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HOUSEHOLD SOLID WASTE MANAGEMENT: COMPOSITIONAL ANALYSIS, STORAGE AND COLLECTION IN THE VITTIN TARGET AREA, TAMALE-GHANA

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Abstract
Municipal solid waste management has become a complex developmental issue. It has been found not only to affect the environment and public health but it is noted to hinder efforts by several Governments especially in developing countries in the management of the environment. The study aimed at assessing waste management practices at the Vittin Target area, to estimate the quantity and components of waste generated. Questionnaires were distributed to 80 respondents and 80 samples of waste were collected from the various households. Data was analyzed using SPSS software. The study revealed high dependence on private waste collection service providers instead of the usual communal collection systems. About 10% of the respondents practiced waste sorting in the study areas. The rate of solid waste generation was 22.07 kg/day whiles the per capita rate of solid waste generation was 0.33 kg/person/day. The waste was sorted into six fractions of which the highest component was organic, 41.5% by weight. Regression analysis showed a significant positive relationship between generation rate of solid waste and the household size. The results indicate that household size could be an important tool to predict the generation rate of solid waste in the study area, in addition to other social and economic parameters. Based on the findings, there should be regular supervision and monitoring of waste collection by the sanitation institutions to prevent any possible outbreak of diseases such as cholera.

Keywords: Municipal solid waste, Waste sorting, Generation rate, Household waste, regression analysis

Introduction

Municipal solid waste (MSW) management is one of the most important environmental issues faced by modern society. In recent years' research has shown that there is a high proportion of organic material in MSW. When MSW containing organic components is land filled, anaerobic bacteria degrade the organic materials producing CH_4 and CO_2. (Vigirl, 2011). Knowing the composition of municipal solid waste is an essential part of the introduction of separate waste collection in municipalities (Končalová & Dubcová, 2011). Composition analysis of waste is where waste samples were sorted either by households or the researcher into various fractions and analyzed by their weight as well as the percentage composition as described by Pichtel (2005) and America Society for Testing and Materials (ASTM D5231-92) (2008). Based on the results of the analysis it will be possible to determine the number of collection containers for each village and also the most appropriate frequency of collection of waste into the recycling centers. (Končalová & Dubcová, 2011). Sorting and recycling of waste have numerous benefits and it is also environmentally friendly compared to the other methods of waste disposal according to the United Nations Environmental Program (UNEP, 2013). With the increasing cost of raw materials, recycling provides a cheaper source of raw materials for manufacturing industries (Henry, 2005). By using recycling, we can reduce extraction or exploitation of raw materials,

fuels and energy as well as reduce the environmental impact arising due to storage on the waste yard (Končalová & Dubcová 2010).

An increasing eminence of life and high rate of resource consumption patterns have had unplanned and undesirable impact on the environment. Cities, towns and communities are grappling with the problem of high volumes and sizes of waste (UNEP-IETC, 2003). There are many issues that surround the way and manner in which various communities, towns and cities in the country handle the various kinds of waste they generate in their household and commercial places, (UNEP, 2005). According to Diaz *et al*. (2006), inappropriate management of waste can attract rodents and insects, which can harbor gastrointestinal parasites, yellow fever and worms. Inappropriate management of waste constitutes a plague to various human conditions, and exposure to hazardous wastes particularly when they are burned, can cause various other diseases including cancers (Diaz *et al.*, 2006). Toxic waste material can contaminate surface water, groundwater, soil and air which cause more problems for humans, other species and ecosystems, (Diaz *et al.*, 2006). In Africa, Municipal Solid Waste Management constitutes one of the most crucial health and environmental problems facing governments of African cities (Achankeng, 2003). This is because, even though these cities are using 20-50% of their budget in solid waste management, only 20-80% of the waste is collected. The uncollected or illegally dumped wastes constitute a disaster for human health and environmental degradation (Achankeng, 2003). The amounts of waste generated also vary within countries, according to the income group from which it originates. The high and middle income groups in many countries have adopted Westernized consumption patterns. The richer the citizens, the more waste is generated, as the case of Accra-Ghana, high income groups generate 0.6kg/capita/day, middle income groups, 0.4 kg/capita/day and low-income groups 0.3 kg/capita/day (Lardinois & Klundert, 1995).

