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Research article

CHARACTERIZATION OF SOLID WASTE IN THE ATWIMA-NWABIAGYA DISTRICT OF THE ASHANTI REGION, KUMASI-GHANA

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ABSTRACT

Solid waste characterization study is fundamental to any proper planning of solid waste management in an area. This study was undertaken to assess the characteristics of the waste generated in the Atwima Nwabiagya District, of Ghana to enhance scientific management of solid wastes in the district. The Direct Waste Sorting was applied to solid wastes collected from fifty-three (53) households with different socio-economic characteristics over a two-week period. Results indicated that the average solid waste generation rate for the district was 0.66 kg/capita/day with a mean daily weight of 109000 kg, expected to grow by 34% by the year 2018. Solid wastes which were biodegradable and recyclable nature were dominated by food, yard and garden waste (54.8 %), plastics (3.1%), metals (0.3%), paper (1.6%), wood (0.3%), glass (0.2%), textiles (0.7%), sand and ash (40%) suggesting that an integrated waste management approach supported by willingness to source-separate wastes could be the best option for the district. With the right knowledge of the general culture of the communities and willingness to source-separate such approach would provide opportunity for the district to maximize revenue through compost preparation, recycling and land reclamation while reducing public health problems associated with management of solid waste.

Key words: solid, waste, characteristics, biodegradable, management

INTRODUCTION

Solid waste is defined as the unwanted remains, residues, discarded materials or by-products which are no longer required for the initial use [1]. Municipal Solid Waste - commonly called trash or garbage, consists of everyday items such as product packages, food scraps, paper, metal, plastics, ceramics, textiles, leather, rubber, bones, ashes,

coconut husk, used batteries, paint and household goods. These types of waste create health and environmental menaces when it is not properly managed. Solid waste management (SWM) may refer to the collection, transfer, treatment, recycling and disposal of solid waste. Waste management poses a great challenge to many nations including Ghana. The problem has become so difficult to curb that human health is threatened. In addition to the effect on human health, roadsides of major towns and cities are littered while streams are blocked by generated waste. There exists a negative correlation between population densities in urbanized areas and increase in per capita waste generation on one hand and the available land for waste disposal on the other [2]. According to the USEPA the various options of waste management are: source reduction and reuse (waste prevention), recycling, composting, waste combustion and disposal in landfills.

One of the districts in Ghana that requires urgent attention in waste management is the Atwima Nwabiagya District (AND) in the Ashanti Region. The Atwima Nwabiagya District, like many other districts close to big cities, is experiencing urbanization as a result of population explosion in the Kumasi Metropolis. Peri-urban areas including the AND that surround the Kumasi Metropolis are now serving as the recipient of the urban drift. This has therefore brought about an ever-increasing generation volume of solid waste generation in the district. However, the district has no appropriate systems in place to handle the situation resulting in indiscriminate disposal of wastes in watercourses, drainage channels and on any available land. Huge piles of waste resulting from uncontrolled open dumping of refuse have developed into mountains close to houses time. Many dumpsites in the district are now very close to or are surrounded by human settlements. Leachates, mosquitoes and flies from these sites have become a menace to inhabitants. During the rainy season, diseases such as diarrhoea and malaria increase in the district. Solid waste management is therefore a very big challenge in the district. The Environmental Protection Agency (EPA) and the Ministry of Local Government Rural Development and Environment (MLGRDE) of Ghana recognize the need for waste management wherever it produces a net cost reduction or positive environmental impact as contained in the national Environmental Sanitation Policy published by MLGRDE in 1999. However no scientific study has been conducted on generated solid wastes in the district.

Characterization and quantification of the solid waste in the district would therefore provide a baseline data based on which an advanced waste management option could be explored for decision-making to address the problem. This would promote human and environmental health in the district.

WASTE

Waste, rubbish, trash, garbage, or junk is the name given to any useless or undesired material. Even though, the term "waste" is the general used, the others are used loosely as synonyms, although they have specific meanings. Rubbish or trash is mixed a household waste, including paper and packaging. The Americans define food waste or garbage to be table waste and kitchen waste. Junk or scrap is metallic part of the waste stream. The European Union defines waste as an object the holder discards, intends to discard or is required to discard. According to the United Kingdom's Environmental Protection Act 1990, waste includes any substance which constitutes a scrap, an effluent or other unwanted surplus arising from the application of any process or any substance or as an article which requires to be disposed off, which has been broken, worn out, contaminated, otherwise spoiled unless the contrary is proven.

Liquid waste is defined as liquid or a mixture consisting of solid matter suspended in a liquid media which is contained within, or is discharged from, any one vessel, tank or other container. Is not in liquid form and has no value to the person who is responsible for it [3]. Although human or animal excreta often end up in the solid waste stream, generally the term solid waste does not include such materials. Synonyms to solid waste are terms such as 'garbage', 'trash', 'refuse' and 'rubbish'. According to [4], solid waste was identified as the second most important problem after water quality.

