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Municipal Solid Waste Management and Characterization in Aksum and Shire-Endaslassie Towns, North Ethiopia

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Abstract
The municipal solid waste (MSW), generated from different activities in the township and city areas is a subject of deep concern for its proper management. The improper management of the MSW is a major cause for water, air and soil pollution. Despite some progress, municipal solid waste (MSW) still poses pressure on Aksum and Shire Endaslassie towns and remains one of the major challenges in environmental management. This study mainly focuses on the technical and regulatory arrangements and characterization of municipal solid waste in both Aksum and Shire Endaslassie towns to identify strategies to improve the present situation. The data for the study was collected through measurement, direct observation and by preparing questionnaires and through discussion together with the experts. The solid waste generation rate (GR), uncompacted density, and weight percentages of combustible and incombustible materials were determined based on the collected data. The results show that the average GR and uncompacted density were 0.54 and 0.49 kg/capital/day and 362.5kg/m^3 and 355kg/m^3 for Aksum and Shire Endaslassie town respectively. The composition of the waste generated in Axum town is dominated by food wastes, grasses and leaf characterized as 'decomposable' (36%) followed by plastic (21%), Ashes (17%) and Paper and cardboard contributed 8%. In the same manner the composition of the waste generated in Shire Endaslassie is predominantly food wastes, grasses and leaf characterized as 'decomposable' (43%) followed by Ashes and dusts (21%), plastics (8%), and Paper and cardboard contributed 7%. The remaining waste, including metals, glass, rubber/leather, textiles, and others accounted for less than 18% and 21% for both Axum and Shire Endaslassie towns respectively. The analysis also indicated that solid waste management capacity for both cases was under stress due to different reasons. Currently, the overall technical arrangement, including storage and discharge, collection and transport, and disposal, is still in poor condition, which leads to environmental and health risks. Finally, it is recommended that these problems should be solved in an integrated manner by improving legislation, environmental education and solid waste management facilities so as to reduce the risk on environmental and public health.
Keywords: Solid waste, characterization, generation rate, disposal, solid waste management

1. Introduction

Urbanization and modernization have rapidly increased the rate of municipal solid waste (MSW) production and disposal in many cities around the globe; therefore, waste management is a major concern in most cities in developing countries (Zhen-Shan *et al*., 2009). According to Tanaka (2006), the generation of solid waste is expected to increase steadily along with economic growth if a lifestyle of mass production, consumption and disposal is continued. Recently, there have been growing concerns about the environmental effects associated with solid waste management, as well as the increasing costs that solid waste management entails. How to address these increases has become an important issue. Inappropriate solid waste management causes air, soil, and water pollution. The solid waste materials block drainage systems, causing overflows during rainy seasons especially in urban regions. Furthermore, the arbitrary dumping of waste pollutes ground and surface areas. Classically, dumped solid wastes will generate a huge amount of polluted leachate that contains high concentration of toxic compounds which can cause severe damage to the ecosystem (Foul *et al*., 2009).

The most visible implication of rapidly urbanizing is, the increasing generation of municipal solid waste. A highly neglected problem with severe health and environmental implications, local governments are desperate to find highly effective, practical solutions for improving solid waste management (SWM) with limited budgets. Moreover, the urban poor suffer disproportionately from bad environmental sanitation, particularly informal waste collectors and recyclers, resulting in illness caused by water- and vector-borne disease. Therefore, SWM has a vital role to play in achieving the Millennium Development Goals in health and environmental sustainability. Although a costly and complex issue, effective delivery of waste management infrastructure and services is essential to improving the health, environment, and overall quality of life for all urban residents (Singha and Pandey, 2001).

Obviously, a reduction in the quantity of generated waste materials minimizes their impacts on the environment. Solid waste matter must either be recycled or reused. When these alternatives are unsuitable, waste must be incinerated with energy recovery and only as a last option, should landfills be employed (Messineo & Panno, 2008). According to Khatib & Al-Khateeb (2009), segregating and composting organic waste, incinerating, and segregating and recycling certain wastes should be considered as management options depending on the efficiency of the proposed collection and landfill measures. In order to determine the practicability of such alternatives, studies on the quantity and composition of solid waste are considered essential. Idris *et al*. (2004) indicated that information regarding the composition of solid waste provides critical data for the formulation of new waste management plans. Waste minimization cannot be carried out effectively without reliable waste composition data. Sufficient waste composition data are required to evaluate the impacts of certain types of waste and to estimate a landfill's life. The composition of the waste varies from time to time and from place to place.

