Decentralized Solid Waste Management in Rural Ghana: A Case Study of Assin Kushea Community in Assin North Municipality

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ABSTRACT: Management of solid waste continues to be a major developmental challenge for developing countries like Ghana. The current focus and attention have been on the collection and dumping of waste in urban communities where generation rate is high to the detriment of rural communities. In this study, a pilot waste management scheme was undertaken in Assin Kushea, a rural community in the Assin North Municipality, to determine the willingness of the community to sort their waste at source, the quantity of waste generated by the community, and the characteristics of the waste to inform the treatment or disposal options suitable for the community. The results of the study showed that the community generates approximately 20 to 40 kg waste per day which comprises about 77% biological municipal waste (BMW) and 23% of residual waste. Laboratory analysis of the waste showed that the moisture content of the waste was about 68%. The percentage volatile solid was about 85.45%, leaving an ash content of approximately 14.55% all by weight of the waste materials. More than 50% of the sampled population achieved 100% source separation efficiency. Given the composition and characteristics of the waste, and the willingness of the community to sort their waste at source, composting or anaerobic fermentation of the organic waste fraction is recommended as the best waste treatment option for the organic component of the waste for the community.

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Several developing countries are known to have poor sanitation and waste management systems. In Ghana, the problem of poor sanitation has become persistent. Over the last few years, the per capita waste generation has dropped from 0.51 kg/day in 2010 to 0.47 in 2015 according to Miezah *et al.* (2015). This notwithstanding, a population growth rate of 2.5 % per annum (National Population Council, 2017) has eroded any gains in the reduction in per capita waste generation. On the contrary, actual waste generation has increased marginally from about 12,700 tons in 2015 to about 13,800 tons of waste per day currently. This figure, by estimation, could reach about 21 000 tons per day by 2040. In spite of the high waste generation potential, only 18% of the generated waste

is being managed well through proper incineration and land-filling (Ghana Statistical Service, 2014). Ofori-Boateng *et al.* (2013) reported that the municipal solid waste (MSW) management challenges include; the uncontrolled dumping of wastes at unauthorized places, inappropriate technologies for incineration and land-filling, and weak enforcement of environmental regulations. Solid waste management practices in the country have largely focused on major cities and towns where the emphasis has been on the collection and disposal of the waste with very little provision or recourse to treatment. This system of waste handling is enshrined in the National Environmental Sanitation Action Plan (Ministry of Local Government and Rural Development, 2010) which lays strong emphasis on

the collection and disposal of waste with little attention on waste valorization or treatment practices. Resource recovery by way of treatment is usually not an option in the current waste management practices in the country. Apart from the Accra composting facility, and a few plastic waste recycling companies in the major cities, municipal solid waste across the country remains largely untreated. The main target for solid waste management is to increase collection and transportation of solid waste to 90% by 2015 and 100% by 2020 with no targets for waste treatment (Government of Ghana, 2007). Interestingly, all these targets were for the main cities: such as Accra, Kumasi, Tema, Takoradi and Tamale where the population densities are high and thus high propensity for waste generation. In the case of small towns and villages, household collection systems are generally non-existent, neither are there any communal collection systems in place. Rather, individuals collect and dump their waste in open fields or designated dumping sites that are not engineered. Thus, little attention is given to the sorting of waste at source. The decentralized system of governance through the district assemblies empowers the various districts to be in control of the waste generated in their respective districts. To give credence to this assertion, a handbook for the preparation of district environmental sanitation action plan was developed by the Ministry of Local Government and Rural Development to guide district planners on how to prepare an action plan to tackle their waste management problems (GoG, 2007). Unfortunately, most district assemblies are yet to prepare their own sanitation action plans to guide

waste management efforts. This could be attributed to the dire financial constraints that most of the district assemblies face regarding revenue mobilization and utilization. Further, most of the district assemblies are poorly resourced, both technically and materially to the point that some are even in debt. Owing to this, they are forced to relegate waste management to the background. Consequently, solid waste management receives very little attention because it is usually considered as a serious drain on the rather meager resources of the districts. In this work, we have studied the willingness of a rural community such as Assin Kushea Community in Assin North Municipality, Ghana to separate waste generated at source, which characterized and quantified and proposed an effective and realistic MSW management strategy with emphasis on sorting of waste at source and treating the waste to recover resources as opposed to the national strategy of collection and dumping of waste.