However, solid waste generation rate and disposal has become a major problem in the Tamale Metropolitan Area. Currently, there is indiscriminate dumping of waste, irregular collection of waste generated and inadequate resources for the management of solid waste in the Metropolis (Puopiel, 2010). It was estimated that the metropolis generates 810 tonnes of waste per day and out of this huge tonnage, only 216 tonnes are hauled daily but a backlog of 594 tonnes remain uncollected (Puopiel, 2010). The choked gutters or drains in our communities, overflowing garbage heaps and litter in every corner of the city are as a result of the tonnes of leftover and uncollected waste coupled with weak local government structures and human factors. The inability of authorities to collect the amount of waste generated has made living conditions unbearable and unfavorable for the city dwellers. The poorer areas in the city are the least likely to access safe disposal and collection of their household solid waste (Palczynski, 2002), hence greatly affected by its insidious social and health impact (Oteng-Ababio, 2011). As such with progress in industrialization and population explosion, Solid Waste has been classified a dangerous status of being "third pollution" that is land or soil pollution after air pollution and water pollution, (World Employment and Social Outlook (WESO, 2013). On the global scale it is difficult to give adequate report of waste generation because countries have different definition of waste and what falls into waste categories. The Basal convention estimated that 338 million tonnes of waste were generated in the year 2001(USEPA, 2003). For the same year (that is 2001), the Organization for Economic Co-Operation and Development (OECD, 2006), also estimated that 4 billion tonnes of waste were generated from its member countries. Despite these inconsistencies in solid waste estimation, waste reporting is still useful on a small and large scale to determine key causes and locations and to find ways of preventing, minimizing, recovering, treating and disposing waste.

Moreover, an accurate knowledge of the quantity and composition of solid waste generated is essential to the success of resource recovery and also knowledge of several other properties of solid waste are also required for proper planning, designing and operation of waste management programs (UNEP, 2005). And with the emergence of private sector participation in the management of the solid waste there is therefore the need to identify the major categories of solid waste

generated in the Vittin Target area and ways to handle such categories. Information of such nature will help to improve the waste management situation in the area. The study highlighted solid waste management practice in the Vittin Target area and provide information that will benefit government and private sector participation in the solid waste industry. The study will also serve as a guide for future research into private sector contribution to solid waste management in the country.

The main objective of the study sought to assess how solid waste is managed in the Vittin Target area. Based on the effective examination, the study further seeks to look into compositional analysis of households' solid waste for an improved waste collection service.

The study seeks to address the following specific objectives;

- To assess the management practices used in the management of solid waste at Vittin Target.
- To determine the types and components of solid waste generated in the community.
- To estimate the quantity of solid waste generated at the Vittin Target community.
- To determine the rate of solid waste generation.

Materials and Methods

Study Area

The study was carried out at Vittin Target in the Tamale Metropolitan Assembly of Northern Region, located at the South Eastern part of Tamale on geographical coordinates of 9º22'12"N and 0º48'33"W. The population of Vittin Target, according to the 2010 population and housing census, is 1,241, with males contributing to 49.7% whilst females constitutes 50.3% with 331 households.

Sampling Procedure and Data Collection

Sample size (S) considered for the study was estimated using the formula $S= \frac{N}{1+N(\alpha)^2}$ Where S= sample size, N= sample frame and α= margin of error (assumed to be 10% with confidence level of 90%). The estimated number of sampled households was 80. Qualitative and quantitative data were used for this study. The qualitative data was obtained mainly from the community through a designed semi-structured questionnaire, by employing a convenient sampling technique while the quantitative data, stratified random and systematic random sampling techniques were used in data collection.

Household Questionnaire Survey

Questionnaires were administered to households to investigate the current waste management practices in the community. The number of persons in each household was also noted from the survey. This aspect of the study was to inquire information on storage site of household solid waste, mode of waste collection and their understanding of source separation of solid waste; hence the questionnaire sought to find out the willingness of households to separate solid waste and their motivation to do so.

