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HOUSEHOLD SOLID WASTE GENERATION RATE AND PHYSICAL COMPOSITION ANALYSIS: CASE OF SEKONDI-TAKORADI METROPOLIS IN THE WESTERN REGION, GHANA

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Abstract

Sekondi-Takoradi Metropolis, one of the rapidly expanding cities of Ghana has been facing serious problems with solid waste management. This is mainly due to the lack of available information about the types and quantity of solid waste generation in the area. Hence, the objective of this study was to determine the rate of household solid waste generation and its composition in the aforesaid city. The methodology and procedures for this study were derived from the Standard Test Method for Determination of the Composition of Unprocessed MSW (ASTM D 5231-92). All samples were hand sorted into 6 waste categories (paper, plastic, organics, metals, glass, and other waste). The study revealed that by weight, organic wastes constitutes the largest proportion of household solid waste (38%) followed by 19% plastics, 7% papers, 4% metals, 4% glass and 28% other wastes (comprising of sand, stones, ash, inert substances). The rate of daily waste generation per capita in the low, middle and high income households were 0.27±0.19, 0.4±0.19 and 0.58±0.24 kg/cap/day, respectively. The study revealed that there is no waste treatment or recovery facility established within the metropolis hence no significant waste recovery and reuse activities exist. The study showed that more than 38 % of the waste generated in Sekondi-Takoradi Metropolis is decomposable organic matter that can be re-used through composting as well as 34% of the waste having recycling potential thereby considerably mitigating the solid waste problem.

Keywords: Municipal solid waste, waste composition, generation, household, recovery

Introduction

Solid waste management (SWM) is one of the most important services provided by municipal authorities' the world over. The ways of handling, collection and disposal of the waste can pose risks to the environment as well as the public health (EGSSA, 2009). The scope and complexity of SWM is expanding and consumes a considerable proportion of the city's budgets. The SWM sector, therefore, deserves careful attention for striking a balance between quality of service and cost effectiveness. In most urban communities, huge volumes of solid wastes are generated every day that need regular collection, transportation and disposal. These operations have to be carried out quickly and efficiently without incurring excessive cost or damage to the environment. Unfortunately in many developing countries, the system for managing wastes is rudimentary and cannot cope with the volumes of wastes generated (Fei-Baffoe, 2010). Success of any municipal solid waste management system relies on precise data about the quantity and types of material being generated as waste. Waste composition studies are essential to any proper waste management strategy for a variety of reasons, including a need to estimate potential materials recovery, to identify sources of component generation, to facilitate design of processing equipment, to estimate physical, chemical, and thermal properties of the wastes, and to maintain compliance with regulations (Gidarakos et al., 2005; Kreith, 1994).

As in all developing countries, increased solid waste generation and related problems in Ghana are due to rapid urbanization and population increase. Sekondi-Takoradi, a rapidly growing city in Ghana is riddled with mounting solid waste management problems. Due to population growth and increases in living standards as a result of its status as the capital city of an oil producing region in Ghana, the types and the quantity of solid waste dramatically increased thereby disabling the SWM system of the city. The severity of the problem is visible through unsightly heaps of wastes along streets, drains, ditches, canals and open spaces of the city (Babanawo, 2006). Lack of any scientific study on the solid waste issue has left the Sekondi-Takoradi municipality with no proper strategy for mitigating the problem. This study hence was focused on determining the types and quantity of household solid waste generated in the city, so as to provide viable information to improve the management of solid waste within the metropolis.

Materials and methods

Description of the Study area

Sekondi-Takoradi metropolitan area is located between Latitude 4° 52' 30'' N and 5° 04' 00'' N and Longitudes 1° 37' 00'' W and 1° 52' 30''W. Bounded to the north of the metropolis is the Mpohor Wassa District, the south by the Gulf of Guinea, the West by the Ahanta West District and the East by Shama District. The metropolis happens to be the smallest district in the region with a land area of 385 Km^2. However, it is the most populated district with a population of 559,548 (GSS, 2010). The metropolis is strategically located in the south-western part of the country, about 242 Km to the west of Accra, the capital city, and approximately 280 Km from the La Côte d'Ivoire in the west. Figure 1 is a map of the study area and figure 2 is the poverty map of the study area showing the various income zones.

