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Research/Technical Note

Quantification of Municipal Solid Waste-The Essential Basis in Waste Management in Tamale: A Ghanaian City

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Abstract: One of the key ingredients to a sustainable functional solid waste systems in any nation is the existence and continual review of data on solid waste management (SWM). Many urban areas in Ghana are heavily polluted with solid waste and Tamale metropolis is not an exception. Households in the metropolis generates enormous amount of solid waste coupled with waste management practices that inevitably affects the environment. The main objective of the study was to determine the physio-chemical parameter of solid waste at Russia bungalows in the Tamale metropolis. In view of this, the specific objectives of the study was to find out the quantity of solid waste generated, determine the moisture content of the waste, and to find out the waste generation rate of the solid waste applying mathematical models. The research gathered data from two main sources namely: secondary and primary sources. The three main techniques employed in gathering the primary data were: preliminary field investigation, physical separation and household survey. The following key findings were established during the analysis of the results and it showed that the quantity of solid waste generated in the study area was 81.70 kg. The total moisture content of the samples was found to be 48.29%, it means that the waste generated can be used as compost to produce fertiliser on farms. This also showed that the generation rate of solid waste was 0.3148 kg/cap/day. Mathematical model showed a weak relation between the quantity of waste generated and household size. Waste generation rates data are crucial in the wider waste systems planning processes. Further studies on source separation of household waste at different areas in the metropolis.

Keywords: Municipal Solid Waste, Moisture Content, Generation Rate, Mathematical Model, Tamale

1. Introduction

Solid waste can be defined as non-liquid material that no longer has any value to the person who owns it or any material that is thrown away or gotten rid of as useless and undesirable [1, 2]. [3] Defined waste management as any activity that aims at diminishing the effects of municipal solid waste on public health and the environment. This may include: characterization and measurement, collection and transportation, separation and resource recovery, processing as well as disposal. Solid-waste management is also described as the collection, treatment, and disposal of solid material that is discarded because it is no longer useful. Solid waste is generated by households as well as industrial, agricultural, private enterprise and healthcare activities. These wastes amass on streets and public places raising much environmental concerns. In developing countries, solid waste management is confronted with challenges including low collection coverage and irregular collection services. Waste management is a main environmental and health challenge around the world today and this is clearer in developing countries of which Ghana is a part. It is acknowledged that solid waste generation is increasing at a faster rate globally as indicated by United Nations Environmental Program (UNEP) and this is confirmed by [4] regarding solid waste generation in Ghana. Ghana presently with a population of about 24.5 million generates about 4.5 million metric tons of solid waste a year. This was made clear

by Zoomlion (ZL) Ghana Limited during a presentation at the United Nations (UN) conference on building partnerships for moving towards zero waste [5]. The huge volumes of solid waste generated in Ghana daily have been credited to rapid urbanisation and increased population growth [6, 7]. The World Bank estimates that in developing countries, municipalities spend up to 50 per cent of their available budget on solid waste management [19]. However, despite this extraordinary expenditure across the developing world, a large percentage of urban solid wastes remain uncollected. Solid waste management is understood as the supervised handling of waste materials from source through recovery processes to disposal [9]. Waste management is a main environmental and health challenge around the world today and this is clearer in developing countries of which Ghana a part. In the past, solid waste was an early problem of mankind, and a growing one that is of main concern to every nation of the world [40, 41]. Tamale is confronted with poor environmental sanitation particularly in the area of solid liquid wastes management which happens to be the single utmost problem in the metropolis. In recent times, municipal solid waste disposal has become a main issue in the Tamale Metropolis. Also, from the waste department of the Tamale Metropolitan Assembly, sometimes for months the waste is not collected and quantity of waste increases [42]. This environmental sanitation problem is similar to that reported in other cities in the country and other neighbouring countries [10, 11]. Significant chemical properties measured for solid waste are: moisture content, volatile matter, ash, fixed carbon, fusing point of ash, calorific value, percent of carbon, hydrogen, oxygen, Sulphur and ash. Wet waste will host more bacteria associated to dry waste. The nutrition in waste also acts as a key factor which decides population balance of species in the waste and direct environment. Immediate analysis of waste aims to determine moisture, volatile matter, and ash and fixed carbon. Definitive analysis of waste aims to analyse percent of carbon, hydrogen, oxygen, Sulphur and ash. The most important aspect of solid waste management is the quantity of waste to be managed. The quantity determines the size and number of functional units and equipment required for managing the waste. The quantities are measured in terms of weight and volume. The weight is fairly constant for a given set of discarded objects whereas volume is highly variable [12]. Waste quantities are usually estimated on the basis of past records of waste generation. The methods commonly used to assess the quantities are (i) load count analysis; (ii) weight volume analysis; and (iii) material balance analysis [12].