MATERIALS AND METHODS

Description of the study area: The study was carried out in Assin Kushea in the Assin Owirenkyi Traditional Area. The Assin Owirenkyi Traditional area falls under the Assin North Municipality and is one of the twenty-two (22) districts in the Central Region of Ghana. It lies within Longitudes 1° 05' East and 1° 25' West and Latitudes 6 ° 05' North and 6° 40' South (Assin North, 2015). The Municipality has 62.8% of its working population in agriculture; farming and animal husbandry (Ghana Statistical Service, 2014).
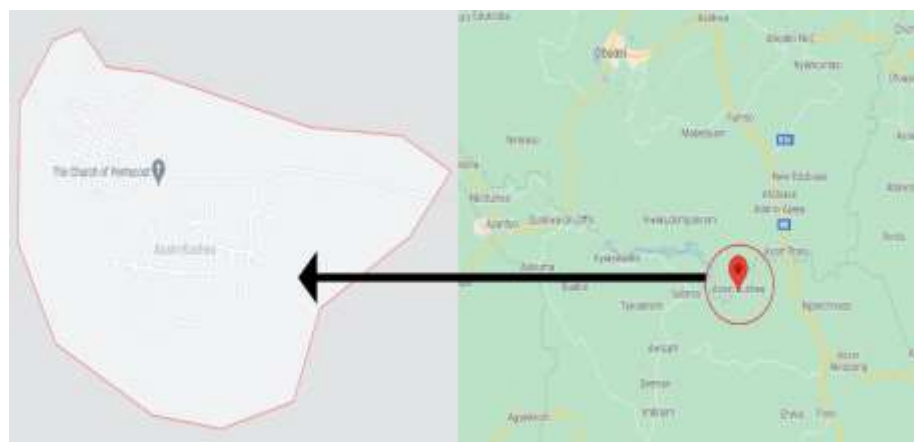

Fig 1: Map of Assin Kushea (Source: Google Map, 2021)

The Assin Kushea Township has been segmented into five (5) different areas. The five put together consist of about 519 houses with a population of 3019, made up of 1481 males and 1538 females (Ghana Statistical Service, 2014). The Township has an average of 103 houses in each of the 5 areas and approximately six (6)

inhabitants per house. According to the Ghana Statistical Service (Ghana Statistical Service 2014), more than half (53.1%) of the waste generated in the Municipality is dumped in open fields. Only 3.6 % of the waste generated in the Municipality is collected and dumped in an organized way. In Kushea

Township, the story is not different. Poor solid waste management is characterized by the absence of waste collection mechanism, unavailability of proper treatment or recycling of waste infrastructure, and the complete absence of a management scheme to properly coordinate the collection and treatment of waste. Households are left to manage their own waste in the best possible manner they may deem fit. This has resulted in mountains of waste over time at five key locations in the township, creating unpleasant sights and odor emanating from the decomposing waste. The mountains of garbage also attract rodents and flies that are known to transmit water and airborne diseases as well as other preventable diseases such as typhoid and cholera.

Public Education: A public forum was held to educate the inhabitants about the importance of good sanitation and proper waste management. This education program was undertaken by a five-member team. The education program took the form of a participatory approach based on multi-criteria decision analysis (MCDA) methods, which sought the participation of stakeholders in the decision-making process for a sustainable waste management solution (Soltani et al. (2015)).

