Generation, Composition and Characteristics of Urban Solid Waste in a Major Khat Producing and Marketing Area in Eastern Ethiopia

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Abstract- **Empirical knowledge about urban solid waste is essential for planning and implementation of proper waste management systems. Thus, the objective of this study is to characterize the solid waste generated in a rapidly growing town of Aweday. For this, randomly selected samples of 93 Households (HHs), 23 *Khat* Rooms, 17 street Shops and a *Khat* Market centre were involved in the study. Wastes, collected from all these sources, were characterized for a week. The finding showed waste generation rates were 5.55 kg HH^{-1} day^{-1}, 5.48 kg $shop^{-1}$ day^{-1}, 67.15 kg $Khat$-$room^{-1}$ day^{-1} and 11,745 kg $Khat$-$market^{-1}$ day^{-1}. Moreover, the finding indicated that about 57,039 kg of total waste generated daily in Aweday town. Household waste formed the highest average daily amount (51%) and the *Khat* Rooms ranked second (25%) while those from the Market (21%) and Shops (3%) followed. The wastes from each source were categorized into 11 components. Mixed leaves of *Khat*, *garaba*, constituted the largest (75%), followed by miscellaneous materials (14%) and plastics (3.3%). Bones, glasses, leathers and metals wastages were minor fractions across generators. The generation of waste positively correlated with family size, monthly income and educational levels of the households. The results indicts the high organic content of the waste spotlight the necessity for frequent collection as well as an opportunity to give top priority to the recycling of the organic waste materials through composting as waste management approach in Aweday. An addition, the charge of waste collection and disposal should be fixed according to the quantity of waste generated.**

Keywords--Urban solid waste, Khat, waste generation rate, waste composition, waste management, Ethiopia

I. INTRODUCTION

Solid waste management (SWM) continues to be a major concern in urban areas throughout the world. Particularly, in the most of developing countries, where SWM is highly neglected, the overall environmental management is ever deteriorating [12]. Only very recently, some developing nations are awakening of the serious consequences of improper handling of solid waste [15]. In most of the low- and middle-income countries, SWM draws on a significant proportion of their municipal budget. Yet, solid wastes pose a serious threat to the environment and public health almost in all of these countries [1].

Ethiopia is no exception. In many cities and towns of Ethiopia, waste management is poor. According to Tewodros et al. [17] solid waste is dumped along roadsides and in the open areas, and is seriously endangering the health and wellbeing of Ethiopian population. Observation shows this is the worst in the commercially active town of Aweday. Aweday is a small town of about 25,000 populations in Eastern Ethiopia. It is known for its high production and commercial exchange of Khat (Catha Edulis Forskal). Khat is consumed for its stimulating effect. The vast majority of the population consumes Khat. Moreover, a considerable size is exported to domestic towns and cities and abroad to Djibouti and North Somalia.

Despite increasing and high revenue collected from the Khat trade, the ever-increasing amount of solid waste arising from it, locally called Garaba, has remained one of the major environmental and social threats. Piles of solid wastes, including Garaba, are observed everywhere in the town – along the roads, in between the Shops, around the houses, in public roadways, streets, drains, playgrounds and other vacant lots. According to some health workers and professionals, in the Aweday town, the vast majority of patients visiting clinics are victims of respiratory and other diseases triggered by these wastes. Some of these wastes might contain even hazardous and non-biodegradable waste components. This situation is making the emerging town of Aweday hostile and unattractive to the inhabitants and visitors. Thus, establishing effective solid waste management systems is the key to not only beauty but also survival and productivity of the population of Aweday.

The answer to starting a successful USW management system not only depends on the availability of adequate funds but also on proper planning and design of the system using accurate planning tools and reliable data [6]. However, such data are usually non-existent in many developing countries [9], including Ethiopia. In response to this identified gap and as a pre-requisite for proper and informed planning of waste management systems, Haramaya University (HU) collaborated with Aweday Municipality, designed a project in order to find proper SWM systems in Aweday context, thanks to the financial assistance of the Switzerland's National Center of Competence in Research (NCCR) North-South. This study is an essential preliminary step towards this goal.