Each household in the AND generated garbage or waste day in and day out. Items that were no longer needed fell were thrown away. These included:

- Organic waste: kitchen waste, vegetables, flowers, leaves, fruits.

- Toxic waste: old medicines, paints, chemicals, bulbs, spray cans, fertilizer and pesticide containers, batteries, shoe polish.
- Recyclable waste: paper, glass, metals, plastics.
- Soiled waste: sanitary pads, cloth soiled with blood and other body fluids
- Others: ash, sand, etc.

WASTE CHARACTERIZATION AND QUANTIFICATION STUDIES

Analysis of the total quantity of waste in the entire waste stream, by weight or by volume, is known as waste quantification. Analysis of the composition of the waste stream, by material types (such as glass, paper, metal, etc.) or by product types (such as glass containers, magazines, cans etc), is referred to as waste characterization. Knowledge of the characteristics of the waste is very important for effective, long-term, waste management planning. Numerous factors are influence the characteristics of municipal solid wastes [5]. Among them are degree of urbanization and industrialization, social customs, per capita income and other factors such as geology, geography and climate. Equally important is the knowledge of waste quantities for calculating the need for and the size of waste disposal facilities, such as incinerators, landfills and recycling facilities. Any meaningful contemporary waste management practice, which uses waste reduction, reuse, recycling and composting for diverting waste from waste disposal facilities, can only depend on information from the composition of waste generated in order to identify products or materials which should be targeted for diversion. Therefore, knowledge of both waste quantities and waste composition is vital for monitoring progress towards the best waste management option in any community.

FACTORS AFFECTING HOUSEHOLD WASTE COMPOSITION

Solid waste composition in households is influenced by such factors as: time, housing type, socio-economic factors, land use, seasonality, weather and climate, demography, type of waste and recycling services provided in an area and culture.

*Demography***:** The profession, age and education structure of a population bear relationship with the composition of waste and recycling scheme.

*Socio-Economic factors***:** The wealth of households influences consumption and disposal patterns at a fundamental level and hence the type and amount of waste produced.
*Culture***:** The way of life of a people living in a place. It influences the perception or attitude that people have on waste generation. This is because culture has an effect on the type of activity undertaken in an area, the types of food people consume and the amount or type of goods purchased. All these in turn affect the composition of waste disposed off.

Time: The amount of waste produced in a household can fluctuate significantly between days of the week, between weeks or months of the year and between years.

*Housing type***:** The housing type in a community can have a large influence on the composition and amount of waste produced. This is so because some housing types may have gardens while others may not keep any. The number of occupants in a household also depends on the housing type and subsequently affects the waste they produce. The housing type has a direct bearing on the socio economic and demographic status of a place.

*Land use***:** The type of activity which a people living in a place are involved in an effect on waste composition. The composition of waste from an agricultural land, commercial area or an industrial setting may differ because of the different activities taking place in each of these places. Waste from a rural development may be different from that of an urban development, in terms of their composition due to differences in activities in the two places.

Seasonality, weather and climate:

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One of the primary factors that affect waste composition is seasonality, since it has an effect on waste generation rates, more especially on organic garden waste. For example waste patterns in the rainy season are different from that of the dry season e. g. the Harmattan, during which trees shed their leaves. The temperature, wind, clouds and precipitation of a place creates fluctuations in waste composition, within the overall pattern of seasonality. Climate, weather conditions of a place over a long period of time has a similar but larger effect within each geographic area. Again, special periods such as Christmas, festivals and other holidays affect the consumption patterns of people and the per capita waste generation rate of a place.

*Type of waste containers and recycling services provided in an area***:** The type of waste and recycling services provided in an area is perhaps one of the biggest impacts on collected household residual composition than any of the above. [6] has recommended recovery for recycling as one of the most effective waste management techniques. The type of waste collection containers used and materials recycled can lead to significantly different capture rates for different materials. It also has a significant impact on materials such as green waste, construction and demolition waste in the household waste stream.

STUDY AREA

The Atwima Nwabiagya District (shaded red) in the Ashanti Region of Ghana (Figure 1) lies approximately on latitude 6°75N and between longitude 1°45 and 2°00 west. The district shares its western border with the Ahafo-Ano South and Atwima Mponua districts, the north with the Offinso District, its south with the Amansie West and Bosomtwe Atwima Kwanwoma districts. The Kumasi Metropolis and Kwabre districts lie to the east of the Atwima Nwabiagya District. The district covers an area of 294.84 sq. km. Nkawie is the capital of the district.