Sorting and Sampling Method: To determine the willingness of the household to properly sort their waste, a sample of twenty-one (21) households based on a population of 519 and confidence level of 95% with a 5% margin of error, were selected and given further education on waste segregation for a period of three (3) days. After this, two waste bins were given to each household for the collection of organic and non-degradable waste materials (also known as residual waste, RW). Data on the mass of the organic and non-degradable materials generated daily were recorded the following morning at about 7:00 am by the team. This process continued for eight (8) days; a minimum standard recommended by SWA-Tool Consortium (SWA Consortium, 2004).

Sampling of organic materials: The specimens required for the sampling procedure were obtained by using the coning and quartering technique (CEN, 2006). Samples from each of the 21 households for each day were thoroughly mixed together to obtain a homogenous composite sample. It was then placed in a single level flattened pile, which was divided into four quarters using ropes perpendicular to each other. One pair of cones at opposite corners was removed from the original sample and the removed material, discarded. The sample was mixed again and the process was repeated until the desired sub-sample size (200 g) was obtained. The resulting sub-sample for

each day was taken to the laboratory on the same day for proximate analysis. In all 8 samples representing each day of sampling were tested. The proximate analysis performed consisted of moisture, total solids, ash, and volatile solids contents.

Total solid and moisture content estimation: Sample containers used were pre-conditioned overnight in an oven at 105 °C to remove any moisture present. The conditioned sample containers were removed from the oven and cooled to room temperature in a desiccator and weighed (W_1). About 100 ± 2 g of the sample was weighed into each of the pre-conditioned pre-weighed sample containers and their respective weights recorded (W_2). The samples were placed into a convection drying oven at 105 °C and dried to constant weight. The crucibles and their contents were removed and allowed to cool to room temperature in a desiccator. The weights of the crucible and oven-dried samples were recorded accordingly (W_3). The percentages of the total solid (Equation 1) and moisture content (Equation 2) were, thus, estimated on a wet weight basis as follows:

$$\% \, Total \, Solids = \frac{W_3 - W_1}{W_2 - W_1} \times 100 \quad (1)$$

$$\% \, Moisture \, content = 100 - \% \, Total \, Solids \quad (2)$$

Loss on Ignition (LOI) determination: The oven-dried samples obtained from the total solid and moisture content tests were used for the LOI analysis. These samples were heated slowly in a muffle furnace to a temperature between 550°C - 600°C and maintained at that temperature until all smoke/flame ceased and organic matter was completely combusted. The ashed samples were removed and then cooled in a desiccator to room temperature and re-weighed (W_4). The percentages of ashes produced for each sample were estimated on dry basis as indicated in Equation 3. The percent total combustible organic matter content estimation was a straightforward difference between the initial oven-dried sample (100 %) and the percentage ash as shown in Equation 4.

$$\% \, Ash = \frac{(W_4 - W_1)}{W_3 - W_1} x100 \quad (3)$$

$$\% \, Volatile \, solids = 100 - \% \, Ash \quad (4)$$

RESULTS AND DISCUSSION
Responsiveness of town folks to waste segregation process: To determine the success of the sorting exercise, respondents were graded on a scale of $1 - 3$. A score of 3 indicated the successful sorting of waste

without the presence of mingled waste. A score of two indicated the presence of at least one mingled waste while a score of 1 indicated the completely failed sorting due to the presence of more than 50% mingled waste in the waste stream. Results of the responsiveness of the township to waste segregation are shown in Figure 2. A significant majority of the households (58%) sorted their waste correctly. This indicates that more than half of the sample size carried out the waste segregation correctly. The result from this study tallies well with results obtained by Zeng et al. (2016) in a similar study in rural communities in China where more than half of the population were willing to sort their waste at source. Given the fact that this was the first time the community was introduced to waste segregation at source, the result was very encouraging. About twenty percent (20%) of the participants responded positively in the exercise even though there was at least one instance of mingled waste in the sorted waste stream. The remaining 22% were passively involved in the exercise. As a result, they failed to properly sort out their waste, thus mixing components of the two waste streams for the entire duration of the exercise. In a similar study using informal based communication and personal interaction, Dai et al. (2016) reported a high success rate of waste segregation purity levels of about 95% in China. Similarly, in a survey of solid waste generation and residence awareness in Da Nang city, Vietnam, 90% of the residents were reported to have said they were willing to corporate with city authorities to segregate their waste according to Otoma et al. (2013). The result of this study, however, pales in comparison with results obtained by Miezah et al. (2015) in selected cities in Ghana where they reported high sorting effectiveness of 80% for selected households across the country. This is expected due to the fact that the literacy level in cities is higher than in rural areas and therefore, most people in cities might be more willing to sort their waste correctly. Interestingly, others like Malik et al. (2015) in a study in Putrajaya (Malaysia) drew a different conclusion, where the willingness level was reported as poor. Further, Malik et al. (2015) reported a low correlation between community participation in recycling programs with community participation in waste segregation and community knowledge of solid waste segregation having regression coefficients of 0.343 and 0.251, respectively. The work attributed the poor acceptance to a number of factors including lack of adequate information, distance to recycling centers, time constraints and limited space in bins as the major factors affecting community participation. However, the results obtained from this study is considerably encouraging and show that the majority of the town