Therefore, as a part of the NCCR, PAMS (Partnership of Action for Mitigating Syndromes of global change) project, the main objective of this study is to carry out a field survey and laboratory investigations as regards the generation, composition and characteristics of the solid waste abounding

the town of Aweday. Specifically, it aims at examining the daily amount of solid waste generation and compositions; the daily per capita solid waste generation; the bulk density and moisture content of the waste; and correlation of waste generation rates with relevant socio-economic parameters of households.

It is believed that, the study will spotlight not only the casual dynamics of the problem, but will also serve as baseline data to illuminate ways of designing and implementing theoretically and pragmatically informed waste management systems for Aweday town. Moreover, as common problem across Ethiopia, the finding would transfer to other towns.

II. MATERIALS AND METHODS

A. Overview of the Study Area

The study was conducted in Aweday town, which is located between 42°2'0" E and 42°3'30" E longitudes and 9°20'45" N and 9°21'45" N E latitudes in Eastern Hararghe Zone of Oromia Region. According to Oromia regional state Urban Development Bureau, the population of Aweday increased from 12,688 in 2004 to 23,670 in 2007 showing higher rate of urbanization. Aweday is surrounded by a mountain range of approximately 2000 m above sea level. Khat is a major cash crop cultivated in most parts of Ethiopia. Particularly, it is a backbone of the economy in Eastern Ethiopia. Khat involves large numbers of people in growing, harvesting, sorting, packing, transporting, loading, and unloading of the commodity. Administratively, the town is divided into 2 Kebeles and 6 "zones" (3 each). In the town, there are total number of 5,245 HHs, 216 Khat Preparation Room (KtPrRs), 307 commercial street Shops (CStShs) and a Khat Market Centre area (KtMart).

B. Sampling Techniques

The field data was collected from 2-8, June 2010 in the PAMS project site of Aweday. A sampling frame consisting of the 6 administrative zones of the town with total residential units of 5,245 was obtained from office of the municipal administration. A stratified sampling method was employed based on two major waste generation sources, the residential homes and the commercial units. Targeted sampling units from 3 conveniently selected study zones, Zone-6, Zone-7 and Zone 8, that comprise residential homes (2610), KtPrRs (211), CStShs (138) and the Khat Market Area were selected.

To enhance the validity and reliability of the data, the sample size was determined using general statistical methods as described in [16]. That is, a 95% confidence interval (CI) and a pre-defined sampling error of 10% for the two strata. From 2611 residential homes, a sample size of 93 was selected by simple random sampling. With the same technique, 75 commercial units were selected from 349 units available in the selected zones, which in turn were allocated by proportion between KtPrRs (45) and CStShs (30). The KtMart (1) was also included in the study, for it is a major solid waste generation site in the town.

C. Sample Collection, Sorting and Measurement

The waste sample was collected by four groups of sixteen individuals (four in each group) assigned to the study zones: (1) eight senior undergraduate students from the Department of Environmental Science, Haramaya University, (2) four enumerators who completed secondary school from Aweday, and (3) four assistants. Before the actual collection was started, all were trained in the field in order to establish common understanding on the planned activities. They also visited the study area, and identified and labelled each survey units with unique identification codes. Moreover, the community participated in the study program; invitation was made to one person from each of the survey unit so that he/she would undertake and ensure that the waste generated in the area was properly collected. Scholars support this method of sample collection [2]. Waste plastic bags of 50 and 100 kg capacities, with particular coding of each survey unit, were supplied to the selected HHs, Shops and Khat Rooms. The coding was made using the two initial letters of the names of each source followed by four digit numbers. For example, the coding of Khat Preparation Room started with KP-0001. Sample collection was carried out in each chosen survey unit every day (24 hr) continuously for one week.