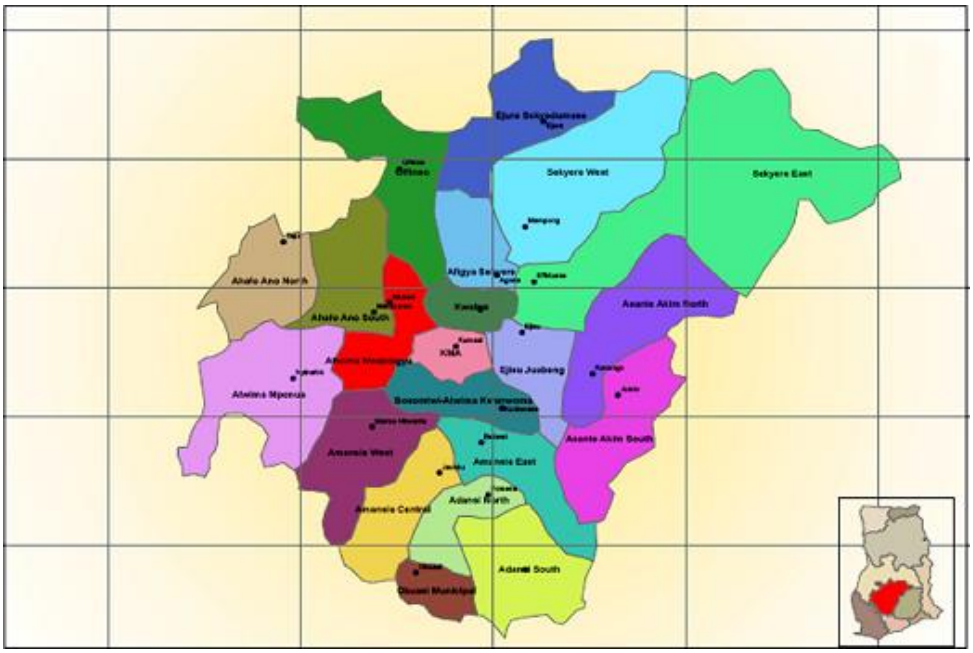

Figure 1: Districts of the Ashanti Region, Ghana

The average daily temperature ranges between 27^{o}C in August and about 31^{o}C in March. Mean relative humidity ranges from about 87 to 91 percent. There were about 11,156 houses 52% of which are of the compound type. The population of the district was 149,025 and a population density of 195.2 persons/ km^{2}. The district's medium term development plan document reveals that there are a number of demerits associated with its border with Kumasi. By virtue of proximity, settlements in the district host a large population of people who live there but work in Kumasi and therefore use the communities as 'dormitories', paying their income tax to the Kumasi Metropolitan Assembly

(KMA). The activities of these people have led to increase in waste generation without commensurate revenue for its management by the district. Open-dumping is the main method of refuse disposal in settlements in the district resulting in mountainous refuse heaps (about 44 piles) in areas such as Nkawie, Atwima Koforidua, Abuakwa, Barekese, Akropong and Asuofia. Due to the poor waste management culture by the communities and the assembly, high incidence of diseases like malaria and diarrhoea were reported by the District
Health Directorate. The numbers of reported cases were: 28,623 for malaria and 1,959 for diarrhoea (ANDA, 2006).

MATERIALS AND METHOD

Waste characterization

The methodology considered for waste characterization was the Direct Waste Analysis (DWA). Direct sorting was used because of its greater accuracy than other techniques, even though it is somewhat costly and time-consuming. This entailed direct analysis of waste collected from the point-of-generation (homes) by sorting at a waste disposal site. The waste was sorted by hand into pre-determined material or product categories. The communities in which the sampling was done were: Atwima Koforidua, Nkawie Kuma and Nkontomire.

FACTORS CONSIDERED IN THE WASTE SORTING EVENTS

Personnel, Health and Safety

Qualified personnel are important for a successful waste analysis programme. Four personnel were recruited from the selected communities (at least one from each community) and were trained by a qualified sorter. Due to the risk posed by the type of materials handled in waste sorting the personnel were given lessons on safety guidelines such as use of protective devices, observation of warning signs and symbols on containers, observation of safety procedures and waste sorting protocols. Potential risks associated with waste sorting explained to them. They were each provided with a pair of wellington boots and of leather hand gloves, overall, disposable nose mask, disinfectant and soap and Emergency Response Agencies' telephone number for their personal safety. Their relevant immunization statuses of personnel were also verified and up-dated. The personnel were guided on their first sorting event. These guidelines also ensured accuracy in the sampling.

Equipment and Materials

In waste management programs, the equipment and materials used are methodology driven. In this study that employed direct waste sorting, the materials and equipment used included trash polythene bags, a ten-kiliogramme (10 Kg) weighing scale, sorting containers and bench, tarpaulin sorting shed, digital camera and mobile phone.