Solid waste management (SWM) is far from a new phenomenon in Ethiopia; It is, however, only in the last few years that the waste issue has moved up on the country's development agenda and received substantial interest. The issue of SWM is addressed in several ways and from different angles. First, the plan states that comprehensive project preparations should be undertaken for all towns and cities for both solid and liquid waste treatment and recycling. However, the existing infrastructures for solid waste collection, transportation and management are not enough. Besides, to upgrade the knowledge and awareness of the community needs much effort. Axum and Shire Endaslassie, as an emerging towns in a developing country, have series problems of solid waste management. The management of solid waste is undertaken by the municipality of town. Several reasons are given in order to explain the poor status of municipal SWM programmes. A lack of financial and human resources as well as organizational inefficiency within municipal bodies are said to cause a lot of trouble. On the other hand, only limited surveys were conducted so far regarding its solid waste generation rate and composition and this in turn creates big problem to manage the waste. As a result the objective of this research is to evaluate the existing solid waste generation rate, characterization and management activities in Axum and Shire Endaslassie towns.

2. Methodology

The research process

This case study research used both quantitative and qualitative data collection techniques. The research design comprised four parts: literature review, gathering and analysing quantitative data, gathering and analysing qualitative data collected through interviews; developing policy-related recommendations for the municipality, and drawing conclusions about the usefulness of the criteria developed for this study for assessing sustainable solid waste management.

Sampling

In any sample survey, sample size determination is an important step. To determine sample size of households those to participate in the study, a sample technique (formula) was used,

$$n = \frac{NZ^2 PQ}{d^2(N-1)+Z^2PQ} \dots\dots\dots\dots\dots \text{Equation 1} \qquad (1)$$

Where n = sample size of housing units
P = Housing unit variable
Q = 1-P
N = Total No of housing units
Z = Standardized normal variable and valued that corresponds to 95% confidence interval equal to 1.96
d = Allowable error (0.05)

Data collection

The household solid waste monitoring in Axum and Shire Endaslassie towns is based on analyses of waste collected on four different collection routes. Daily household solid waste amount was collected from each town throughout one year both in the dry and wet seasons. Samples were collected three times from 140 samples of Aksum and Shire Endaslassie towns. The samples in each quarter were selected randomly from each kebels equally and Aksum town has four kebels and Shire has five kebels therefore, 35HHs and 28HHs were selected from each kebels of Aksum and Shire towns respectively.

The collection of the samples was based on the number of persons per family, district, and duration (storage time). Special forms were prepared for the purpose of sample collection. These forms contained the following information: name, number of persons in the family, district, duration (storage time), date, and volume (m^3) and amounts of garbage, plastic, paper, metal, glass, cloth, and total weight (all in grams) of waste. Samples were collected in special plastic bags and each plastic bag was weighed separately.

In addition to this, interviews with key informants were conducted in order to generate qualitative data. Interviewees were selected from four groups on an opportunistic basis: Family members, people involved in the design/implementation of the solid waste management program; experts in waste management; and experts in policy design/implementation.

Data analysis

The collected samples were analysed to obtain their characteristics in the following manner.

Generation rate: generation rate (GR; weight of waste produced by person per unit time) was determined based on a weight–volume analysis,

$$GR = \frac{\text{Weight of solid waste(g)}}{\text{Population}*\text{Duration(day)}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation 1} \qquad (2)$$

The reason for measuring GR is to obtain data that can be used to determine the total amount of waste materials to be managed. The use of detailed weight–volume data obtained by weighing and measuring each load will certainly provide better information on the density of the various forms of solid waste at a given location. Data for the whole municipality was calculated as a weighted average considering the numbers of inhabitants in different urban areas.

Bulk density: Bulk density (kgm^{-3}) of solid waste is defined as the weight of waste per unit volume of uncompacted waste. Density is a significant criterion for the evaluation of storage, collection, transportation, and landfilling of waste (Yousuf & Rahman, 2007). A bucket with known volume was used as a container for measuring waste volume. The value of bulk density was evaluated using,

$$\text{Bulk density} = \frac{M1-M0}{V} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation 2} \qquad (3)$$

M_0 is the mass (kg) of the measuring bucket; M_1 is the mass (kg) of the measuring bucket and its contents; and V is the volume in m^3 of the measuring bucket.