Every day, after the waste has been collected, a new bag, marked with the same code, was given to each survey unit for the next round of waste collection in the following 24 hrs. The waste-laden bags were transported by a truck to a convenient central place for further analysis. On the 1st day, the collected waste was discarded to ensure that the waste was generated in the last 24 hrs. Those units which failed handing in the waste accordingly were eliminated from the program. Of the 93, 45 and 30 total HHs, Khat Rooms and street Shops selected, respectively, 8.6%, 49% and 43% of them were eliminated, respectively. Thus, total waste samples of 595, 161 and 133 were collected from HHs, KtPrRs and CStShs, respectively. In the Khat Market area, the entire waste was removed, using a front-loader-machine, from the area a day before the actual date of sample collection started. From 3 to 4 full truck loads per day, a random sample of one full truck waste of 16 m3 was sampled each day over the 7-day survey period. Furthermore, a measured weight-to-volume index of the waste was used to obtain the weight of the fresh waste. The total number full-load truck was counted to determine the total weight of the waste. The composition of the market waste was obtained from composite samples by quartering of the full-load. The waste collected from each source was processed within four hours after collection. During the first visit, the team also collected the following socio-economic parameters using a brief questionnaire: (1) from households, the number of people per HH, address, age, sex, income, level of education; and (2) from Khat Rooms and street Shops, the estimated floor area (m2).

The collected waste was then processed as recommended in [19]. For daily waste generation rates, each survey unit was treated individually. All the wastes collected daily were weighed in pre-weighed bags and registered on a sampling sheet. The weight of the waste alone was obtained by difference. For each source, mixed composite samples of 50 to 170 kg were made from each bags or truck to determine the loose bulk density (BD) of the wastes using the measured

volume and weight with a calibrated bin. The BD was calculated as:

$$BD = \frac{Weight\ of\ waste\ (kg)}{Volume\ (m3)}$$

The samples were then spread flat on a clean plastic sheet (2 x 3 m2) and were manually sorted into 11 components: Food waste, Leaves, Papers, Metals, Textiles, Plastics, Glasses, Leathers, Hazardous materials and miscellaneous materials. Each component was weighed and recorded.

2 kg of composite samples of compostable and/or combustible fractions (leaves, food, soft papers and the miscellaneous) was collected in polyethylene bags and transported to the Central Laboratory of Haramaya University. The moisture content was analysed immediately. Samples of 100 g were taken in triplicate, dried to a constant weight in an oven at 105 ℃ for 24 hrs and cooled in a desiccator. The difference in weight was recorded [18]. Moisture content refers to the percentage of weight lost in drying of the sample.

III. RESULTS AND DISCUSSION

A. Demographic and Socio-Economic Characteristics

Many socio-economic and other variables influence rate of solid waste generation. Yet, in this study we assumed that all sections of different income-groups were to be included during the random sampling. The descriptive statistics of variables have emerged in this study (Table I). The results indicated that the average sample household was 6.5 persons, which is 26% higher than the regional (Oromia) average of 4.8 [4]. The average age of the respondents were about 31 year, while the average year of schooling of the respondents and the most educated member of the family were found to be 2.76 and 6.40 year, respectively. The mean monthly income of the household was 2,306.58 Ethiopian Birr (EBR). Similar types of socio-economic parameters were studied by Sujauddin et al. [11] in Bangladesh. In their study, they capitalize on family size, employment, level of schooling, duration dwelling and age.

B. Urban Solid Waste Generation

1) Sources of Waste:

When reporting the generation and composition of urban solid waste in this particular study, not all the non-household sources are included. For instance, restaurants/cafeterias, offices, schools and other institutions are not included in the sampling. Because, presumably they contribute small or insignificant size of the total solid waste generated. This was later validated and confirmed with municipal experts. Thus, only the major contributors are included, namely (1) households, (2) street Shops, (3) Khat Preparation Room and (4) the Khat Market Centre area, each which is discussed next.

2) The Generation of Household Waste:

595 samples of waste were collected from 85 residential homes during the 7 days period of the study. Results are summarized in Table 2. The daily total waste for the sample HHs (85) ranged from ~422 to 468 kg with an average of

446 kg and a standard deviation (SD) of 20 kg. This narrow range and smaller SD of the mean are indicators of small variation of the amount of HH waste over the seven days period. Moreover, during the same period, a total of about 3,302 kg or 3.3 tones of solid wastes were collected, from the total sample population of 556. Translated to a daily per capita rate of 0.85 kg for the study area, this value is far greater than the daily per capita household waste generation reported across some other towns and cities in Ethiopia; for instance are the average rate of 0.157 kg/person/day in Jimma town [10] and 0.25 kg/person/day in the capital city or Addis Ababa [21]. The value is also far greater than the average solid waste generation rates reported for low-income countries (0.4 to 0.6 kg/person/day), but it is within the range (of 0.7 to 1.8 kg/person/day) reported for fully industrialized countries [5], [3]. The high per capita generation is mainly attributed to the common practices of high consumption of Khat (mostly in groups) and high reliance on fire-wood, which concomitantly generates a huge volume of solid wastes (garaba) and ashes from individual households in the town of Aweday (Table IV).