Solid Waste Characterization and Measurement

In the determination of the composition of solid waste by weight/day, selected households were given polyethylene bags with numbers tagged for easy identification to keep the waste generated on daily basis. The polyethylene bags were collected daily (evenings) and gathered at a point where they were emptied for segregation and measurement. Wastes obtained were sorted into different classes to identify the components of waste generated and the different components of waste were weighed separately using a spring balanced and top pan weighing scale to determine their quantities.

The percentage composition of each of the components was calculated by the formula:

$$\frac{Weight\ of\ separated\ waste}{Total\ of\ mixed\ waste\ sampled} \times 100 \ldots\ldots\ldots (1)$$

The per capita rate of waste generation (PCWG) was also determined using the formula:

$$\frac{\text{Weight of MSW generated}}{\text{Total number of persons in the household} \times \text{Observation period}} \ldots\ldots (2)$$

Data Analysis and Presentation

Microsoft Excel and descriptive statistics of Statistical Package for Social Science (SPSS V.23) were used to process data into tables and charts for interpretation and discussion. Simple percentages were used to analyze both the quantitative data and qualitative data

obtained from household sampling and questionnaire administration. Regression analyses was conducted to determine the inter-relationship between measured variables (waste generation rate and household size)

Results and Discussion

Demographic Characteristics of Respondents

Data on the demographic characteristics of respondents with reference to their age, gender and educational status were collected for this study. This data was collected to establish the relationship between variables. The study showed that out of 80 respondents interviewed, about 59% were females and 41% were males. This indicated that females were more involved in waste disposal than their male counterparts. Most of the respondents have some form of formal education, since over 85% of the respondents had received formal education from primary through to tertiary. This simply means that many of the respondents were literate and were able to demonstrate adequate knowledge of what waste is and its effects on human lives. The analysis of educational status of the respondents is of importance for some reasons. First, knowledge of the educational level is vital in supporting service providers in developing strategies or programs to enhance environmental education. Also the level of education relates to attitudes towards solid waste service programs (Azubike *et al*, 2016).

Major Waste Components

The study identified six main components of household solid waste generated at Vittin Target (Fig.1). Biodegradable organic materials represented the single largest component of the waste stream representing 44.5% by weight followed by others (ash, silt and sand) at 27.6%; Non-biodegradable organic material (plastics, 15.8%; metal 7.4%; glass, 4.7 %). However, the organic content, despite being the largest single component waste, at 44.5% is low in terms of volume compared to the plastic content at 15.8%.

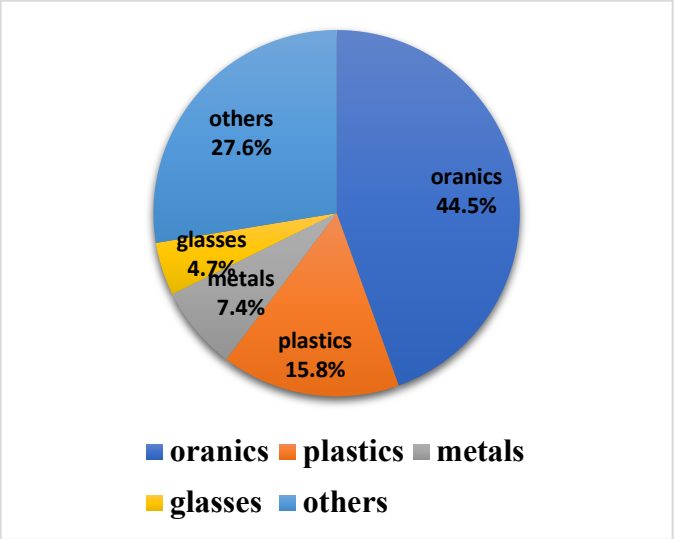


Figure 1: Components of Household Solid Waste

The high percentage of bio-degradable organics in the study area implies that, the people depend mostly on organic foods and this could be as a result of the peri-urban nature of the areas. The high putrescible waste being generated in the study area require prompt conveyance of waste containers to avoid the incidence of flies and stench from rotting of waste which could impact negatively on the environment (Waldron *et al.*, 2004 cited by Otoo, 2013).

