

# Characterization of Municipal Solid Waste Management in Bahir Dar City, Ethiopia

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## Abstract

Solid waste management is a multidimensional and challenging issue faced by developing countries due to huge waste production and ineffective management. The solid waste management (SWM) system was studied to identify the key issues in Bahir Dar and a survey was conducted to provide statistical guidance for effective management of solid wastes. The results show that, the household solid waste (HSW) generation was 0.34 kg per capita per day (kg/c/d) as of 2019. Food waste and yard waste took the majority share (81.08%), the rest were paper and cardboard (7.3%), plastics (4.2%), glass and ceramic (2.36%), metals (0.8%) and other materials (4.25%). The municipal solid waste (MSW) management system practiced in Bahir Dar was to be improved. First, the waste collection and sorting system was weak. Second, the waste composting and recycling efficiency was very low. Third, waste transportation and disposal management were not standardized and environmentally sound. It is suggested that government commitment, full stakeholders' engagement, and investment are essential to achieve the goal of sustainable solid waste management.

**Key words:** Waste Management, Household Waste, Waste Characterization, Bahir Dar

## 1. Introduction

Worldwide population has been growing rapidly, specially in developing countries[1, 2]. Such rapidly growth of population, together with the economic boom and rising and shifting of community living standards has led to an increasing MSW generation rate [2, 3]. The MSW management has become a worldwide challenge[4] [2, 5]. In urban areas, solid waste composition is more complex and heterogeneous[6]. In most of developing cities, the generated solid waste is not managed properly with respect to storage, collection and final disposal, and leads to serious issues [7-10]. Basic municipal solid waste management procedure refers to collecting of solid waste from residential, commercial and public areas, and then transport to the landfill [11,12]. A weak MSW system could lead to atmosphere, water and soil pollution and jeopardizes the public health [13, 14].

The collection stage is identified as a key problem due to the lack of knowledge, ability, and willingness. In developing countries, solid waste collection rate reaches up to 50% [15]. Municipal solid waste management (MSWM) accounts for 20-50% of government budget with 80-90% of that spending on waste collection [16]. However, less than 50% of the population obtains the services[17, 18]. It is very difficult to sustain the SWM system with government budgets [19] and local authorities has started to cooperate with private sectors[20, 21]. In addition, MSWM is strongly influenced by social-cultural, environmental, political, legal, and economic factors, which need to be all addressed to achieve a sustainable MSWM [22].

This study is to assess the entire SWM system in Bahir Dar, quantify and characterize the daily household (HH) solid waste analyze the household features, and then recommend on how to establish a sustainable SW management system.

## 2. Data and Methods

### 2.1 Description of The Research Area

This research was conducted in Bahir Dar, the capital city of Amhara national state of Ethiopia and is divided into 6 sub-cities administration. The city was awarded the UNESCO<sup>1</sup> Cities for Peace Prize in 2002. It is approximately 180km away from the ancient historical city of Gondar and 568 km away from Addis Ababa which is the capital city of Ethiopia. It covers an area of 16,000 hectares and the population has been rising and reached 388,683 in recent years (projection based on figures from Ethiopian Central Bureau of Statistics (ECBS),2007).