TABLE I FREQUENCY, MEAN AND STANDARD DEVIATION OF THE PARTICIPANT HOUSEHOLD CHARACTERISTICS

Variable name	Frequency	Percent	Cumulative percent
1. Family size (persons/hh)			
1	3	3.5	3.5
2	4	4.7	8.2
3-5	24	28.2	36.5
6-8	38	44.7	81.2
>8	16	18.8	100.0
Mean = 6.52 (persons/hh), standard deviation = 2.86 (persons/hh)			
2. Age of the respondent			
14-20	6	7.1	7.1
21-30	46	54.1	61.2
31-40	26	30.6	91.8
41-50	5	5.9	97.6
>50	2	2.4	100.0
Mean = 31.05 (years), standard deviation = 8.17 (years)			
3. Years of Schooling of the respondent			
0-4	58	68.2	68.2
5-8	16	18.8	87.1
9-10	8	9.4	96.5
11-12	3	3.5	100.0
Mean = 2.76 (years), standard deviation = 3.54 (years)			
4. Years of Schooling of most educated family member			
0-4	36	42.4	42.4
5-8	16	18.8	61.2
9-10	14	16.5	77.6
11-12	6	7.1	84.7
>12	13	15.3	100.0
Mean = 6.40 (years), standard deviation = 4.97 (years)			
5. Total monthly income of the HH (EBR)			
<1000	22	25.9	28.2
1000 to <2000	18	21.2	51.3
2000 to <3000	14	16.5	69.2
≥ 3000	24	28.2	100.0
Mean = 2306.58 (ETB), standard deviation = 2178 (EBR)			

TABLE II SUMMARY OF THE SOLID WASTE GENERATION AND CHARACTERISTICS IN THE AWEDAY TOWN OVER THE 7-DAY SURVEY PERIOD

Waste generator	For the 7-day survey Period (kg)[a]			Total generator (kg)	Daily total generation (kg)[b]			Bulk density (kg/m³)			Per capita Generation /day[c]
	Range	Average per type	SD		Range	Average	SD	Range	Average	SD	
HHs	12.5-84.4	38.9	14.2	3,301.9	422.7-467.9	446.2	19.6	373-512	432	98	0.85
CStShs	7-77	42.9	23.0	729.2	99.9-233.0	120.3	45.6	210-254	226	24	0.45
KtPrR	73-980	470.1	284.4	10,811.0	1,350-1,750	1544.5	137.5	244-286	263	22	1.31
KtMart 11,745.1 kg/day	-	-	-	82,215.9	10,541-12,649	11,745.1	1,126.8	226-264	243	19	-

HHs = 85 residential HHs; StShop = 17 street Shops; KtPrRs = 23 Khat Preparation Rooms; KtMart = 1 Khat Market centre.

aThe data represents the total waste collected consistently from the individual HH in 7 days, e.g. for the ''Range'', one HH totaled 12.5 kg in 7 days while another totaled 84.4 kg in the same period in Aweday.

bPooled (i.e. all sample HHs) total waste collected per day, e.g. all sample HHs in Aweday showed lowest total waste quantity of 422.7 kg on one day and a highest waste quantity of 467.9 kg on another day.

cPer capita generation: kg/pers/day for HH; kg/m2 /day for StShop and KtPRs; kg/day for KtMart.

On an individual HH basis, the total waste collected over the 7-days-survey period was in the- approximate range of 12 to 84 kg per household with an average value of 40 kg (SD = 14). That means one household contributed a total of about 12 kg while another contributed about 84 kg during the 7-day survey. The relatively wide range (Table II, column 2) and large standard deviation of the mean (Table II, Column 4) for the study area reflects the large variation in the quantity of waste generated in the households with varying economic status. This agrees with the data presented in Fig. 2.