The waste composition for items such as metal and glass at 7.4% and 4.7% respectively are similar to UNEP's International Environmental Technology Centre (IETC) (2009) average figures from Accra, Ibadan, Dakar, Abidjan and Lusaka. Also, the organic content representing 43.5% of the overall waste stream falls within the UNEP/IETC's range of 35-80%. The composition of plastic waste is an important issue in the management of waste. `This is because the types of plastic waste generated affect the technique in its disposal and is necessary for deciding on reuse, reduction and ultimately recycling of waste (Otoo, 2013).

However, the plastic waste generated (15.8%) at Vittin Target is higher than the 11.01% and 10.71% for the low and middle income levels respectively as recorded by Peprah (2013). There is a consistent rise in plastic waste since 1993 when an average of 4% was recorded

by Schweizer & Annoh (1996) up to the year 2000 when Fobil (2000) recorded an average plastic composition of 8% largely due to the increased use of plastic packaging materials. Plastics do not decompose and compact easily which is why it significantly affects transportation cost and landfill operations (Peprah, 2013*)*. Metal and glass waste were both recorded at 7.4% and 4.7% respectively and these are higher than metal at 4.65% and glass at 2.57% recorded by Peprah (2013). The differences in the various compositions of waste generated might be attributed to the differences in the living standards of residents, their lifestyle and economic scale of consumption.

Sustainable amount of waste components that could be termed recyclable waste (i.e. glass, metals, and plastics) were also identified. The quantity of recyclable materials in the study area present an opportunity for recycling ventures in the area by investors and the Metropolitan Assembly. Recycling of the waste can also reduce the amount of waste that has to be transported to the disposal sites. It may also encourage waste sorting among residents if the waste is bought as raw materials. This could also improve the economic standings of households in the study area (Otoo, 2013).

Solid Waste Generation Rate

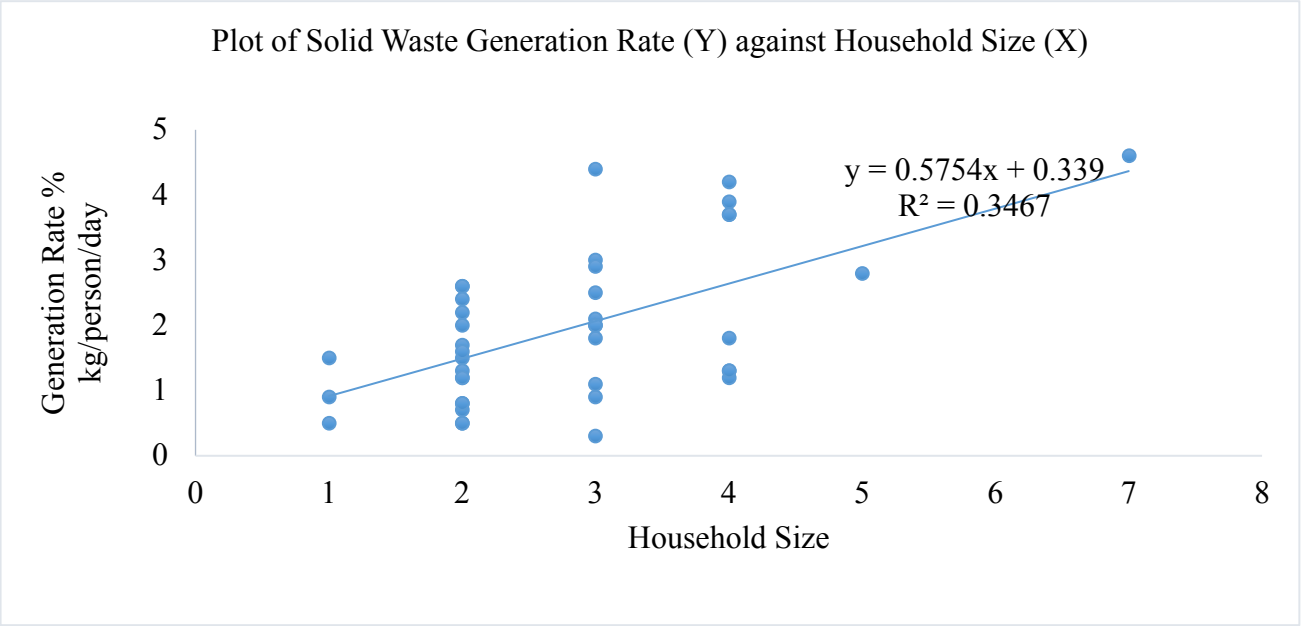
The rate of generating solid waste was 22.07 kg/day and the per capita rate of solid waste generation was 0.33 kg/per capita/day in the community. This is similar to the rate of waste generation in Tamale Metropolitan area (0.34 kg/person/day) but lower than the rate of waste generation in the Kumasi Metropolitan area (0.75 kg/person/day) and that of the capital city Accra (0.74 kg/person/day) as recorded by Miezah *et al* (2015). The differences in the waste generation rate could be attributed to the lifestyle and the economic activities in the area. The figure recorded in this study also falls below the comparison of waste generated in developing countries, which ranges from 0.4–0.6 kg/person/day (Chandrappa & Das, 2012). However, waste generation rate across Ghana irrespective of the economic considerations ranged from 0.2 to 0.8 kg/person/day. This is also the range for most of the cities in Sub-Saharan Africa (Friedrich & Trois, 2011; UNEP, 2013).