folks may quickly embrace and adapt to the process of waste segregation at source willingly.
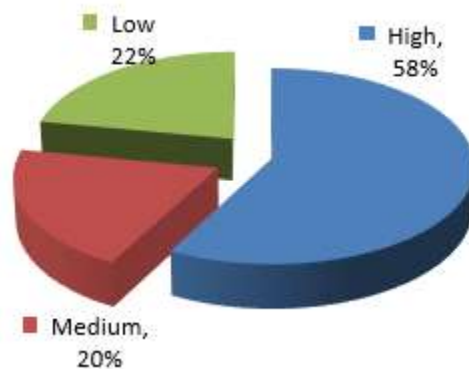

Fig 2: Responsiveness of the households to waste separation at source

Waste Quantification: Figure 3 presents the quantities of waste generated by the household on a daily basis. The average waste generated per day was 3.49 kg/household and a total of 570.45 kg of combined waste was recorded for the entire duration. This resulted in a per capita combined waste generation of approximately 0.32 kg/day. With a population of about 3000 inhabitants, total waste generation in Kushea was estimated to be about 1 ton/day. Even though this pales in comparison to waste generated in big cities like Accra and Kumasi, there are several such communities in Ghana with similar socio-economic characteristics and population size. The cumulative effect of such high generation of household waste in rural communities, which are often not accounted for nationally, could be devastating and catastrophic. The quantity of waste generated was largely dependent on factors such as lifestyles, cultural practices, economic status, literacy rates and the eating habits of the households. The per capita waste generation is generally lower by 0.15 kg/day than the reported national average of 0.47 kg/day but slightly above the national average of 0.28 kg/day in the districts where majority of the rural communities are located as reported by Miezah et al. (2015). A variation in the daily generation rate was observed. Waste generation was higher and above the average on days 4, 5, 6, 7 and 8. However, the highest daily generation rate was observed on days 5 and 6. These days happen to be Saturday and Sunday. As a predominant farming community, many households spend most of their time in the farms during the day resulting in lower waste generation by the households. Rather, afternoon meals and sometimes dinner are prepared on the farms. Secondly, Saturdays and Sundays are set aside for big social events like weddings and funerals in the community. During these periods, the households prepare a lot of food at home which leads to increased

waste generation. Additionally, such events attract foreigners and visitors from the major cities and the visitors contribute to waste generation in the community during these periods. As noted by Mateu-Sbert et al. (2013), a 1% increase in tourist population in Mediterranean Island of Menorca leads to an increase of 0.282% in municipal solid waste in the region. A similar study on the effect of tourism on waste generation potential by Martins and Cro (2021) over a period of 22 years (1996-2018), in the Madeira Island concluded that tourism accounted for 41.9-46.6% of the solid waste generated in the region. Even though visitors to Kushea for social events on