3) The Generation of Non-household Waste:

Non-household solid waste (NHSW), here, refers to solid wastes generated from major commercial units (street Shops and Khat Preparation Room) and the Khat Market area in the Aweday Town. The profiles of waste collected daily from these sources are also summarized in Table II. On individual unit basis, the 7-day range was 7 to 77 kg (average = 42.9, SD = 23) per Shop and 73 to 980 kg (average = 470 kg, SD = 284.4) per Khat Room. These reveal a wide range of variation occurs with waste-generation among and between Khat Preparation Room and commercial street Shops. The daily average ranges 100 to 233 kg (average = 120 kg, SD = 45.6) for the sampled Shops and 1,350 to 1,750 kg (average = 1,544.5 kg, SD = 137.8) for the sampled Khat Rooms. The wide range and large SD of the mean for the Khat Rooms indicates that there is higher variation of the total waste generated by these Rooms over the 7 days in the week. In other words, the total waste generated from Khat Rooms varies more from one day to another in the week as well as between one to another Khat Room compared to the commercial street Shops (and HHs) which are, relatively, invariable. The finding has important implications for planning solid waste management systems. For instance, introducing different rate of waste collection service fees and different waste collection frequency for Khat Rooms, which

corresponds to the amount of wastes they generate, and in contrast, considering uniform rate of waste collection fees for the street Shops.

The finding suggests that the Khat Market centre area (KtMart) needs a special consideration. The daily waste collected at this area was between 10,541 and 12,649 kg, with an average of 11,745 kg day-1 (Table II). Within the only 7-day survey period, a total of 82,246 kg or about 82 tones of solid waste was generated from this Market. This is immense size.

4) Total Generation of Urban Wastes:

Based on the emergent data, the total amount of solid waste generated in the entire urban areas of Aweday is categorized into household waste materials and non-household waste materials. In this study, data obtained from households and major commercial establishments or units are used to estimate the total waste generated in the town as a whole. In other words, some non-household waste sources such as institutions and restaurants could not be included in the total waste estimates, primarily for the season mentioned earlier and also for there is no such data reported in literature. As displayed in Table III, the analysis shows bout 57,039 kg of solid waste was generated on daily basis in Aweday in June 2010. Out of this, the household waste formed the highest component (51%) and the non-household waste from *Khat* Rooms followed (25%).

While the survey was conducted, it was observed that the municipality provides a solid waste collection service only in the Khat Market centre area (21%). At this area, the municipal trucks dispose the waste on daily basis in open areas around the town. That means, at least 79% of the daily waste generated in Aweday during the survey period was simply disposed along roadsides and into open area by the generators.

TABLE III TOTAL DAILY URBAN SOLID WASTE GENERATION FROM MAJOR SOURCES IN AWEDAY

Waste source	Generation rates	Quantity	Total qty. generated (kg day^{-1})	Distribution (%)
HHs	5.55 kg hh^{-1} day^{-1}	5,245 hhs	29,107	51
CStShs	5.48 kg unit^{-1} day^{-1}	307 Shops	1,683	23
KtPrR	67.15 kg unit^{-1} day^{-1}	216 Rooms	14,504	25
KtMart	11,745 kg unit^{-1} day^{-1}	1 Market	11,745	21
Total in 2010			**57,039**	**100**

The finding suggests urgent solid waste management planning to be in place in Aweday. For example, frequent or daily waste collection schedules for *Khat* Market area , three days a week for *Khat* Preparation Room, two days a week for HHs, and once a week for commercial street Shops. In addition, more waste collectors around HHs are required, especially for HHs since the daily total waste generated in these areas is far greater than others (See Table III).

C. Composition of Urban Solid Waste

In planning solid waste management systems, the composition of waste is as much an important consideration as its quantity. Nevertheless, this depends on food habits, cultural traditions, socio-economic status and climatic condition [7]. Table IV displays a summary of the physical composition of solid wastes collected in the survey area.

From the analysis of the sample wastes, eleven components of the waste emerged (Table IV). The composition profiles show leaved make the highest proportion for each of the four waste sources. The Khat Market waste formed the maximum organic leaves at 94%. Wastes from Khat Rooms (92%), street Shops (59%) and HHs (55%) follow. Together with the food waste fraction, about 76% of the average waste generated from Aweday was organic and bio-degradable. This value is greater than what is reported for other Ethiopian cities like Jimma, which is 60% [10]. The organic leaves waste is mainly made of leaves of Khat (garaba), and other plants leaves and grasses used for wrapping and packing the Khat. Some of the main leaves for wrapping Khat are dhumuga (Croton macrostachys), dengego (Rumex abyssinicus) and eucalyptus. That means the predominant component of the waste stream in Aweday town is mainly produced as a by-product of Khat preparation and consumption.