Relationship between Generation Rate versus Household Size

The study showed a weak but positive linear relation between household solid waste generation rate per capita and the household size which presumes that the rate of generation per capita increases with increasing household size (fig.2). This may be attributed to the fact that people with high household sizes were more prone to bagging their waste anyhow and disposing it anywhere. Also, the household size was positively correlated with the amount of waste generation (R^2= 0.3467). This is confirmed by a previous study which recorded that household per capita waste generation rate is influenced by the number of residents per household (Pfeffer, 1992), although studies conducted in the USA to evaluate domestic waste generation rates indicated a fall in per capita values from 1.25kg/day for two residents to 0.4 kg/day for ten residents (Pfeffer, 1992). This might be attributed to a shift in their consumption patterns and also there might be a positive change in attitude towards waste management due to their educational level.

The increase in waste generation is therefore not always proportional to the increase in household size. The relationship, according to Pfeffer (1992) and UNESCO (1996) showed that the rate of reduction was most rapid between two and five residents, after which the rate decreased and was virtually independent of household size when the number exceeded ten. This is in agreement with the findings of this study that find a positive correlation between household size and amount of waste generated. Also, the finding of this study is in agreement with that of Sankoh *et al.* (2012) who found that amount of waste generated positively correlated with family sizes in Freetown, Sierra Leone. However, this study is in disagreement with Abu-qdais *et al.* (1997), as cited by Mbeng *et al.* (2012), who recorded decreasing household generation rates per capita with increasing household size as a result of economies of scale in the consumption of goods and packaging in low income countries.

Figure 2: Scatter Diagram of Solid Waste Generation Rate against Household Size



Predictive Model for Household Per Capita Generation Rate

Data from the summary output in Appendix 3 was used to explain the model developed to predict the per capita generation rate taking the household size as the independent variable. From the model (y = 0.5754x + 0.339), R^2 is a measure of the extent to which the total variation of the dependent variable is explained by the regression (Sykes, 1992). The regression gives an R square value is 0.3467 (fig.2), which means the estimation model explained about 35% of the entire regression. This number tells how good or bad the model is. The R square value ranges from 0 to 1, with 0 being a terrible model and 1 being perfect model. The model gave a P value of 0.000528 which is less than 0.05 significant levels, working with an alpha value of 95% confidence interval.

Past studies showed that a model was too poor to make a prediction if the R square value is less than 35% of the entire regression (Mendenhall 1990 as cited in Thanh *et al.* 2010). The predictive model chosen explained 35% of the entire regression hence considered statistically good enough to make a prediction for the rate of generation per capita per day using the household size as the independent variable.