Solid waste characterization: the collected solid wastes were divided into different components. The weight percentages (%) of domestic solid waste components were determined in this study for decomposable (food wastes, grasses and leaf), plastic, paper, metal, glass, textile and Ashes and dust wastes. The remaining waste consisting of hair, bones and small pieces of charcoal was categorized as 'other'. Each material fraction was weighed after the sorting.

Combustible and incombustible materials: the weight percentages of combustible and incombustible materials are calculated in the following manner.

Combustible material (%) = Plastic (%) + Paper (%) + Textile (%) (4)

Incombustible material (%) = Metal (%) + Glass (%) (5)

Recyclable materials: In this study, plastic, paper, metal, and glass are considered as recyclable materials due to their valuable and potential for recycling.

3. Results and discussion

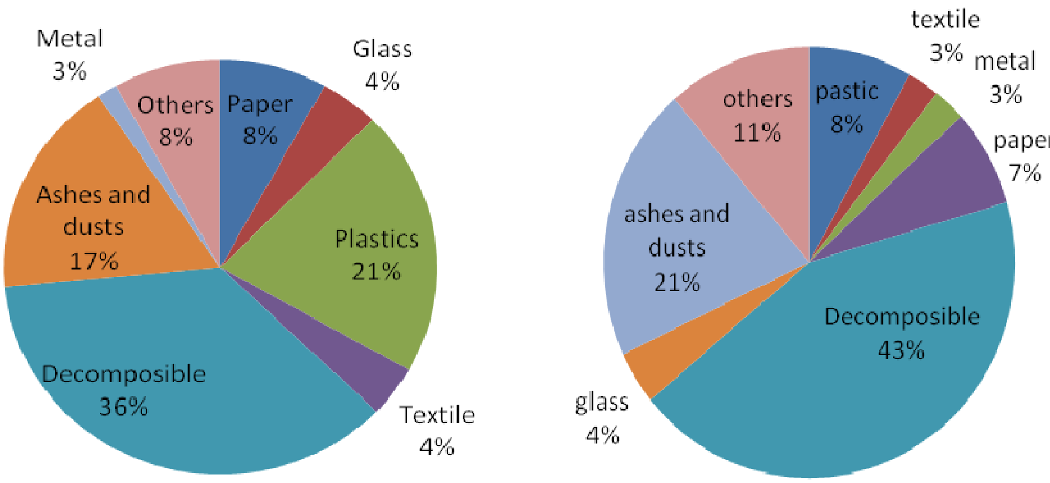
Solid Waste Generation

The result of the analysis shows that the average daily solid waste generation per individual was estimated at 0.54 and 0.49 kg/capital/day for Aksum and Shire Endaslassie town respectively. Generally, the amount of solid waste generated daily in 2013 is 313.33 and 263.57 quintal in Aksum and Shire Endaslassie towns respectively. However, only limited amount is collected and transported and the decomposable parts of this have been segregated and used for compost production while the rest has been taken to the disposal area.

Solid Waste Characterization (Composition)

The solid waste components were determined after sorting a known weight of sample in to different waste streams and weighing the sorted components separately. The waste characterization was conducted twice, in January and in July-August 2013 representing the dry season and the rainy season, respectively.

The result of the study showed that the municipal solid waste is an aggregate of all substances ready for disposal. The composition of the solid waste was almost homogenous in nature across the study areas. The solid waste (Figure 1 (a) and (b)) consisted predominantly plant origin while the animal and the industrial origin were very small in most of the samples. Of the plant source, vegetable residues take the greatest portion. Overall composition includes paper, plastic, vegetable peelings, ashes, grasses, used shoes, pieces of cloth, small bottles etc. However, the waste aggregate more frequent in the whole mass of household waste was house sweeping, which is composed of soil and dust followed by pieces of paper and vegetable peelings.