As is displayed in Table IV, the miscellaneous formed the 2nd highest fraction of the solid waste. HHs generates the highest fraction (34%), followed by Shops (13%). This category of the solid waste includes ashes, dusts, manures, etc. This high fraction in the HH waste is possibly related to the use of traditional fuel wood as energy source. Analysis of the nature of the ashes shows that it is very dense and appears to share the dominate weight in the overall wast.

Although the Ethiopian Government banned the manufacture and import of plastic bags of less than 0.33 mm in thickness in 2008 [13], such type of plastics are still abundantly in use across Ethiopia including Aweday Town. The plastic wastes, mainly of thin polythene type, locally called festal, and plastic bottles (mainly of packed-water) formed about 3% of the average total wastes in the study area. Shops generate 7% of the plastic wastes, while HH generates 5%, with relatively high content of bottles and festals, respectively. Festal is largely used as bag for Khat and other items in Aweday town as well as other parts of Ethiopia. Since it is use-and-throw, it is discarded everywhere and becomes part of everyday waste stream of the town, damaging the environment and regularly affecting animal health for they consume it.

Both textile (9%) and paper (8%) recorded as high in the Shop-waste category. The percentage of food waste is found to be the highest (3%) in HH category. Overall, bones, glasses, leathers and metals are comparatively of minor components of the wastes from all the sources. Although the hazardous waste fraction such as discarded dry cells and discarded medicine constituted small amount of the generated wastes, out of the HH only 0.26%, due attention should be given to separate it, at sources of its generation to avoid contamination of the potentially useful organic fractions.

Finally, the data reveal that the compostable (e.g., foods and leaves wastes) and non-compostable (remaining components) portions of the solid waste from major sources in the Aweday town were recorded at about 76% and 24%, respectively. These values agree with most values reported of third-world towns and cities. For instance, according to the World Bank, generally, all low- and middle-income countries have a high percentage of compostable organic matters in the urban waste stream, ranging from 40 to 85% of the total [20]. In developing countries, the average city waste stream is composed of over 50% organic material [8]. The large organic content in the Aweday town wastes indicates the necessity of frequent collection and removal, on the one hand, and, on the other, an opportunity for recycling of the organic wastes into valuable resources like compost.

TABLE IV TYPICAL COMPOSITION OF THE SOLID WASTES IN AWEDAY TOWN BY THEIR SOURCE (JUNE 2010)

Waste source	Waste category (w/w%), wet										
	Food waste[a]	Leaves[b]	Bones	Paper[c]	Metal[d]	Textile[e]	Plastic[f]	Glass[g]	Leather[h]	Hazardous[i]	Miscellaneous[j]
HHs	3.16	55.3	0.11	1.63	0.26	0.58	4.76	0.17	0.22	0.26	33.6
CStShs	0.79	59.3	0	8.18	1.10	9.12	7.23	1.57	0	0.16	12.6
KtPRs	0	92.37	0	0.25	0.02	0	0.16	0.03	0	0	7.13
KtMart	0.60	93.50	0	0.35	1.24	0.19	1.05	1.62	0.38	0.30	0.74
Average	**1.14**	**75.12**	**0.03**	**2.6**	**0.66**	**2.47**	**3.3**	**0.85**	**0.15**	**0.18**	**13.52**

HHs = 85 residential Households; CStShs = 17 street Shops; KtPRs = 23 Chat Preparation Room; KtMart = 1 Chat Market centre.