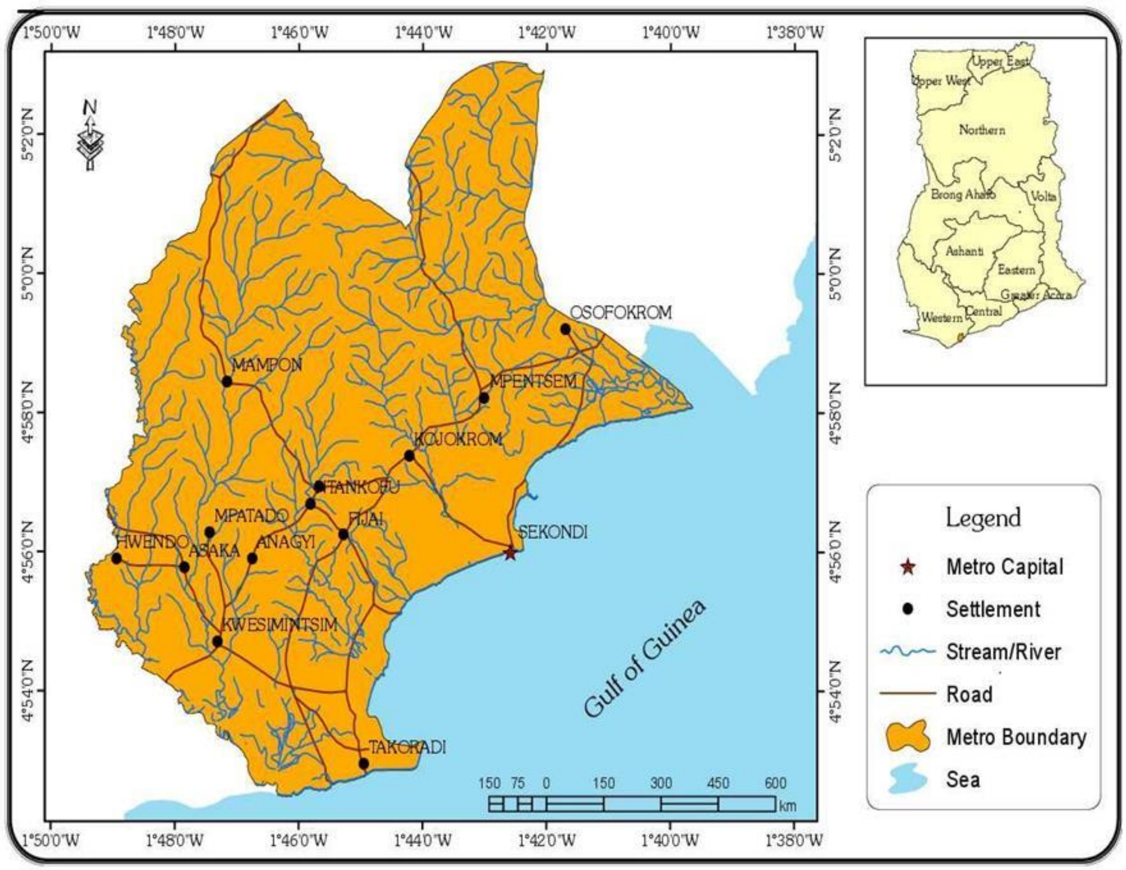

Figure 1: Projected map of Sekondi-Takoradi Metropolis in Western Region of Ghana