(a) Aksum (b) Shire Endaslassie

Figure 1 Solid Waste Composition of Aksum (a) and Shire Endaslassie (b) towns

The pie chart on Figure 1 (a) shows the solid waste composition of Aksum town. The solid waste consisted predominantly of food wastes, grasses and leaf characterized as 'decomposable' (36%) by weight followed by plastic (21%). The proportion of the Ashes and dusts was 17% and paper and cardboard contributed 8%. Various other fractions constituted the remaining 18%. However, on the landfill site there was a lot of paper and card board in which its source is mainly from Aksum University. The amount of ashes is exaggerated because the source of energy for the community in the study area is from natural forests and charcoal. Some waste fractions were not found in the waste stream. This can be explained by the recycling and reuse of waste in the informal sector. For example, Iron materials and old rubber shoes are collected and sold to small traders who subsequently sell them to retailers.

In the same manner the solid waste composition of Shire Endaslassie town was described on Figure 1(b). However, there are some changes in composition percentages from the composition of Aksum town and this may be due the socio economic and living condition variation of the communities in the towns. As illustrated on Figure 1(b), the largest percentage of solid waste food wastes, grasses and leaf characterized as 'decomposable' (43%) followed by ashes and dusts (21%) which is higher than in Aksum. The lowest amount of solid waste type in both towns is metal and this is because nowadays any metal is collected and sold by the collectors to the retailers.

Finally, the result has been summarized by grouping according to their importance for recycling, reusing or incineration to get energy. Therefore, if the solid waste management technologies were implemented properly only 25% to 32% of the solid waste collected can be disposed for Aksum and Shire Endaslassie town respectively. The rest can be changed into beneficial resources rather than a waste.

Table 1 characterization of the SW composition according to their importance

S.No.	Characterization	Solid waste type	Total percent	
			Aksum	Shire Endaslassie
1	Recyclable	Decomposable, paper and plastics	65	58
2	Combustible	Paper, plastic and textile	33	18
3	Incombustible materials	Metal and glass	6	7
4	Others	Ashes and others	25	32

Existing Solid Waste Collection and Transportation

Solid waste collection of both towns is being implemented by house to house using trucks and horse cart. By using these mechanisms in both towns the SW collectors have addressed once for residential users and twice for offices weekly.

Figure 2 Solid waste transportation mechanisms

The type of solid waste collection is commingled that is mixed of all wastes, however, recently in Shire Endaslassie town the municipality declares to the community to separate the solid waste at home in each households into two bags. The red bag for non decomposable and the green bag for decomposable solid wastes.

Existing Solid Waste Recycling and Reuse

Now a day's solid waste recycling and reuse is being practiced in both towns of the study area. Solid waste segregation and then composting process has been carried out in the compound of the disposal area. From the collected solid waste around 36% in Aksum town and 43% in Shire Endaslassie town was used for composting process. The area selected for recycling or composting of decomposable organic wastes is easily manageable because it is inside the compound of disposal area. However, in Aksum town during the rainy season the composting pits will be filled with water due to run off coming from the surrounding and the composting process will be interrupted during that time.

Figure 3 Separations of decomposable solid wastes and composting pits preparation

Moreover, the group of people involved on the activity of solid waste management will be replaced annually by other groups or may have a renewed contract and during the transition period totally the solid waste collection, transportation and composting process will not be carried out.

Existing Solid Waste Disposal

The existing solid waste disposal (SWD) of both towns is located around 1.5 to 2km distance from the town border. Generally, the existing solid waste disposal system of both towns does not follow adavnced and improved methods and one of the major risks which are expected are surface and ground water pollution. Other problems of the disposal areas is the bed for disposal is not lined and does not have any drainage system which collects the leachate therefore, the leachate easily joins to the groundwater and this toxic liquid causes high pollution.