General safety procedures
The following were some of the safety guidelines adopted for the waste collection and sorting:

- All sorting personnel were in good physical condition, not allergic to odours and dust and could read warning signs or labels on waste containers.
- No eating, smoking or drinking was allowed during sorting activities. Food and water were kept away from the sorting area to avoid being contaminated.
- Extreme care was taken in the handling of material to be sorted.
- Spills, dirt and residue on the floor were immediately wiped out to prevent slip
- Replacement of damaged protective gear was done immediately after such occurrence.
- To ensure prompt notice of accident no person was allowed in the waste sorting area alone.
- Any physical discomfort, abnormalities, fatigue or light-headedness was immediately reported to the supervisor who arranges for relaxation by the personnel to relax for recovery.

Waste Classification System

The British Colombia Manual listed 15 categories of wastes. However it recognizes that depending on the goal of the study, fewer categories may be required [8]. In this study, the waste stream was categorized into groups of items that were relatively easy to recognize (to facilitate accurate sorting) and to the extent possible, the number of categories were minimized to reduce the level of effort and cost involved in conducting the study. The waste classification which was used after a pre-sort site assessment of the solid waste dump sites of Koforidua, Nkawie and Nkontomire was:

- Food waste, garden-and-yard waste
- Plastics
- Metals
- Paper
- Wood
- Textiles
- Glass
- Others

Sampling design

The heterogeneous nature of Nkawie Kuma necessitated the use of random sampling in order to reduce the risk of potential biases. The strata considered in the town were Government Bungalows, the Zongo Community and the Indigenous Community. Even though Koforidua has six sub towns or strata, they were virtually homogeneous. The criterion used was a simple random sampling within each of these strata in proportion to their size in the actual population. Nkontomire was also homogeneous community. Therefore simple random sampling was the method used in this case.

Level of sampling

Household Single Waste Bin Sampling was used for the sample collection since there was no coordinated waste collection system in these studied communities. Each of the randomly selected households was provided with four (4) trash bags. The bags were put into their waste collection bins for collection of wastes generated in their households. Wastes were collected bi-weekly (Wednesdays and Saturdays) for sorting into the various components.

Sample collection and size

Ten (10) households were randomly selected from each of the three strata in Nkawie Kuma Township. After the first week the mean and standard deviation of the data collected were used to calculate the actual sample size, according to the equation:

$$n = \left[\frac{z_{\alpha/2}\sigma}{E}\right]^2 \quad \text{..... equation (1).}$$

Where n = the sample size
z = the critical value
α = the probability that a given percentage of measurements are rejected and
E = the permissible error margin.
Knowing the sample size, 6 households were taken from each of the stratified strata for the actual sampling in the second week and the whole procedure repeated to get the sorted composition of the solid waste in Nkawie. In Koforidua five (5) houses were selected from each of the six subdivisions and the sampling procedure described applied. Four (4) households from each of the subdivisions (a total of 24) were sampled for sorting in the second week after calculating for the required sample size. Sampling in Nkontomire was done by randomly selecting eighteen (18) households from thirty eight households for the sorting event. In all, seven (7) out of 60 people did not participate in the actual sorting events: five (5) from Koforidua, one (1) from Nkawie Kuma and one (1) from

Nkontomire. The number that participated (53) however was still higher than the calculated sample size of 40 for the entire Atwima Nwabiagya District making it an appropriate sample size. The iterative process (table 1) for the determination of sample size by [9] was adopted:

Table 1: Summary of iterated sample sizes

Confidence Limit, p (%)	Error Margin, E (%)	Sample size, n (households)
99	1	29127
95	5	675
95	20	42
90	10	119
85	15	40
80	20	18

Sample sorting

Sorting was done for individual households since the analysis and characterization of the waste in the various houses were of interest. Each household waste was poured unto a wooden bench, sorted into food, yard and garden waste, plastics materials, metals, paper, wood, glass materials, textiles and other components and the weight of each of the component waste materials noted for onward analysis. After each sorting event the area was cleaned-up and the waste materials disposed of. All materials and equipment used for the sorting were cleaned. Debriefing exercise was then undertaken to discuss the items found in the waste and the possible sources of such waste.

Sample evaluation

In order to make inferences about the population from which samples were taken inferential statistics was used. The considered parameters were the mean, the standard deviation and the error margin. The waste generation rate of each town, as well as of the entire district, were calculated by averaging the weekly totals of each household waste collected over the observation period and dividing by the total number of persons in the households. The mean daily weight of waste generated was obtained by multiplying the waste generation rate by the current district population size.