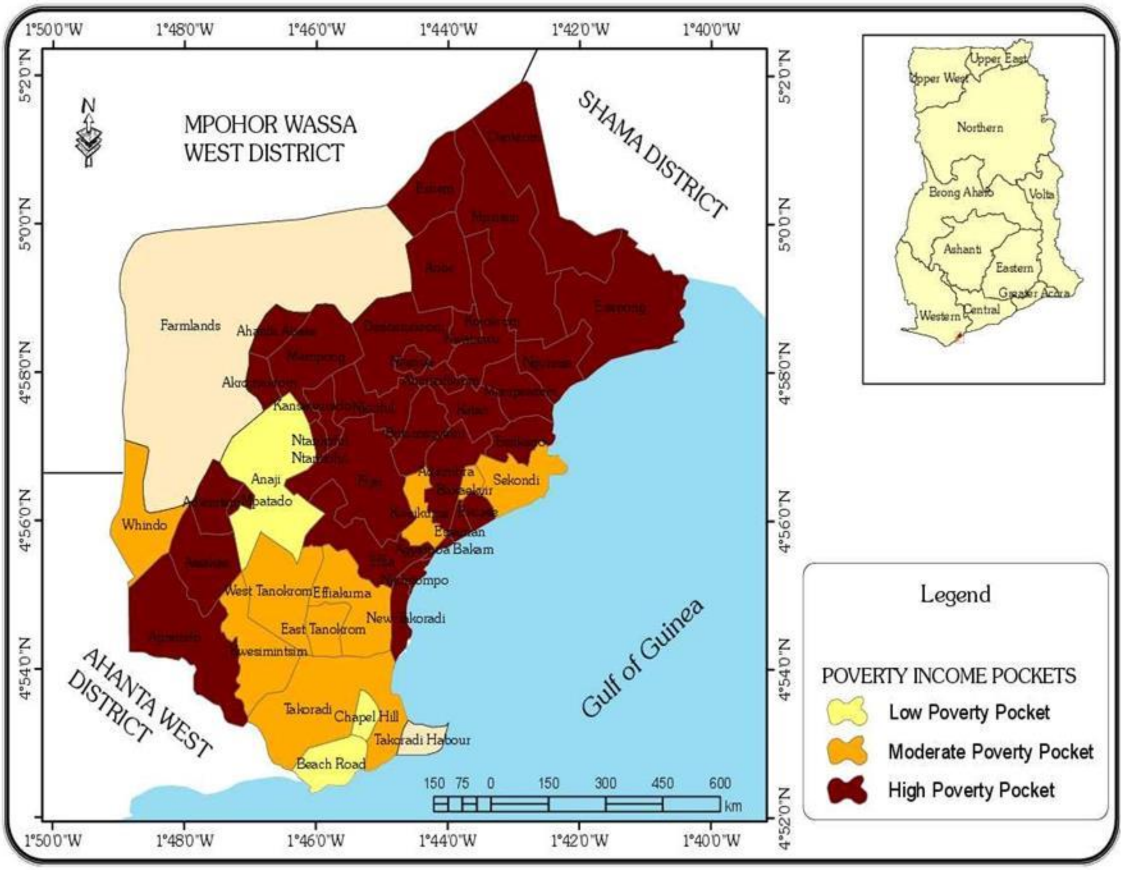

Figure 2: Poverty Map of Sekondi-Takoradi Metropolis in Western Region of Ghana

The metropolis has an equatorial climate. Woodlands are found in the northern and central parts, while thickets intermingled with tall grass species are located along the coast, especially in areas where there are no permanent crops. It has fairly uniform temperature, ranging between 22^{o}C in August and 30^{o}C in March. The metropolis has a mean annual rainfall of 2,350 mm (STMA, 2012).

Waste management practices in Sekondi-Takoradi Metropolis.

Decisions on organization of waste management arrangements within the metropolis are vested in the Waste Department of the Assembly who organizes waste collection for a three tier system (high income, middle income and low income zone) on a contract and franchise basis (Fei-Baffoe et al., 2014). The two main methods of solid waste collection within the metropolis are the door to door collection and the communal waste container system. The door to door collection which is usually done on franchise basis is carried out by private waste collection firms in high and in some middle class income areas at a fixed cost.

Communities that do not enjoy this service and who are usually from the deprived or low class income areas patronize the communal container system.

Operations of both public and private waste management institutions cover 72% of the metropolis leaving 28% unattended to. The private waste collection firms take a greater chunk of percentage with respect to waste collection within the metropolis whilst that of the assembly takes only 23% out of which most are evacuation activities. Within the coverage areas where solid waste collection is done, current statistics show that 69% of solid waste is collected and disposed of leaving 31% of the waste uncollected (Fei-Baffoe et al., 2014).