Saturdays and Sundays cannot be classified in the strictest of sense at tourists, they swell up the live population during these days and therefore have a high tendency to contribute to increased waste generation. Thus, like tourists, it can be inferred that the influx of people into a community contributes to increase in MSW generation and this could be the case in Kushea as well. Lastly, most families prepare their traditional meals during the weekends. Traditional meals like "Fufu", "Ampesi" among others generate significant amount of waste and thus could contribute to the increased generation rate during the weekends
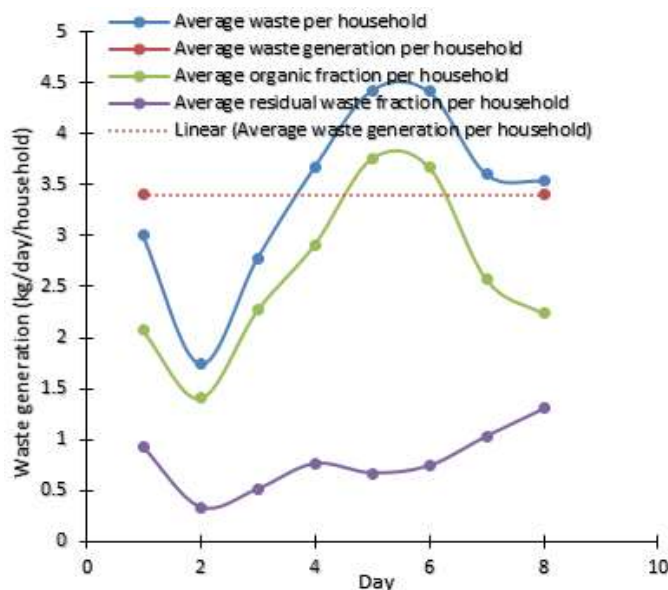

Fig 3: Waste generation per household for the duration of the study

Waste composition: Figure 4 shows the composition of waste generated in the Kushea community. The organic component of the solid waste generated was found to constitute about 77% of the entire waste. This comprised mainly of foodstuff residues and food waste. The huge organic fraction was in agreement with figures reported by Miezah et al. (2015), where the organic fraction of municipal household waste was found to be about 67%. The residual waste comprised packaging materials such as plastics, paper, glass, and used clothes of total waste generated. The per capita of the residual waste was found to be 0.028 kg/person/day which was far below the national average of 0.53 kg/day/person as reported by Miezah et al. (2015) and Ofori-Boateng et al. (2013). It is instructive to know that the study area is largely rural in nature with very little sophisticated lifestyles. Family meals are prepared and eaten at home from fresh agricultural produce rather than processed food. As a result, it is expected that the residues of the

foodstuff will increase the fraction of biodegradables in the waste stream.
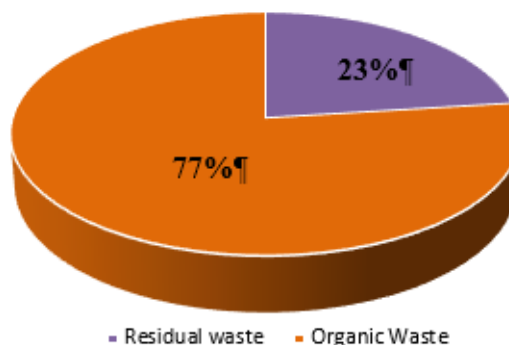

Fig 4: Waste Composition by fraction

Proximate Analysis: Proximate analysis of the waste stream is usually essential to select the most appropriate waste treatment method. Results from the proximate analysis of the waste stream are presented

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in Table 1. The waste was generally found to be wet with a moisture content of about 68.6%. This is largely expected due to the dominancy of the organic component of the waste. Total solids fraction was found to be about 31.4%. The volatile organic compounds were also found to be about 85.45% of the total solids. The waste stream has total ash content after combustion of about 14.55% and fixed carbon content of 48.83%. The results obtained were in consonance with similar waste characterization study undertaken by other researchers; Fobil et al. (2005) and Adu and Lohmueller (2012) reported greater than 50% moisture content for municipal waste generated in Ghana. These results were further corroborated by Kuleape et al. (2014) in another study carried out in Akosombo, an urban community in Ghana where they reported moisture content of between 25-76% of the municipal solid waste generated in the community and percentage ash content between 2.2 – 19.0%.