RESULTS

Table 2: Mean and standard deviations of the waste generated in a one-week period in Koforidua, Nkawie Kuma and Nkontomire

Township	Sample Mean, μ	Sample Standard deviation, σ	Number of samples, N
Koforidua	15.4063	6.5145	30
Nkawie Kuma	31.0412	19.8846	30
Nkontomire	47.5047	18.0554	30
Entire ANDA	30.7170	20.3588	90

Table 3: Percentage composition of waste produced in the Atwima Nwabiagya District

Component of Waste	PERCENTAGE			
	Nkawie Kuma n =17	*Nkontomire n = 17*	*Koforidua n = 19*	*Atwima Nwabiagya District*
Food, yard and garden	68.08	43.51	63.13	54.77
Plastics	4.55	1.21	5.92	3.10
Metals	0.18	0.09	0.89	0.35
Paper	1.15	0.31	1.33	1.64
Wood	0.09	0.36	0.34	0.27
Glass	0.07	0.01	0.39	0.22
Textiles	0.53	0.80	1.40	0.67
* Others	25.35	53.70	26.59	38.99

* 'Others' category *basically consists of sand from sweepings and ash*

Table 4: Comparison of Waste production per day in Koforidua, Nkawie Kuma and Nkontomire

Component of Waste	PERCENTAGE		
	Nkawie Kuma n =17	*Nkontomire n = 17*	*Koforidua n = 19*
Food, yard and garden	24.90	3.04	0.11
Plastics	0.23	0.20	0.00
Metals	0.04	0.02	0.00
Paper	0.05	0.17	0.00
Wood	0.01	0.00	0.00
Glass	0.02	0.02	0.00
Textiles	0.06	0.02	0.00
* Others	1.05	1.05	0.13

Biodegradables were the dominant component of the sampled wastes (55%). This was followed by wastes in the 'others' category (basically consisting of sand from sweepings and ash), other recyclables and textiles in order of decreasing magnitude (Figure 2).

Table 5: Per capita waste generation rate for the *Atwima Nwabiagya* District

Waste component	Per capita/day
Food garden/Yard waste	0.021
Plastics	0.021
Metals	0.002
Paper	0.011
Wood	0.002
Glass	0.001
Textiles	0.004
Others	0.259
Total	0.664