There is no waste treatment or recovery facility established within the metropolis hence no significant waste recovery and reuse activities exist. The only form of recovery and reuse activities is by scavengers who search through waste in temporary storage areas and at final waste disposal site for items considered to be of economic value. These scavengers mostly use their bare hands and at times sticks for separation and picking of the items which are dictated mostly by type, market value and demand.

Pre sampling and sorting site assessment

Prior to initiating the actual sampling and sorting events, it was critical to conduct site assessments at each of the solid waste and residential facilities across the socio-economic zones. The purpose of the site assessments was to promote support and cooperation from residents and staff of the Waste Management Department of the Sekondi-Takoradi Metropolitan Assembly for the sorting/sampling events and to initiate the gathering of data to develop the sampling and sorting plan for each category.

Identification of households

Based on their life standards, income levels, housing structure and presence of basic social amenities, communities within the area of study were categorized into low income, middle and high income groups (CHF, 2011) (Figure 2). Households which were categorized under low income (the poor) were those who are living in slum areas. A simple random sampling technique was used to select one community from each residential class grouping within the metropolis for the study. With respect to the generation rate and composition study, 20 households were selected randomly from each residential class grouping: Ngyiresia, Sekondi and Chapel Hill representing low income, middle income and high class income zones respectively. Twenty (20) households were selected for the study in each income group mainly because it is the appropriate number to use in achieving the minimum sample size of 100 – 200 kg needed for the characterization studies as stipulated by EPA (1996). The household unit selection for the study was based on the willingness of that particular household to take part in the research. The daily solid waste generation rate (DSWGR) of the town as well as per capita per day solid waste generation rate (PCPDSWGR) at household level of the socio-economic areas was calculated according to equation 1(Fobil, 2000).

Per Capita Waste Generation = $\frac{Total\ solid\ waste\ within\ 7\ days}{7\ days\ x\ total\ family\ size\ of\ 60\ households}$…….Eq. 1

Household solid waste sample collection and sorting

Considering variations between days in waste composition and generation rate, a week round (7 day) sampling was conducted for each socio-economic zone (King and Murphy, 1996). Trash bags given out to the various households within a particular socio-economic stratified community in the study area were inscribed with a special code. Quantification of waste was done at the point source of waste generation with a spring balance (weighing scale) before collection. Afterwards a simple random sampling technique was employed to obtain a representative sample of 10 trash bags from each socio-economic zone from the many trash bags supplied to the various households for the manual sorting process. The waste sorting was done on a 10 mm thick plastic sheet. The ideal sample size used for characterization study was between 100 and 200 kg (minimum 100 kg) (EPA, 1996). The figure below shows the point source waste weighing process.

Figure 3: Point source waste quantification

In determining the composition of the waste to be disposed of, representative samples were taken and sorted into predefined material categories as depicted in Table 1 below.

Table 1: Descriptions of Waste Component Categories

Category	Description
Organic	Yard waste (Branches, twigs, leaves, grass pruning and trimmings, and other plant material), food waste
Plastic	Bottles, expanded polystyrene, film plastic, other rigid plastics
Paper	Office paper, computer paper, magazines, glossy paper, waxed paper, newsprint, cardboard, old/torn books.
Metal	Ferrous (Iron, steel, tin cans,), aluminum, and non-ferrous non-aluminum metals (copper, brass, etc.)
Glass	Bottles, drinking glass, jars, mirrors, louvers, auto windscreens, computer monitor screens etc
Other waste	Rock, sand, dirt, ceramics, ash, leather, textile and other primarily materials not included in the above component categories

Source: surreywaste.info, online

The material categories used included organic, paper, plastics, glass, metal and other miscellaneous waste. In this vein, the percentage composition of each residential waste component generated from households with respect to the socio-economic strata was determined by dividing the total amount of a particular solid waste component type collected over a week with the total amount of solid waste of all components within 7 days multiplied by 100. Figure 4 below shows the process of sorting and weighing of waste fractions at the municipal dumpsite.