The predictive model for household solid waste generation rate is written as:

Y = 0.5754X + 0.339……. Equation 5.1

Where Y = the dependent variable (generation rate per capita). X = the independent variable (household size)

Therefore, a way of estimating the per capita waste generation rate is to take the slope of the regression between the household size and waste generation rate into account. In this regression, the intercept is fixed at zero (y = ax + b, b=0, assuming that if the household size is zero, waste generation must be zero). This gives a predicted value of 0.529 (Fig.3).

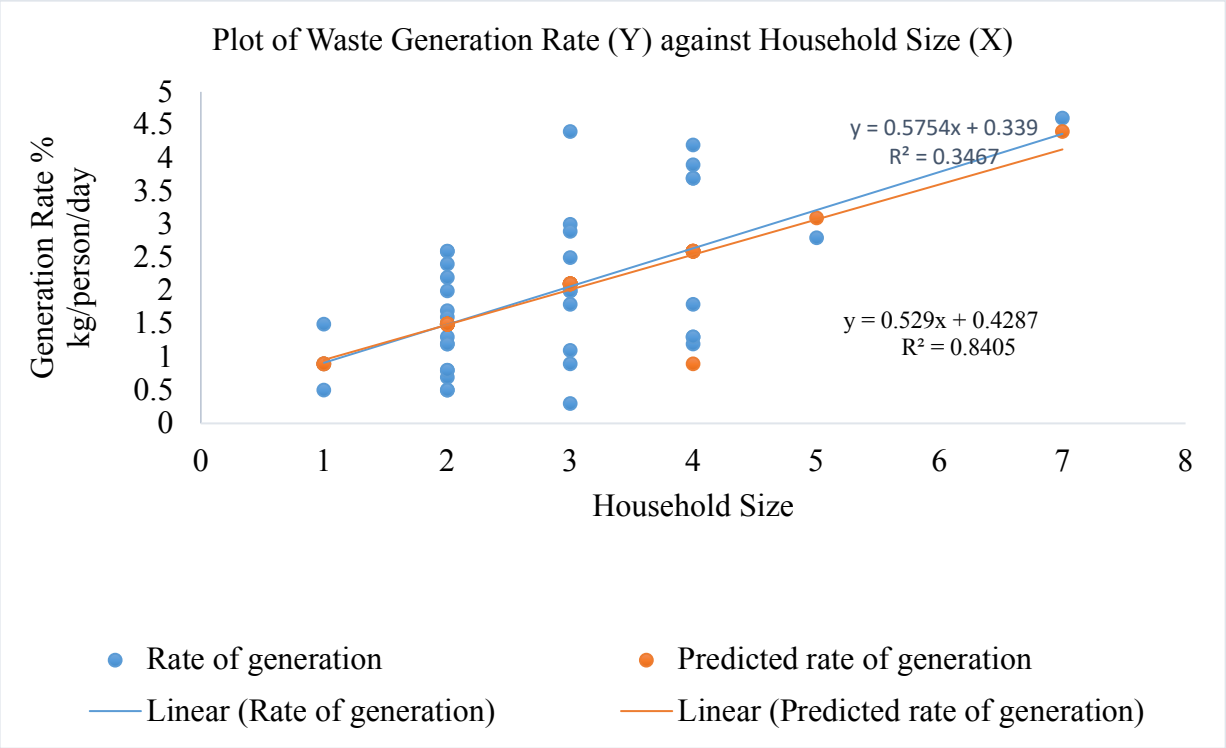


Figure 3: Predicated Model for Waste Generation Rate

Respondents Knowledge about Waste Recycle Possibilities and Their Educational Levels

Table 1: *Relationship between Knowledge of Recycling Possibilities and Educational Status of Respondents*

Knowledge of recycle possibilities	Educational status of respondents					Total
	Primary	JHS	SHS	Tertiary	None	
Yes	0	0	7(25.9%)	18(66.7%)	2(7.4%)	27(33.8%)
No	2(3.89%)	7(13.2%)	17(32.1%)	19(35.8%)	8(15.1%)	53(66.2%)
Total	2(2.5%)	7(8.8%)	24(30.3%)	37(46.3%)	10(12.5%)	80(100%)