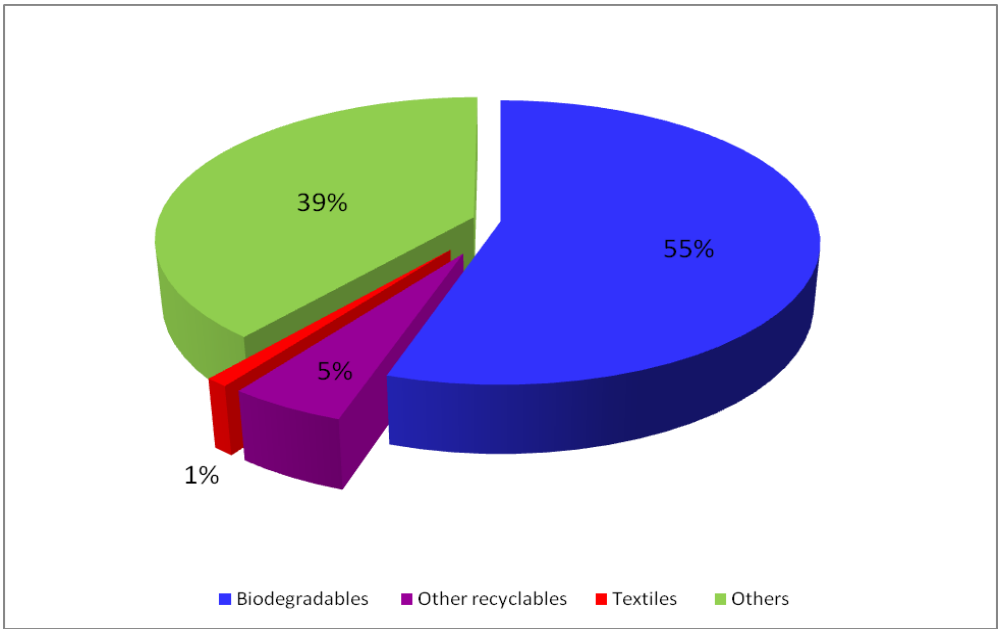

Figure 2: General household waste types in Atwima Nwabiagya District

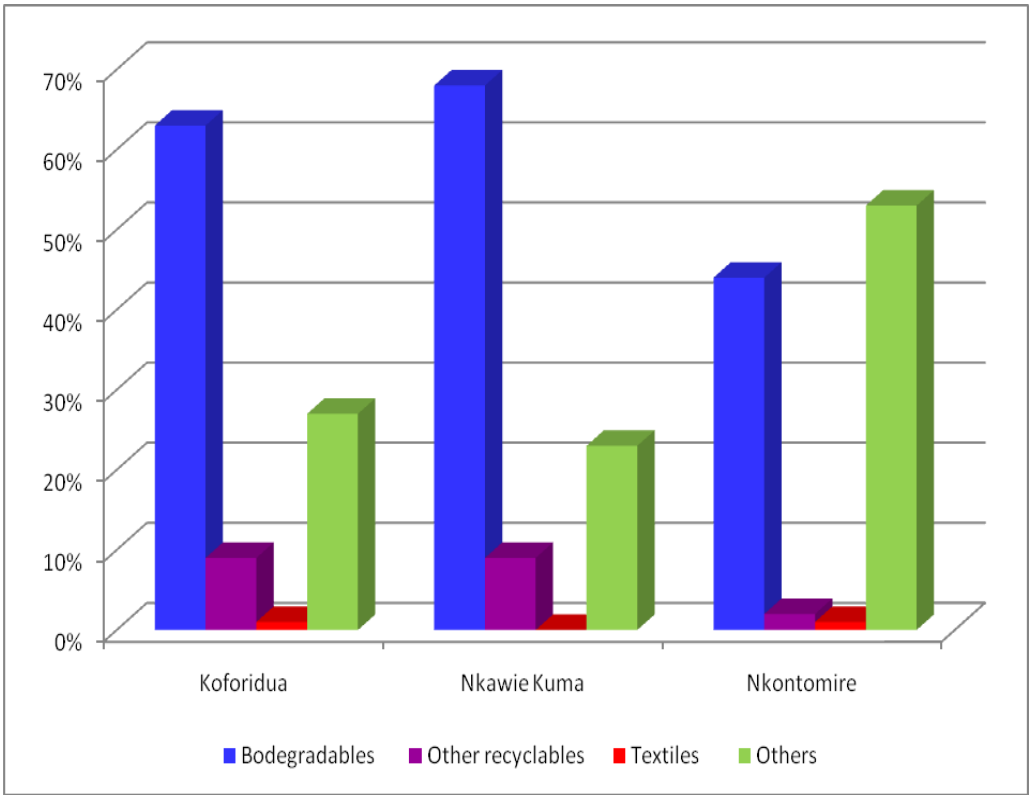

Figure 3: Comparison of waste generation rates in Koforidua, Nkawie Kuma and Nkontomire

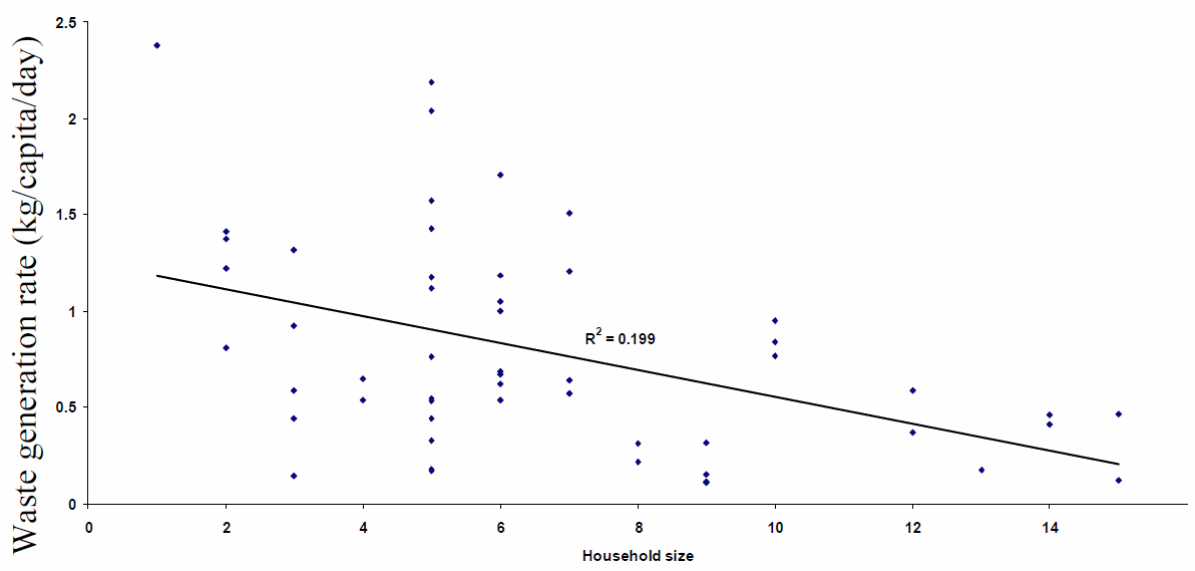

Figure 4: Waste generation rate and household size relationship in ANDA

DISCUSSION

The per capita waste generation rate for the entire Atwima Nwabiagya District was 0.66 kg/capita/day (Table 5). Even though this waste generation rate is higher than that from the 0.2 – 3.0 kg/capita/day noted by the WHO expert committee report (Number 484) on developing nations, it was comparable to the 0.41-0.9 kg/capita/day in Accra [10].