Figure 4: Sorting and weighing of waste fraction

Statistical Data Processing and Analysis

Quantitative data obtained from sample residential houses through direct measurement (solid waste generated) were analyzed using charts, averages, ratios and percentages as a major summarizing tool with the aid of Statistical Package for Social Science (SPSS 16.0). The average waste generated by the different households was calculated for low, medium and high-income levels with comparative analysis of average waste generation rate done with respect to the socio-economic levels.

Results and Discussion

Waste composition across the various income groups

The increase of solid waste quantity is directly proportional to the waste generation and the increase of population as per the study report. The generation of solid wastes, which result from human activities, varies in different types of dwelling, as well as in different socio-economic groups. The type produced depends upon various factors, such as the standard of living, occupation and habits of the contributing population, which in turn are affected by climatic and dietary habits. However it has been shown that these are not the only governing factors. Among others, socio-economic factors that have been said to influence solid waste generation are person per dwelling, cultural patterns, education and personal attitudes (Al-momani, 1994).

Table: 2: Physical composition of household waste in Sekondi-Takoradi Metropolis

Component % by Weight	High Class zone	Middle Class Zone	Low class zone
Organic	39	60	18
Paper	10	7	3
Glass	8	2	3
Plastic	24	20	15
Metal	6	4	3
Other items	13	7	58
Total	100	100	100

Comparison of aggregate waste composition in the various income zones

It was observed that solid waste composition varied from one income area to another depending upon activities being operated in that particular area. It was further noticed that solid waste generation is directly correlated with levels of economic development and activity. Hence high income areas produced large quantity of waste in comparison to low income areas (Medina, 1997). This is explained by the relatively high food consumption trends of higher income groups and the increased purchases of packaged products and reading material. Metals and glass recorded low percentages across the socio-economic zones. This is because metals and glass are reused at the household level and sold to informal recycling sources (Carboo and Fobil, 2004).

A high amount of inert substances such as stones and sand were recorded in the low income area. This was attributable to the prevalence of buildings which lack tiled or cemented floors. Hence all the sweepings from their compounds contain a large proportion of inert substances which increases the weight and volume of waste and the cost of haulage. The increase in the use of plastics for shopping and packaging of treated water for sale in the metropolis have increased the volume of plastics in the waste stream from 8.5% according to waste management data of the Sekondi-Takoradi metropolis in 2007 (Fei-Baffoe et al., 2014). This was observed across the socio-economic class zones. However this packaging revolution has not been correspondingly backed by appropriate plastic waste management policy, which has left many cities in Ghana littered with plastic waste (Fobil, 2000). Thus, it is creating disgusting visual nuisances and other public health problems. This is concerning, as plastic is a problematic waste due to its persistence and the environmental damage it causes (Carboo and Fobil, 2004).

The composition study revealed that paper also has a substantial presence in the overall waste stream. It was however highest in the high income zones, moderate in the middle income zone and lowest in the low income zone. This confirms the notion that residents who live in the high class zone are the educated and thus carry out a lot of paper work as compared to the middle and low class zones (Armah, 1993). Paper, just like the plastic contributes to clogging of drains and visual unsightliness, but the shorter time taken for paper to decompose makes it a less problematic waste. However, a proper reuse, recycling and composting facility program adopted for the metropolis can safe guard and prolong the life span of the landfill or municipal dumpsites within the metropolis.