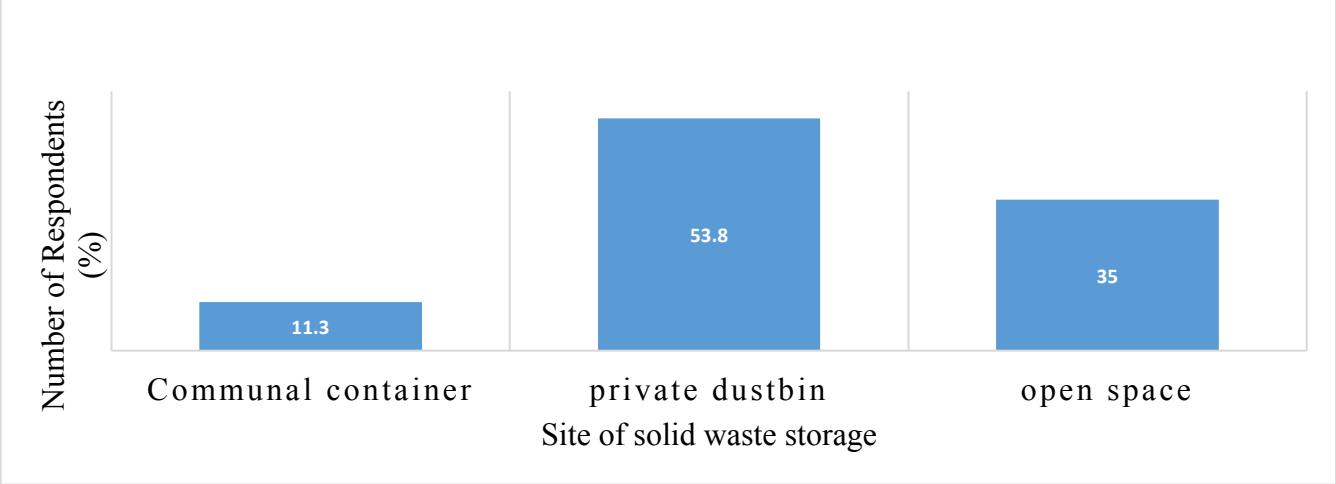
The study assessed the knowledge level of respondents on recycle possibilities. From table 1, 66% of the respondents indicated that they have no knowledge of recycling possibilities as revealed by this study. Out of these respondents, 17% had basic education, 32% attained secondary education, 36% had tertiary education and 15% did not have any formal education. However, 34% of respondents had some form of knowledge about recycling possibilities.

This implies that despite environmental and economic benefits of recycling activities, there is low rate of recycling because there are no organized and effective recycling programmes in operation and the informal sector remains largely the active source of recycling in Ghana. This confirms the fact that only 2% of the solid waste generated in Accra, the capital of Ghana is recycled in a recycling facility (Global Project - Accra as cited by Thompson, 2010).

Place of Storage of Household Solid Waste

The study (Fig.4) indicated that, the commonest place of solid waste storage is private dustbins representing about 54% of the respondents. This could be influenced by the living standards and life style of these categories of respondents. Quite a high number of the respondents (35%) resorted to dumping of waste in open spaces.

Figure 4: Place of Solid Waste Storage



Mostly this practice happened in the low class residential areas of society. The rate (35%) of open space waste dumping in this study area could also be attributed to the high cost of monthly charges for the collection of waste, long distance between public skip and households as well as irregular collection of waste by management institutions. This could lead to littering and heaping of waste thus making the environment unsightly. It is worth noting that those who made use of the communal container were the minority representing 11%.

Mode of Waste Collection

The study revealed that the main mode of waste collection service in Vittin Target area included communal dumpsite (skip container) and door to door collection while others indicated burning of waste as a means of waste disposal. From the survey, 51.3% of the respondents indicated that their waste was collected directly from their house, that is, door to door. The high rate of door to door collection of waste is attributed to the fact that the area is considered a high class residential area. The beneficiaries of door to door mode of waste collection paid a monthly charge ranging from a minimum of GH₵15 to GH₵50 depending on the size of the waste container and the waste collection agents involved.