The daily waste production in Nkawie Kuma was 4,530 kg. This was higher than the 3,900 kg and 200 kg produced for Koforidua and Nkontomire respectively. Although Koforidua had the highest population (about 8,394) as compared to those for Nkawie Kuma (6125) and Nkontomire (343) respectively and therefore was expected to generate the highest amount of solid waste per day it was rather in Nkawie Kuma where the highest amount was recorded. This may be due to the higher per capita waste generation rate associated with Nkawie Kuma as compared to Koforidua and Nkontomire. The higher waste generation rate in Nkawie Kuma (0.74 kg/pers/day) as compared to the other communities may be due to the comparably higher income levels of inhabitants of Nkawie Kuma.

Being a district capital Nkawie Kuma was also inhabited by a working class who were mainly staff of the Atwima Nwabiagya District Assembly and its allied institutions including the Health Service, Ministry of Education and the Ministry of Agriculture, who earned relatively higher incomes in the district and therefore may account for the higher per capita waste generation rate recorded for Nkawie Kuma. The waste generation rate observed in Nkawie Kuma compared favourably with the 0.76 kg/person/day observed in 2004 by [11] and 0.78 kg/person/day for the cities in Ghana, but lower than the 1.08 kg/person/day observed by [12] for low and middle income groups in Kumasi and the 0.68 kg/pers/day and 0.60 kg/pers/day for Accra and Kumasi respectively. However, it was higher than the range 0.40-0.60 kg/person/day reported by [13] as the pattern of municipal refuse quantities and characteristics for low income countries.

Koforidua generated waste at a rate of 0.47 kg/pers/day, a rate that was comparable to that on the campus of the Kwame Nkrumah University of Science and Technology, Kumasi for middle income groups in Wenchi. It however fell outside the general range of solid waste values for developing countries and therefore calls for better management practices to avert the occurrence of any serious health related problems. The [14] recounted that over

80 per cent of the cities of developing countries do not possess an adequate and meaningful refuse management systems.

Nkontomire, and Nkawie Kuma and Koforidua (peri-urban communities) possessed characteristics typical of rural and urban settings respectively. Generated wastes were dominated by food-yard and garden waste with compositions of 44%, 68% and 63% respectively (Table 3), conforming to an observation by [15] who noted that waste in rural settings has high organic content and susceptible to rapid decay. These results compared also with the 64% and 65% recorded respectively for Kumasi and Accra.

The largest component in the solid waste stream (63.1 percent) was food-yard-and garden waste components. This might have contributed to the high percentage composition of biodegradable materials in the waste generated in Koforidua. This is an indication that the community's waste contains a large amount of organics and therefore suggested a potential for use as compost. The 9% recyclable waste and the 6% plastic in the entire waste suggested that revenue could be generated if recycling management practices were adopted. The observed quite substantial amount of plastics including polyethene bags in the sampled waste in the studied communities could be attributed to the use of these communities as 'dormitories' by inhabitants who work in the urban areas mainly Kumasi and Nkawie. The communities therefore served as recipients of the plastic containers (carriers) for the various items bought from these urban areas.

The high degree of plastic used as containers for various items and as substitute for glass could also explain why glass recorded low levels in the waste. Wood is used as a source of fire for domestic purposes in the communities and is therefore not disposed off in wastes. This could account for the remarkably low amount of wood recorded in the waste.

The [14] reported that Koforidua had a higher number of tailors and dressmakers than any other town in the district. This, coupled with its larger population size could explain the relatively high percentage of textiles (1.4%) in waste generated in the town. An average waste generation rate of 0.74 kg/day/person was observed in Nkawie Kuma. The waste was collected from 17 houses in the town strata of Government Bungalows, the Indigenous Community and Zongo Community.

It was also observed that Nkawie Kuma generated the highest quantity of biodegradable waste (68%). This may be due to the existence of a Zongo Community in Nkawie Kuma as well as the relatively higher population size (second to Koforidua which has no Zongo). Greater proportions 'Tuo Zaafi', a type of food which is composed of a high proportion of leafy (biodegradable) wastes might have led to generation of leafy wastes which increases biodegradable wastes.