(i) In load count analysis, the number of individual loads, the corresponding vehicle characteristics, and weight of each load are recorded over a specified period of time [13].

(ii) Weight and volume data and analysis are important in designing refuse storage containers and compaction equipment. Volumetric measurement of the waste depends on how much the waste has been compacted and whether it is a dense material. In weight and volume analysis, each load is weighed to provide better information on the density of the various forms of solid wastes at a given location.

(iii) Materials balance analysis for each given source, such as an apartment complex or a commercial unit, is the reliable way to determine generation rates [13].

(iv) Against this background, this study was based on three key objectives: to determine the quantity of the solid waste generated, to evaluate the moisture content of solid waste and to estimate the waste generation rate, applying mathematical models.

Figure 1. *Map of Ghana showing the Tamale Metropolitan Assembly (Adapted from http://mci.ei.columbia.edu/).*

Description of the Study Area

Tamale is Ghana's fourth-largest city (Figure 1). It is the capital town of the Northern Region of Ghana and more precisely in the Kingdom of '*Dagbon*' and has a population of more than 360,579 people according to the 2010 census and is the fastest-growing city in West Africa [14, 15]. The metropolis has an estimated land size of 646.90180 square metres. The city is located 600 km (370 mi) north of Accra. It has a rainfall regime of about 740 – 1230 mm. The temperature ranges between 33 to 39°C on the average. Due to its central location, Tamale serves as a hub for all administrative and commercial activities in the Northern region. It has 26 administrative sub-metros viz. Bole District, Bunkpurugu-Yunyoo, Central Gonja, Chereponi, East Gonja, East Mamprusi, Gushegu, Karaga, Kpandai, Kumbungu, Mamprugo, Moaduri, Mion, Nanumba North and South, North Gonja, Saboba, Sagnarigu, Savelugu-Nanton, Sawla-Tuna-Kalba, Tamale Metropolitan, Tatale Sangule, Tolon, West Gonja, West Mamprusi, Yendi Municipal and Zabzugu representing districts. A case study of Russian Bungalows which is a suburb of Jakarayili in the Tamale metropolis. Russian bungalows serves as a boundary with Changli to the west and Kukuo to the south and Jakarayili to the east. According to the population and housing unit, the population at Jakarayili is 1,837 and it is estimated that an average of 11 people live in a house [14].

2. Methodology

For the purpose of this study, Russia bungalows in the Tamale metropolis was selected. Quantitative field measurements of municipal solid waste was carried out in December, 2016, at stipulated period to determine its quantity, composition, moisture content and waste generation rate, applying mathematical models. The municipal solid waste was deliberately allowed to accumulate over specific period of time thus twenty four hours (24 hours) to obtain an appreciable quantity for the quantitative analyses. In total, municipal solid waste from the various households at Russian bungalows in the Tamale metropolis were analysed during the study period. The composition of household solid waste was categorised into six major components, namely, plastics, glass/bottles, organics, metals, textiles and others. Total amount of waste generated was computed from the sum of household solid waste quantity from various households emanating from the study community during the study period. Municipal solid waste in this study therefore refers to the waste generated from the various households in the study area. The quantity of the various households solid waste generated in the study area was therefore expressed as a percentage, various types of solid waste was computed. Further, secondary data was obtained. The number of samples of this research was calculated by using Yamane formula with 95% confidence level [8]. It is estimated that about 800 people live in the study area, an average of 11 people live in each household [14]. This is shown in Equation 1 below:

$$Sample\ size, n = \frac{N}{1+N(\alpha)2} \quad (1)$$

n = sample size; N = sample frame, α= margin error.

Random sampling technique was used to select 41 houses in the study area.

The composition of household solid waste was categorised into six major components, namely, plastics, glass/bottles, organics, metals, textiles and others.

Microsoft excel 2010 was used for the analysis. Data was processed and presented on charts and tables. Regression analysis was also done to determine the relationship between sample weight and household size.

3. Results and Discussion

Quantification of Municipal Solid Waste from Study Community

The results of the study, as shown in Figures 2, 3 and table 1, indicate that, the total composition of the solid waste generated in the area were as follows: 16.99% plastics (polythene, plastic bottles, packaged goods made of plastic and rubber), 4.16% glass/ceramics, 55.08% organic (vegetables/food waste, Paper/book/printed materials, Cardboard, fruits, leaves/grass/wood, animal excreta, straw and crop residue), 5.79% metals (tin/aluminium), 0.87% textiles (thread, yarn, fabric, or cloth) and 17.11% others (silt, sand, stones, ash). The total quantity of solid waste generated in the study community was 81.70 kg.