Figure 4 ways of solid waste disposal in the area

4. Conclusion and recommendation

The daily per capital Solid waste generation of both Axum and Shire Endaslassie towns was found to be 0.54 and 0.49 kg/capital/day respectively. This figure is higher as compared with the solid waste generation rate which is assumed by municipality of both towns (0.18 and 0.15 kg/capital/day respectively) to be as average and plans have been provided based on that rate. Therefore, the municipalities should take ground assessment to develop further plans to tackle the increasing solid waste load on the system. The composition of the waste generated in Axum town is dominated by food wastes, grasses and leaf characterized as 'decomposable' (36%) followed by plastic (21%), Ashes (17%) and Paper and cardboard contributed 8%. In the same manner the composition of the waste generated in Shire Endaslassie is predominantly food wastes, grasses and leaf characterized as 'decomposable' (43%) followed by Ashes and dusts (21%), plastics (8%), and Paper and cardboard contributed 7%. The remaining waste, including metals, glass, rubber/leather, textiles, and others accounted for less than 18% and 21% for both Axum and Shire Endaslassie towns respectively. With this high portion of decomposable waste, composting of the waste and using the compost as an organic fertilizer would be the best option for sustainable municipal solid waste management in both towns. In the Study area it has been shown that technical arrangements in terms of storage, discharge, collection and transport, and disposal are neither sanitary nor environmentally acceptable. The waste collected from the households, community dust bins and road sweeping is transported and dumped on the outskirts of the towns is considered as its management. The availability of the waste land in the outskirts facilitates the unscientific method of disposal. The environmental impact factor is being ignored. Therefore, it is important to improve municipal solid waste management practices together with strict enforcement of regulations from the national to the local level.

The current institutional effectiveness, monitoring and enforcement of municipal solid waste management practices needs to be improved with a clear characterization of waste and waste management practices. The responsibilities of all stakeholders (residents, industries, hospitals, and private service providers) need strengthening, while sufficient resources need to be allocated for monitoring and enforcement. The public must be made aware of the negative consequences of improper waste management practices, and also their accountability in paying for better waste management services. Further, the environmental education should be targeted to every sector. Generally, the existing soild waste collection, transportation and disposal system should be improved. The 3R's principles (reduction, recycling and reuse) should be introduced at house hold level and by organizations. The landfill area in both towns should be upgraded to protect the percolation of leachate and to control the hazardous and infectious solid wastes.

References

Christensen TH (2011) Introduction to waste management. In: Christensen TH (ed.) Solid waste Technology and Management. Chichester, West Sussex, UK: Wiley, p. 3–16.

Diaz L.F., Savage G.M., & Eggerth L.L. (1999) Overview of solid waste management in economically developing countries. In: Proc. Of Organic Recovery and Biological Treatment, ORBIT 99, Part 3,pp. 759–765. Rhombos, Berlin, Germany.

Fauziah SH and Agamuthu P (2009) Sustainable household organic waste management. Malaysian Journal of Science 28: 135–142.

Foul AA, Aziz HA, Isa MH and Hung Y-T (2009) Primary treatment of anaerobic landfill leachate using activated carbon and limestone: batch and column studies. International Journal of Environment and Waste

Management 4: 282–298.
Gentil EC, Gallo D and Christensen TH (2011) Environmental evaluation of municipal waste prevention. Waste Management 31: 2371–2379.
Idris A, Inanc B and Hassan MN (2004) Overview of waste disposal and landfills/dumps in Asian countries. Journal of Materials Cycles and Waste Management 6: 104–110.
Khatib I and Al-Khateeb N (2009) Solid waste treatment opportunities in the Palestinian authority areas. Waste Management 29: 1680–1684.
Jin J, Wang Z and Ran S (2006) Solid waste management in Macao: practices and challenges. Waste Management 26: 1045–1051.
McDougall, F., While, P., Franke, M. & Hindle, F. (2002) Integrated Solid Waste Management: A Life Cycle Inventory. Oxford, UK: Blackwell.
Messineo A and Panno D (2008) Municipal waste management in Sicily: practices and challenges. Waste Management 28: 1201–1208.
Patel M, Lal, Rajnikant Jain, et al. (2010) Assessment of the municipal solid waste & status of implementation of municipal solid waste (management & handling), rules, 2000 in the state of Madhya Pradesh, 2008 – A case study. Waste Management & Research 29: 558–562.
Tanaka, M. (2006) Symposium on the Challenge of Asian toward 3Rs. Okayama University, Japan. Retrieved from http:/ www.env.go.jp/ recycle/3r/en/asia/02_05/01.pdf (accessed 20 April 2010).
Yousuf TB and Rahman M (2007) Monitoring quantity and characteristics of municipal solid waste in Dhaka City. Environmental Monitoring and Assessment 135: 3–11.
Zhen-shan L, Lei Y, Xiao-Yan Q and Yu-mei S (2009) Municipal solid waste management in Beijing City. Waste Management 29: 2596–2599.

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