[a] Food waste = food remains, vegetable & fruit ,[b] Leaves = Yard waste, 'garaba' and other leaves/grass,[c] Paper = Cardboard, Packing materials/Book/ Printed materials,[d] Metals = can/tin.,[e] Textile = cloth/fibers ,[f] Plastic = containers/bottles/polythene (sheet/bag)/mobile card,[g] Glass = glasses, ceramics,[h] Leather = rubber, discarded shoes/belts,[i] Hazardous = discarded dry cells /electric parts /medical waste.,[j] Miscellaneous = ash/dust/sand/stones/pebbles/etc

D. Bulk Density and Moisture Content of the Solid Waste

The bulk density of waste is a vital parameter for planning, scheduling and designing of SWM infrastructures. Table II shows that the bulk density of the HH waste ranged from 373 to 512 kg m-3 with the average of 432 kg m-3 (SD = 98). These values are larger than the range of 205 to 370 kg m-3 reported for the capital city, Addis Ababa [21], but fall within the range (250-500 kg m-3) reported for low-income countries [5]. The bulk density of the wastes from Shops, Khat Rooms and Khat Market were much lower than for the HH waste (Table II), but fall within the range reported for middle-income countries [5]. The larger average density of HH waste sources could be due to the higher content of miscellaneous materials (33.6%) such as ashes, dusts and so forth, rather than wastes from the other sources (Table IV), which had higher content of bulky leaves or paper fractions. The density of the waste in the compactor truck after compaction recorded as high as 300 to 400 kg m-3[5]. This indicates that a compactor truck of similar volume capacity can carry HH waste equal to the quantity of waste carried by non-compacting truck, on one hand, while it can carry more than double the quantity of wastes carried by a non-compacting truck from Shops, Khat Rooms and Market areas, on the other. By implication, a compaction truck should be avoided for transportation of HH wastes due to its high density. Moreover, the implication is that, if the HH waste is simply deposited in the landfills without compaction, the life of the landfills would relatively be longer.

Likewise, the moisture content of the HH and street Shop organic wastes were about 36% and 31%, respectively. These are lower than the 40–80% range reported as typical of low- and meddle-income countries [5]. The relatively high content of Miscellaneous (dusts/ashes/etc) materials in the HH and papers in the Shop wastes may be responsible for the relatively low moisture content of these wastes, because these do not retain much moisture. On the other hand, the moisture content of wastes from the Khat Rooms and the Khat Market Centre were 55% and 62%, respectively. These values generally fall within the range reported for low- and meddle-income countries [5]. This high moisture content may be attributed to the large content of the wet leaves and

the small fraction of miscellaneous materials in the waste of each source.

E. Relationship between Waste Generation and Socio-Economic Factors

Correlation analysis was employed to identify the degree of association between waste generation rates and socio-economic factors, with the assumption that the latter determines the quantity of the daily quantity of solid waste generated by HHs. There is currently no official standard that defines the different income groups in Ethiopia. Hence, a system of grouping was devised solely for the purpose of this study.
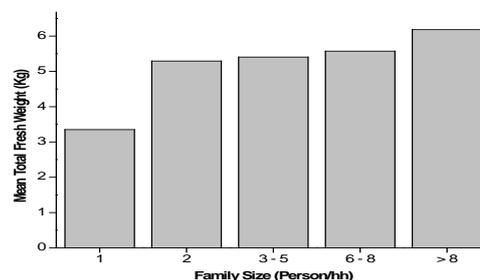

Fig. 1 Generation of HH solid waste based on family size (r =0.879; p = 0.05)

The generation of HH waste was found to be positively correlated with family size (r = 0.879; p = 0.05), which means families with more members generate a larger quantity of solid waste per day (Fig. 1).

A positive correlation was found between household income group (r = 0.468; p = 0.53) and waste generation rate. This point to the conclusion that families earning more per month have the tendency to generate a larger quantity of solid waste each day (Fig. 2) compared to those earning less. Contrary to this, the urban population is usually charged the same amount of fee for waste collection, irrespective of their socio-economic class. The educational level (number of years in school) of the relatively most educated member of the family (r = 0.837; p = 0.08) and of the respondents (r = 0.925; p = 0.07) was found to be positively correlated with

the rate of generation of SW. This reveals that the higher the level of education of a family member or the respondent, usually the head of the household, the larger the quantity of SW generated each day (Fig. 3 and Fig. 4). What is usually expected is that a family consisting of members having higher educational level generates lesser quantity of SW each day. As is observed in this study the trend emerged to be totally the inverse of this.
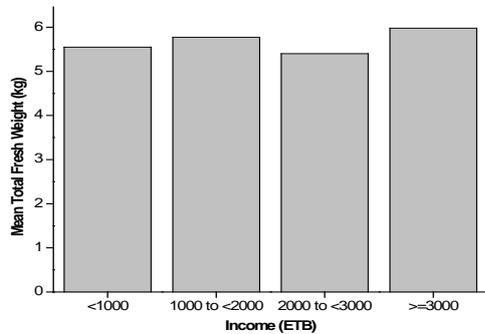