However, the rate at which waste was burned as a means of solid waste disposal in the community is high. Field data by Fiafor (2010), in his study 'Effects of waste management on local governments revenue: a

case of Assin North Municipal Assembly' revealed that 5.8% of the people of Assin North burned solid waste resulting in effects on public health through release of toxins. Adepoju & Salimonu (2010) also indicate that 37.5% of respondents in Osun State, Nigeria burned their waste. The rate (36.2%) of waste burning in this study area could be attributed to the high cost of monthly charges for the collection of waste, long distance between public skip containers and households as well as irregular collection of waste by management institutions. Also 13 % indicated their wastes are collected by the use of the Skip container system.

Frequency of Waste Collection

The study revealed that about 46% of respondents indicated that waste was collected once a week whilst 21% of the respondents revealed that waste was collected twice a week. Also 5% of the respondents indicated that waste was collected thrice a week and in some instances throughout the week as indicated by 4% of the respondents. The study also reveals that, about 24% of the respondents do not know if the waste is collected or not. The collection of waste once a week could be attributed to the fact that the study area is large and waste management institutions in the area have limited resources to carry out daily collection of waste. This could perhaps lead to heaping of waste at the dumpsite. And due to the high content of degradable organic, these waste decomposed posing problems of odor and other related health issues like cholera, diarrhea and also serving as breeding places for disease causing organisms like mosquitoes to the households. The result from this study has further validated evidence that the quality of solid waste services in a particular area is influenced by both the specific conditions that prevail in the area and the socio-economic status of the community receiving the services (UNESCO, 1996).

Respondents level of satisfaction with current SWM

Table 2, illustrated the level of satisfaction by respondents with respect to waste management services in the study area. The study showed that 13% and 41% of the respondents were very satisfied and satisfied respectively with current solid waste management situation in the community. This high level of satisfaction indicates that these category of residents appreciate the strategies of the waste collection services and sanitation situation in the area. However, 32.5% and 18.8% of the respondents were dissatisfied and very dissatisfied respectively with the way waste is managed in the community. This could be attributed to reasons such as irregularities of waste collection, high cost related to waste collection and long distance they have to cover in order to dispose of their waste using the public skip system.

Table 2: Level Satisfaction with Waste Management Service in the Community

Level of satisfaction	Frequency	Percentage
Very satisfied	10	12.5
Satisfied	33	41.3
Dissatisfied	22	27.5
Very dissatisfied	15	18.7
Total	**80**	**100**

Conclusions

The current study observed high levels of organic waste generated in the Vittin Target Area. The per capita rate of solid waste generation in the study area was 0.33 kg/capita/day while the rate of solid waste generation was 22.07 kg/day. The linear regression analysis revealed a weak but positive relationship between household size and solid waste generation rate. Majority of residents in the study area did not consider waste as a useful resource and therefore did not practice waste sorting before disposal. High percentage of respondents in the study area depended on the private dustbins of waste storage while quite a higher number of the respondents practiced open dump system of waste disposal. On the payment for waste collection, majority of the residents paid a monthly charge ranging from a minimum of GHC15 to GHC50 depending on the size of the container for the door-to-door waste collection service. The study highlighted that households were not completely satisfied with current solid waste management in the community and this is supported by 46.2% of the respondents that

expressed their levels of dissatisfaction with respect to the waste management situation.

Based on the findings of the study, the following are recommended for efficient and effective management of solid waste in the study area.

More dustbins should be provided by Waste Management Institutions for residents in the area for waste storage. This should be provided particularly for households without bins in the areas to avoid dumping of waste in the open space.

Households should also be encouraged to sort their generated waste into various components to enable management institutions recover resources and also reduce the cost involved in transporting waste to the landfill.

Residents should be taught how to make compost out of biodegradable organic waste to fertilize their backyard gardens so as to reduce the use of chemicals fertilizers and to reduce the quantity of waste they dispose of.

Again, relatively young men and women who are unemployed and have no educational qualification in the area should adopt the waste pre-collection system, where they will be tasked by the small organizations and micro enterprises to collect the waste and dump in collection containers for final disposal and this will serve as a source of employment.

There should be regular waste collection by institutions involved to avoid heaping of waste and over flowing of waste containers with solid waste. At least, waste should be collected three times in the area.

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