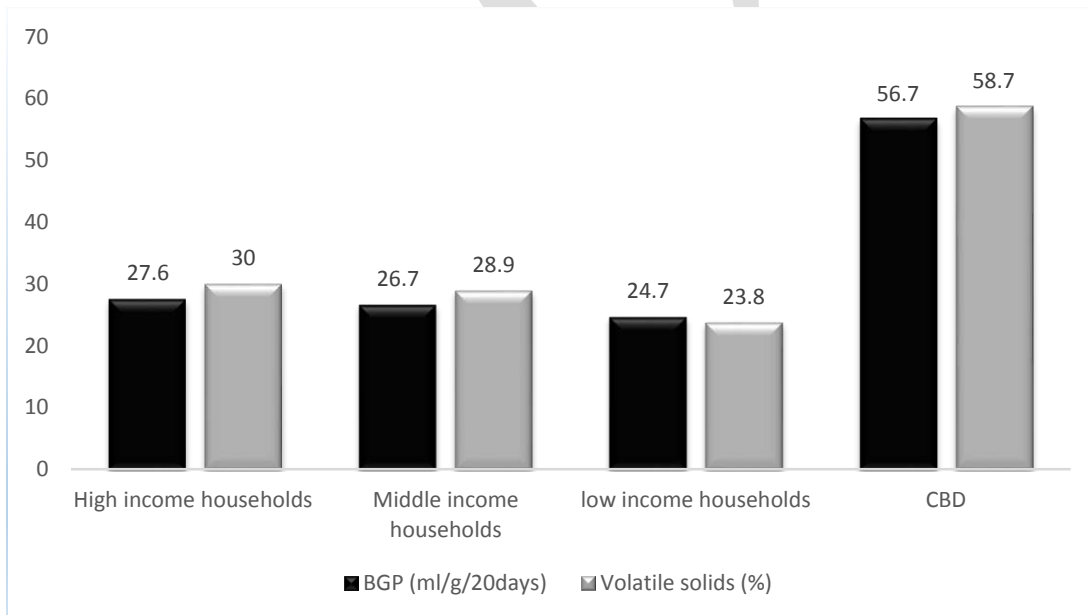


Figure 4. Biodegradability of solid wastes as estimated by volatile solids and biochemical gas potential

The rate at which the various components can be degraded varies markedly. For practical purposes, the principal organic waste components in MSW

are often classified as rapidly and slowly decomposable.

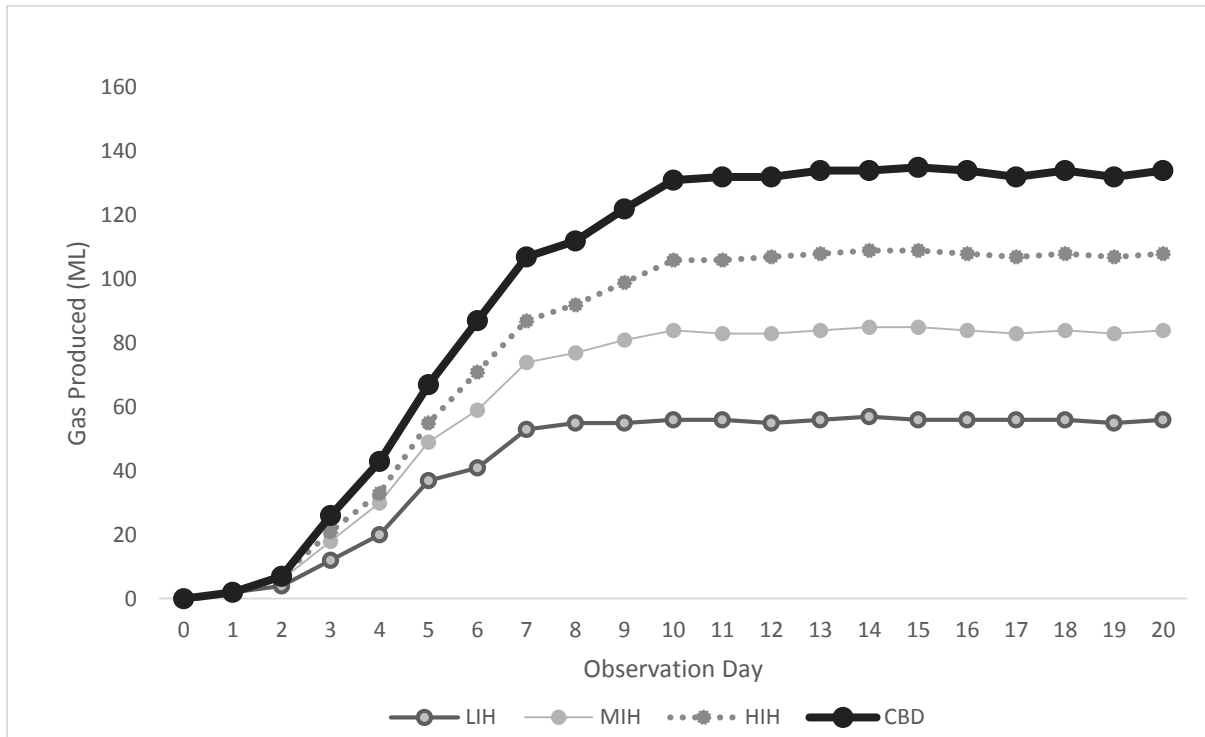


Figure 5: Trend in gas production of the wastes as measured by the biochemical gas potential by the Marritte fluid displacement method

As observed in figure 5, there was no difference in the gas potential among wastes from the three residential areas, a reflection of the nutrient content of the waste. The CBD had a statistically higher biochemical gas potential and also the type of wastes had high percentage of volatile solids and this might be due to the non-kitchen type of waste as opposed to the residential areas.

Decomposition of organic compounds produces methane and hydrogen sulphide. The hydrogen sulphide is responsible for the putrid odour associated with decomposing waste therefore poorly maintained disposal sites causes bad odour and risks of methane emission as greenhouse gas (Crutzen, 1999). The methane emission from

Municipal Solid Wastes depends on the quantity and composition of the solid waste dumped at site (Hocks, 1983; US EPA, 1994) and a significant amount of gas eventually makes its way to the atmosphere (Mor *et al.*, 2006). The composition of the waste deposited at the landfill site should be therefore be ascertained for the estimated of gas emissions potential of the land site.

Conclusion

Solid waste from Eldoret municipality is composed largely of organic material from domestic and commercial sources that would include hotels and restaurants. Metal and glass proportionately constituted a large fraction of the waste probably a reflection of construction activities in this fast growing town. The organic material is highly

degradable and can be either be composted or fermented for biogas production with subsequent disinfection. The percent composition may not reflect the similar values as those obtained straight from source. Thus sorting at the source may provide an accurate composition of the waste.

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