Fig. 2 Generation of HH solid waste based on monthly income in Ethiopian Birr (ETB) ($r = 0.468$; $p = 0.53$).
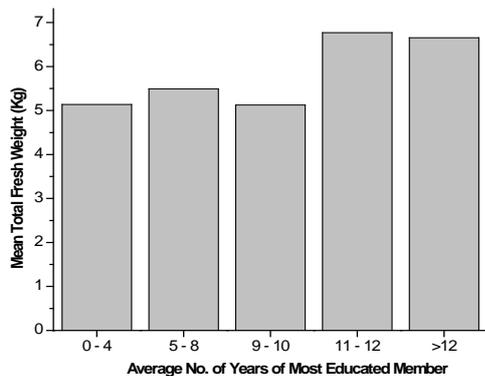
Fig. 3. Generation of HH solid waste based on years of schooling of the most educated family member ($r = 0.837$; $p = 0.08$).
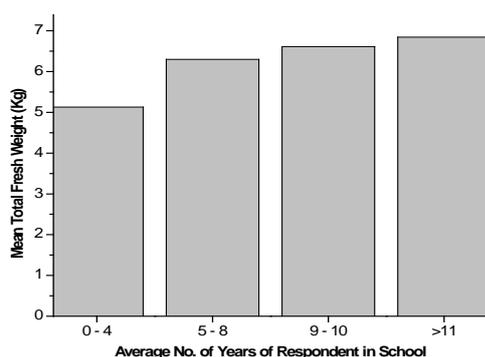

Fig. 4. Generation of HH solid waste based on years of schooling of the respondent ($r = 0.925$; $p = 0.07$).

IV. CONCLUSION

The study was performed in Aweday town for the duration of one week in June 2010. The objective is to determine the waste generation, composition and characteristics of USW from major sources and to correlate waste generation with some socio-economic parameters of households. The findings revealed that the daily per capita household waste generation rate was 0.85 kg. The generation rate on the basis of survey unit was 5.55 kg HH-1 day-1, 5.48 kg Shop-1 day-1, 67.15 kg Khat-Room-1 day-1 and 11,745 kg Khat-Market-1 day-1. These translate to 57,039 kg, which was generated on daily basis in Aweday in June 2010. Out of this, the household waste formed the highest component (51%) and the non-household waste from Khat Rooms followed (25%). In addition, the generation of waste positively correlated with family size, monthly income and educational levels of the households.

From the analysis of the sample wastes, eleven components of the waste emerged: organic leaves, food, papers, metals, textiles, plastics, glasses, leathers, hazardous and miscellaneous wastage materials. The results reveals that the compostable (food waste and leaves) and non-compostable (other components) portions of the solid waste from major sources in Aweday were recorded at about 76% and 24%, respectively.

The objectives of the study were largely met. The findings may serve as a useful tool in making decisions as to which SWM technologies or approach will effect the desired impact. i.e., from the findings, it might be gathered that the recyclable material composition of the solid waste, like plastics and metals do not warrant investment in recycling as a waste management approach. In other words, the recyclable materials are found to be not in appreciable quantity. However, the high organic content of the waste indicates not only the necessity for frequent collection but also an opportunity to give top priority to the recycling of the organic waste materials through composting. However, for sustainable operation of this action, it needs further investigation. In addition, the study has showed that the households that have larger earnings generate more waste. Thus, the charge of waste collection and disposal should be fixed according to the quantity of waste generated.

To end, valid and effective assessment of waste stream cannot be one-off activity, as it varies with population number, seasons, income level and so forth [14]. Thus, to give a more complete picture of the urban solid waste situation, this type of study needs to be repeated during all seasons of a year. For Aweday, this study also needs to consider waste generation sources which were not covered in the study, for instance, restaurants, medical centres and offices. Information on community's perception of waste is vital.

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