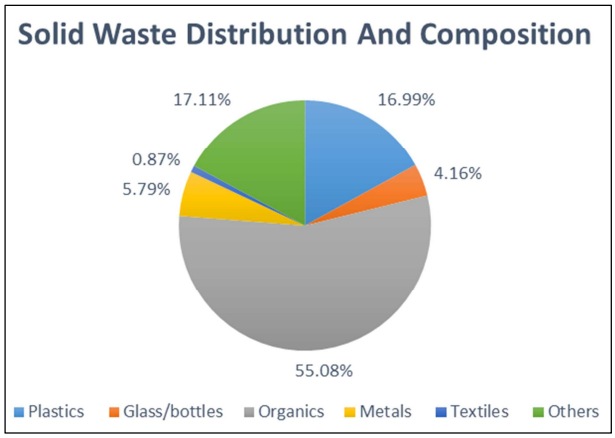

Figure 2. *A graph showing the various solid waste distribution, composition and percentages in study community.*

As figure 2 depicts, waste composition for items such as metals and glass, at 5.79%, 4.16% respectively, are similar to [16] average figures from Accra, Ibadan, Dakar, Abidjan, and Lusaka. The organic waste was 55.08% of the total solid waste. This corroborates the findings of [17, 18], who reported that more than half (55-61%) of the solid waste stream in Kumasi is organic in nature while my findings on the plastics and metals were 16.99% and 5.79% respectively which totalled to 22.78%, this represented quite a significant proportion of the solid waste. This is does not agree with [17],

who reported that; plastics (7% -10%) and metals (2% -3%) constitute insignificant proportions. The reason being that since the study area was a middle income area, they bought more packaged products that mostly consisted of plastics thereby increasing the plastics and hence solid waste in the study community. It also agrees with the findings of [19-21], who stated that the average Ghanaian waste stream includes over 50% organic materials. The total quantity of solid waste that was generated daily was 81.70 kg. This quantity generated thus 81.70 kg maybe as a result of more packaged waste materials, this agrees with the findings of [22]. The population was 173. The quantity of municipal solid waste generated in the study area was very high (81.70 kg), this accounted for the fact that the study area was a middle income area. This corroborates with the findings of [23] who said that quantity of waste generated is mostly associated with the economic status or income of the society or area. It is noteworthy however that, the quantity of solid waste generated is lower in countries with lower gross domestic product (GDP) and vice versa [23].

As figure 3 depicts, there is an inverse relationship between household size and sample weight in Russia bungalows. The relationship from the graph is also consistent with reports by other researchers in other study areas [24-26], who conducted their research in Nigeria. Another explanation to this graph is that because some people living in the area are rich, they tend to buy more packaged products and therefore more waste generation. This means that an increase in household size does not necessarily mean an increase in waste generated. This finding is consistent with [27] who argue that generation rate is also affected by the person's income status or standard of living of individuals. Thus the waste generation within the study areas could be explained by other socio-economic factors such as household size, education, cultural patterns and personal attitudes and income as identified by [28]. These factors were reflected in the findings of the present study.