Nkontomire, on the contrary was a rural community (homogenous). Average waste recorded was 0.73 kg/person/day. This was comparatively higher [16] and may be due the high quantity of sand present in the sweepings of the community. Almost all compounds found in Nkontomire were not cemented, therefore sand was swept into dust bins to be dumped. This could account for the 53% recorded for "others"- which basically consisted of sand and ash. As a typical farming community, Nkontomire with abundance of food smaller quantities of foodstuffs such as cocoyam, yam and plantain and left-over cooked food, which otherwise could have been eaten end up in solid waste bin. This might have contributed among other things to the biodegradable materials which constituted 44% of the waste generated. The relatively low amounts of plastics, paper and metals (1.2%, 0.3% and 0.1% respectively) was therefore expected. However, the waste generation rate observed in Nkontomire fell within the range observed for low income groups in Wenchi.

Results of the study were comparable to [17]. This rate called for immediate action to avert the occurrence of possible waste management crisis in the district. Waste from Government Bungalows abounds in metals due to the relatively high incomes levels and for that matter consumption of canned foods leading to high amount of metals in the waste. The waste composition were based on the aggregate weight wastes collected from the study households, once it had been sorted into the various classes. The waste was largely organic. Food, yard, garden waste and wood collectively account for 55% of waste by weight (Figure 2). This percentage found was similar to that found in

residential waste characterization studies in other developing countries e. g. Guadalajara in Mexico and Gabarone in Bostswana. [18] observed 53% for Guadalajara. [19] noted 58% for Guangzhou in China while [16] reported 68% for Gabarone in Botswana in Africa.

FORECAST OF WASTE GENERATION

Results of this study show that the amount of waste generated in the Atwima Nwabiagya District would increase by 34% in ten years (between 2008 and 2018). Population growth could be the driving force behind these projections.

Relationship between waste generation rate and Household size

Several studies on solid waste management have shown a link between waste generation per capita and household size. [16] and [20] established a weak negative relationship between the two. The negative correlation between the two observed in this study (Figure 4) was therefore not surprising.

Potential Waste Management Options

Many factors can affect the selection process e. g. waste generation and waster composition. Both of these factors determine waste planning and management [21]. Waste generated in the district is multi-classed and included biodegradables, recyclables and others (sand from sweepings and ash) (Figure 2). Biodegradable waste formed 63%, 68%, 44% and 55% for Koforidua, Nkawie Kuma, Nkontomire and the entire district respectively. Given its biodegradable nature, much of it can be recovered for reuse as fertilizer by composting to enhance agricultural production [22].

Composting is a waste management option that can be seriously considered. It could also be used for land filling or for biogas production which has a potential of reducing deforestation, by serving as substitute for firewood. The use of compost produced for soil amendment needs in the district's demonstration farms and also by individual farmers in the AND as an alternative to artificial fertilizers, if encouraged through education would be helpful. Composts could be supplied to farmers or sold at a very subsidized price in order to recover cost of maintenance of the composting equipment.

Five percent (5%) of waste from the district is recyclable. With the world today witnessing an increasing cost of raw materials, recycling provides a cheaper source of raw materials. The district could therefore explore the opportunity to increase revenue through waste recycling. Waste classed "others" which consisted mainly of sand from sweepings and ash forms 39% was second to biodegradable waste. This could be used for filling by the mining and sand-winning industries for land reclamation.

Waste Collection and Transfer

The households in the study areas place their wastes in bins, baskets, etc. and the final transfer them to dump sites. Although household collection is laudable, an enhanced benefit is achieved if source-separation which involves systematic separation of the waste at the household level is employed. This may reduce the incidence of contamination resulting from comingling of the different kinds of waste.

The entire district mainly consisted of medium to low income settlements, therefore for the peri-urban areas like Koforidua, Barekese, Abuakwa, Adankwame, Akropong and others the 'block' or 'bell' system of waste collection will be ideal; where service collection vehicles could be made to operate on predetermined routes in the communities at set days and times of the week.

In the rural and low-income settlements in the district (which formed 36% of the population) as well as markets and lorry parks, Communal Container Services would be suitable. This consists of replaceable skip or roll-on- roll-off containers placed at predetermined locations for households within a convenient radius to hold waste which is emptied daily at a disposal site. However, for the few high and medium income areas like the Abuakwa New Sites,

Nkawie Government Bungalows, Koforidua New Site, Banking Flats, Formulation Residential Area, and Esaase New Site Door-to-Door Collection Service could be encouraged.

CONCLUSION

Solid waste in the Atwima Nwabiagya District is of biodegradable, recyclable and of textile origins and is dominated by food-yard-and-garden waste (54.8 %), plastics (3.1%), metals (0.3%), paper (1.6%), wood (0.3%), glass (0.2%), textiles (0.7%), sand and ash (40%). The multi-class nature of waste generated in the district necessitates the use of the integrated approach to manage solid waste in the district. This would enable the waste to be effectively managed since the benefits of the various practices (including compost formation and recycling) could be maximized. This would minimize the menace caused by solid waste and enhance the economic value of compost and recyclable solid wastes in the district and in doing so, promote public health.

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