Table 1: Results of proximate analysis of the organic fraction of the waste

Parameter	Moisture	Total Solids	Volatile Solids	Ash	Carbon
Units	% OS	% OS	% TS	% TS	% TS
Average	68.60	31.40	85.45	14.55	48.83
RMS	68.82	31.86	85.62	15.55	48.93
Standard Deviation	5.79	5.79	5.86	5.86	3.35
Coeff. of variation	0.03	0.07	0.02	0.14	0.02
Standard Error	2.05	2.05	2.07	2.07	1.18
Conf. Level (95.0%)	± 4.84	± 4.84	± 4.90	± 4.90	± 2.80

NB: OS = Original Sample; TS = Total Solids

Treatment options: Communities such as the study area with such a small population often do not attract the attention of the government to manage their waste. They are mostly left on their own to devise sustainable means of managing their waste. As such, opting for high-technology means of waste treatment might not be sustainable. More so, the technical capacity to manage and maintain such equipment may be a huge barrier due to the relatively low level of literacy in such communities and the general absence of vibrant economic activities. Most appropriate waste treatment strategies employed over the world consider the integration of value addition processes. Some of these processes are recycling, biological treatments and disposal on engineered landfills with energy recovery (Boyea *et al.* (2010)) and (Rentizelas et al. (2014)). Given the characteristics of the waste at Kushea, although incineration is considered to be cost-effective, thermal treatment cannot be considered as a waste treatment option for the entire waste stream of the study because of the high moisture content of the organic fraction. A significant amount of energy will have to be used to dry the wet material to ensure clean and efficient combustion (Sun et al. (2015)). This will increase the cost of operation, thus, making it an expensive option to pursue. However, successful implementation of the waste segregation at source can lead to plastics and other high calorific waste materials being collected separately and combusted in a controlled manner to generate energy that can be used for heating as suggested by Rentizelas et al. (2014) or just to reduce the volume of waste entering the disposal site. Composting of the organic fraction comes up as a better option due to the high organic fraction of the waste. Generally, one (1) ton of composite is considered as equivalent to 7.1 kg N, 4.1 kg P_2O_5 and 5.4 kg K_2O (McDougall et al. (2001)). This nutrient recovery option on a large scale can supplement, if not replace, the nutritional deficiency of Kushea farmlands since farming is the mainstay of the local economy. Also, composting would be a comparatively cheaper option, especially with the windrow system which is easy and cheap to manage and maintain. Low-technology composting at the decentralized level could also generate jobs and become sustainable if the process is linked to organic farming. This notwithstanding, further study is required to establish the nutrient content of the organic fraction to justify the choice of composting. Even though bio-gasification may not be considered as a waste management option according to Couto et al. (2014), given the high organic fraction of the solid waste stream at Kushea coupled with the high volatile solids content, digestion of the organic fraction to generate biomethane is considered as a feasible option. Therefore, composting using low-cost technology coupled with biomethane generation are recommended options for Kushea community. Considering the low level of plastic waste generated, the community can, for instance, consider innovative use of plastic waste such as making of pavement blocks for use in the community or can collect them in large quantities, in a controlled manner, and sell to recycling companies in other parts of the country. In recent times, thermal cracking of plastics to generate fuel has become of interest however, the health implications of the toxic gases released as well as the inhalation of black carbon have been thoroughly investigated and thus may not be recommended in the interim but could be a viable option in the near future.

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Conclusion: We have studied the potential of waste sorting at source of Assin Kushea (a rural community) which are often not considered in national waste management policies. Through sensitization and public education, the Kushea community cooperated and responded positively to waste sorting at source. Laboratory analysis showed that the organic fraction is very wet with high volatile organic compound fraction. As a result, composting or anaerobic digestion is recommended. This case study can serve as basis for policy direction as well as a baseline study for other rural communities across Africa.

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