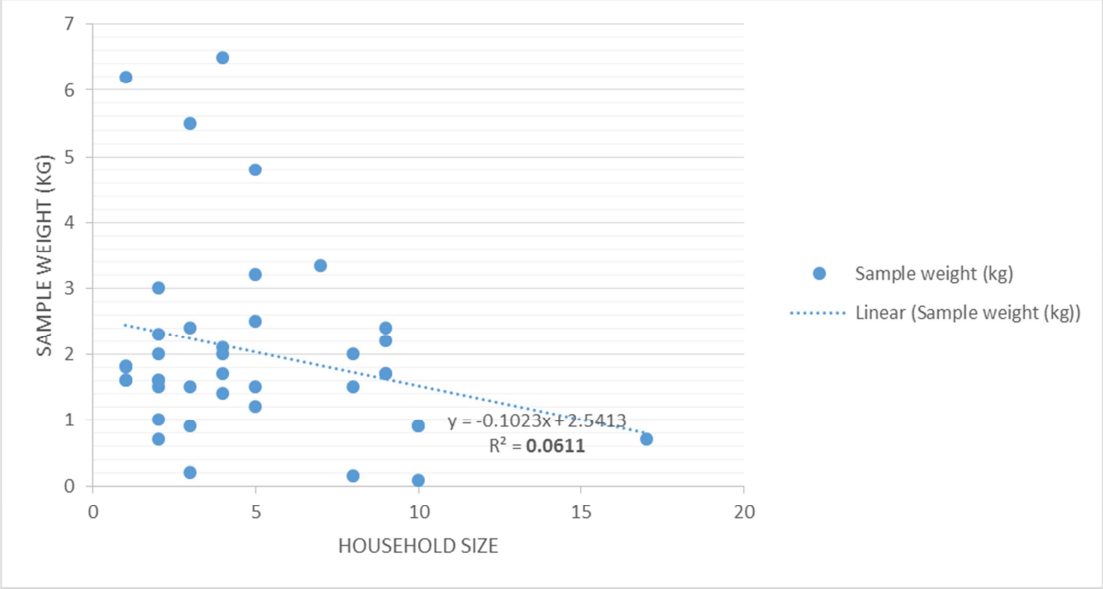

Figure 3. *A scatter diagram showing sample weight (kg) plotted against household size.*

Table 1. *Shows various samples and corresponding wet, dry weight and moisture content.*

Wet weight (g)	Dry weight (g)	Moisture content (%)
528.63	211.68	59.96
573.31	312.20	45.54
123.61	77.67	37.17
286.55	109.62	61.74
159.30	153.04	3.93
1671.40	864.21	48.29

The table depicts that the moisture content was 48.29% for the study area. The moisture content in the waste generated in Russia bungalows was significantly high, and this determines the viability of composting or anaerobic digestions rather than waste combustion. This may mean that municipal solid waste from middle-income areas may not be suitable for waste to energy conversion programmes because of its moisture content that is 48.29% from the research. This corroborates the findings of [29], who conducted similar research in Dhaka city and had almost the same values for moisture content. It is also consistent with the findings from a recent study in Aurangabad city, India, which pointed out that, solid waste moisture content ranged from 21–63% [30]. This findings is consistent with [22] who had values to be about 50%, since the value we recorded was approximately equal to the values of [22]. The level of moisture found in the waste can rather be used or is ideal for composting. The ideal moisture content required for efficient composting is 45–50% [31, 32]. The moisture levels of municipal solid waste are indicators for consideration of waste to energy conversion, the fourth option on the waste management hierarchy [33-34].

The Russia bungalows community, having a total population of about 1,187 [14], generated 0.3148 Kg/cap/day. This findings is consistent with the united nations environmental protection [35], who estimated solid waste

generation rates falls between 0.2 to 0.5 kg/cap/day for sub-Sahara Africa of which Ghana is no exception [36, 35], The per capita waste generation accounts for the various income groups (high, middle and low income group) and hence from the values gotten it indicates a middle income area. Higher generation rates have been reported for OCED (Organization for Economic Cooperation and Development) countries, 1.39 kg/cap/day [37]. Municipal solid waste in Accra on wet basis shows a daily per capita generation rate of 0.40 kg [38, 39], this value is almost equal to the findings in this dissertation which was 0.3148 kg per capita per day.

4. Conclusion

The study has established that the total or overall quantity of waste generated in the area was 81.70 Kg. This quantity generated was as a result of more packaged waste materials. The main aim of waste management was to reduce waste since less waste collected means less cost and also more waste will be recycled. The study also showed that the types of solid waste generated within the study area had a large amount of organics in it thus 55.08%. This accounted for the fact that there were trees in most houses so they sweep and collect leaves/grasses which forms part of the organics. The high percentage of organics means that we can use it in composting to serve as fertilizer for farmers. The study also determined the moisture content of waste generated in the study area. It was revealed that the moisture content was 48.29%. This means that the waste generated is not appropriate for incineration because more energy will be needed to reduce the moisture content before incineration. Finally, the study also determined the solid waste generation rate by applying mathematical model. It was observed that the waste generation rate in the area was 0.3148 kg/cap/day. This meant that knowledge of the waste generation rate multiplied by the population will give us the waste generated daily. Also, the regression diagram showed a weak but negative relationship between sample weight and the household size in the study community. This means that many individuals in a household hold does not necessarily affect the waste they generate. It may have been caused by the income that individuals in the various households generate. The study proposes education on source separation so as to produce sorted raw waste materials for the purposes of waste recovery, household members should be educated and encouraged to practice composting of waste to produce fertiliser for farms and energy since most of the waste generated in the study area contained high amount of organics (food waste/paper/leaves/grasses) and further research work is needed at different areas in the metropolis in the wet season so as to determine how waste generation is influenced by season and climatic factors.

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