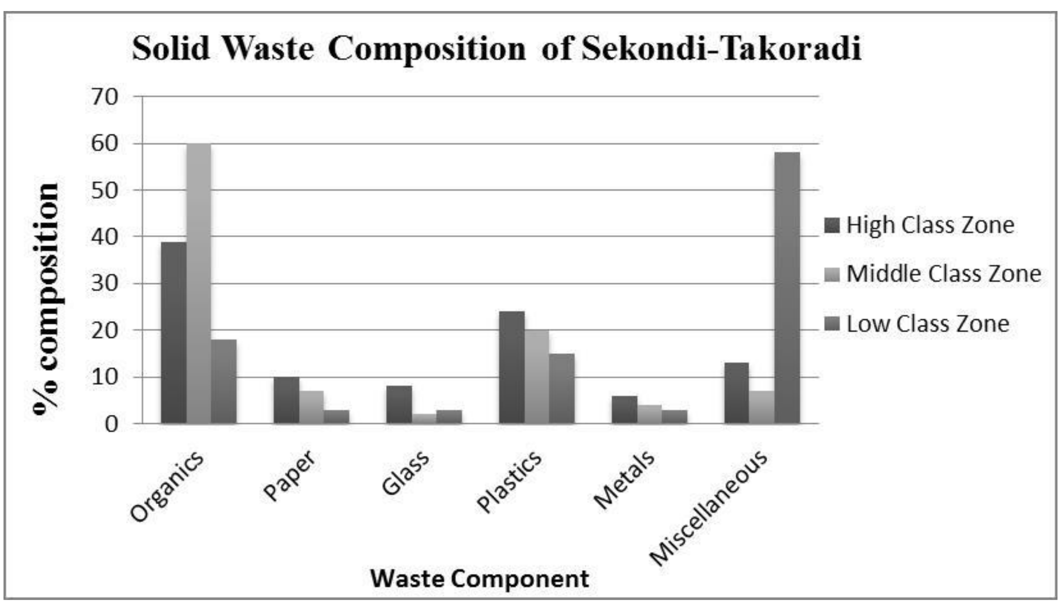

Figure 5: Aggregate composition by major material category

Overall solid waste composition in Sekondi-Takoradi Metropolis

In mixed socio-economic zone (all zones), organic wastes constituted the largest component (38%) in the waste stream by weight. This was followed by plastics which comprised of 19% of waste composition. The category of "plastics" included all grades of plastic bags, bottles, packaging and all grades of hard and soft plastics from toys, appliances and many other sources. Paper, being the third in components order makes up 7% of the waste stream. Subsequent to paper, metals and glass represented 4% each in the waste stream. The other miscellaneous materials, which are mostly made up of inert substances such as sand, stones, ash and fine materials, constituted 28% of the total waste generated. This result falls in sync with household waste separation studies conducted by a waste management company called Zoomlion and AKTP Associate in 2009 which had organic waste representing the highest figure of 69% in the waste stream followed by plastics 17%, metal and glass recording 2% each, paper 5% and other miscellaneous waste also recorded 5% (Miezah, 2012).

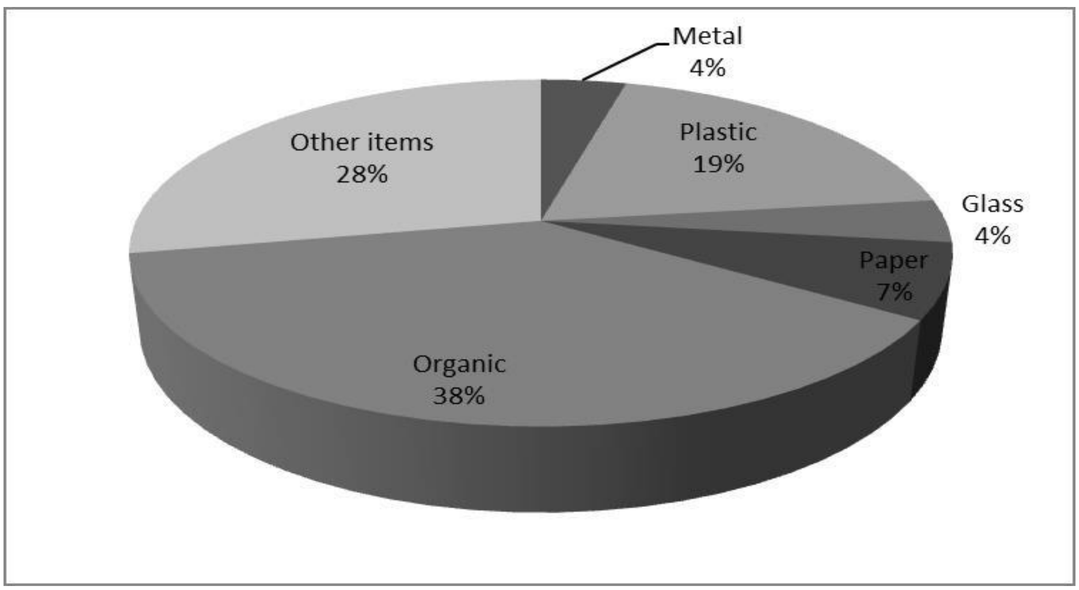

Figure 6: Overall household solid waste compositions (mixed class zone)

Waste Generation in the Households

Table 3 shows that average waste generation by the households per capita per day was 0.58 kg/cap/day in the high income zone, 0.4 kg/cap/day in the middle income zone and 0.27 kg/cap/day in the low income zone. Waste generation was higher in the high class zone and the middle class zone with the low class zone recording the lowest figure. The daily solid waste generation rate per household by weight for the low income group was 1.2±0.92 kg/day, that for middle was 1.27±0.58 kg/day and that of the high income group was 1.64±0.84 kg/day. According to the table the household size of the study area in its entirety was 3.7 with the high, middle and low class zones recording 2.95, 3.6 and 4.65 respectively. The overall per capita per day solid waste generation rate in the Sekondi-Takoradi metropolis is 0.37 kg/cap/day.

Table 3: Household solid waste generation rate in the various income zones

Zone	Waste Generation kg/HH/day	Per capita waste generation Kg/cap/day	Total waste (kg)	Family size (Average)
High class zone	1.64±0.84	0.58±0.24	228.9	2.95
Middle class zone	1.27±0.58	0.4±0.19	177.6	3.6
Low class zone	1.2±0.92	0.27±0.19	167.5	4.65

Several composition and generation studies show that solid waste generation varies from one area to another and thus it is based on multiplicity of factors. And one of such factors as stated by Fei-Baffoe (2010) is that the Municipal solid waste generation is directly correlated with levels of economic development and activity. Hence the composition of generated waste is extremely variable as a consequence of seasonal, lifestyle, demographic and legislation impact. In a similar fashion the composition and generation of solid waste observed in the three selected income zones within the metropolis followed that trend as the highest figure of rate of solid waste generation per Table 2 was recorded in Chapel Hill residential area (high class zone) followed by Sekondi township (middle class zone) and lastly Ngyiresia (low class zone), a confirmation of the positive correlation between income and waste generation. Taking the current population of Sekondi-Takoradi Metropolis of 559,548 (GSS, 2010) into account, the daily, monthly and yearly solid waste generation rate (residential sector) of Sekondi-Takoradi Metropolis are estimated to be 207, 6418 and 75,567 tons respectively. For the city of Accra, estimated daily waste is over 2500 tons per day

(Fobil, 2000) and 1200 tons/day for Kumasi Metropolis (KMA, 2010). Higher solid waste generation rates along these cities are attributable to high population. However, existing collection capacity could only keep up with about 55% of these figures with the remaining percentage left to accumulate in the city core areas for a long period of several months. This becomes a veritable recipe not for only mosquito and fly breeding but also factories from which emanated obnoxious odours as well as offensive smell. (Fobil, 2000)

Conclusion

To know the organic waste proportions is extremely relevant to estimate the methane gas generation during anaerobic decomposition and reuse the waste to generate energy or to use this portion to produce compost (Al-Momani, 1994). In this regard, this study shows that waste in Sekondi-Takoradi Metropolis contains an organic component of above 45%, taking into account paper. A large proportion of waste generated in the city (72%) can be reused, whether by recycling or energy recovery, thereby generating financial, environmental, and social returns that would otherwise be lost to disposal in municipal dumps. However, due to a combination of factors such as the lack of waste management plans, recycling practices, recycling industry, development policies, as well as minimal financial profits of recycling companies, coupled with the ignorance of local authorities regarding the potential value of waste material, the disposal of potentially marketable waste material is a practice that will likely continue.

Based on the findings of the study, the following measures are recommended for the effective management of waste within the metropolis:

- Adoption of integrated waste management program.
- Establish buy-off centres.
- Educate residents on waste separation practices, minimization and reuse, composting and recycling programs.
- Establish composting and recycling facilities since more than 72% of the waste component have composting and recycling potential.

Acknowledgement

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