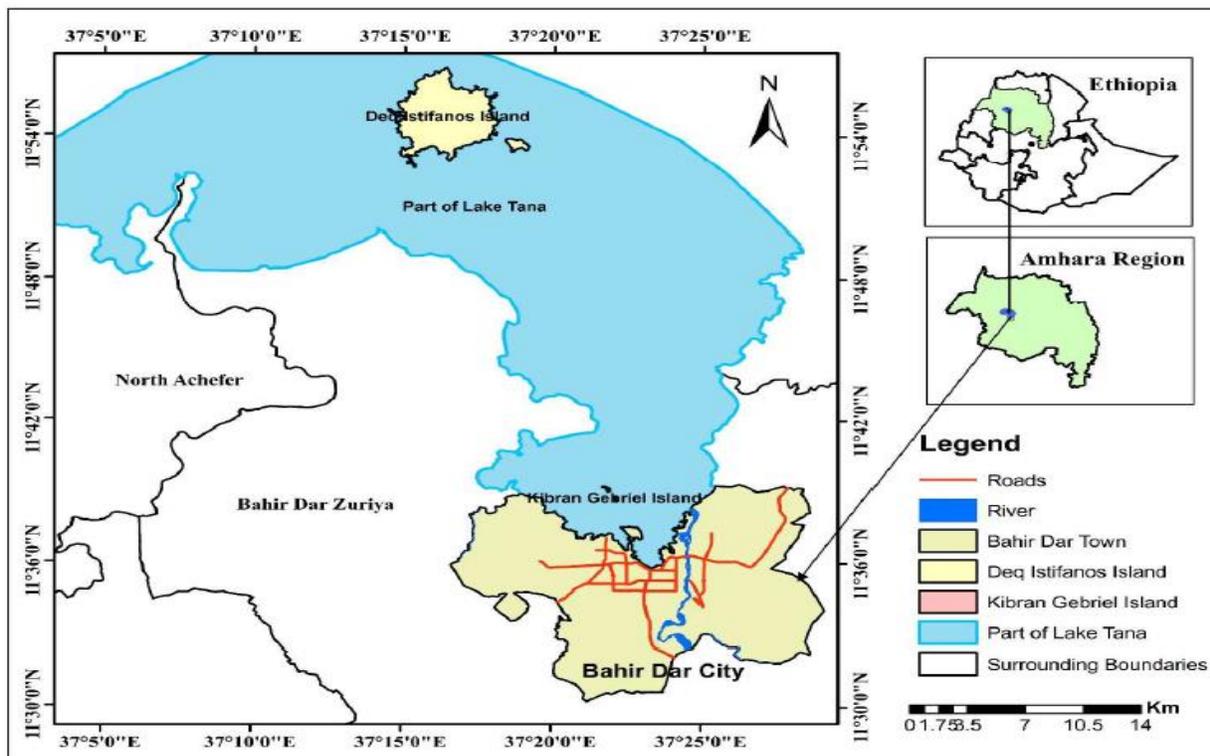


Figure 1: Geographical setting of the study area

Source: - [23]

### 2.2 Municipal Solid Waste Management Survey

A survey is designed to evaluate the current MSWM system. Firstly, interviews along with a questionnaire was completed by households. Secondly, interviews were conducted on micro-size waste collection service providers, MSW administration office

workers and other stakeholders. The questionnaire is designed to collect the data on residents' socio-economic characteristics, behavior pattern (i.e., reuse, waste separation and disposal), willingness and ability of paying for collection services, and their satisfaction level to the current service.

The survey on households (over 15years old) was conducted from Aug to Sep, 2019. It started randomly with the first family then moved towards the next with 4 houses in-between. If the selected household refused, it was replaced by the next one. From Sep to Oct, 2019 face-to-face interviews were conducted on waste collection service providers, transportation service providers and municipal solid waste administration officers. The aim is to collect the information on MSW collection quantities, availability of collection services, collection equipment and transportation, final disposal methods, collection fees, location of disposal site, environmental and socio-economic impact of SW to the city. Self-employed services providers were also included. Field investigation and interviews are conducted for robustness check from Aug to Oct 2019.

### 2.3 Waste Characterization Study

Random sampling techniques are used for computing the household waste composition[24, 25]. As stated by Sharma and McBean, [26] thirty samples are usually enough for solid waste characterization of the whole city. The SW sample collection was conducted in each selected household for eight days in Sep, 2019. Collection of wastes was conducted by giving identical size plastic bag for each 30 households and house code was labelled. At the time of waste collections, additional plastic bag was provided for the following day collection. Each household was instructed only to put their daily solid wastes generated in the plastic bag. To ensure for the accuracy of data, the first day waste was rejected. From the total sample we were analyzed, 16 sample from the Facilo sub city and 14 from the Tana sub city. And the sample size from each location is representative of the respective populations in each sub area. Components of solid waste were separated, measured and recorded based on a standard procedure. each sample was classified into the following components: (1) Glass and ceramics, (2) Plastics, (3) Paper and cardboard, (4) food and yard waste (organic waste), (5) Metals, (6) Other waste (Textiles, leather, wood, ashes, etc.). Data from the various sampling locations were compared using single factor analysis of variance (ANOVA). The F critical values were calculated using an alpha value equal to 0.05 and time steps as the replicate.

## 3. Results and Discussion

### 3.1 Solid Waste Generation and Management in Bahir Dar Municipality

Daily MSW generation in 2019 was roughly 421.125 M<sup>3</sup>/d. The percentage of organic components is the largest. Table 1 shows the MSW generation and the collection amount from different sectors. Including Agriculture and tourism sectors. Community residences sectors, commercial sectors (agricultural, tourist place, hotels, fish markets, shops), institutional sectors (governmental and non-governmental office) and street cleaning sectors. Fig. 2 shows the per capita MSW generated by different cities of Ethiopia.

Table 1. Municipal Solid waste generation from different sources M<sup>3</sup>/day

Sources of solid waste	Solid Waste Generated and collected
Total solid waste generated	421.125
Total Solid waste collected	344.5
MSW Collection rate	82%
Residential Solid waste collection	188.52

Commercial solid waste collection	84.51
Institutional solid waste collection	59.33
Street sweeping collection	12.42

Bahir Dar SW generation rate was 0.44 kg/c/d, it is the second largest. The city Laga Tafo has the highest solid waste generation rate (0.43Kg/c/d), in relation to the population (25,099).

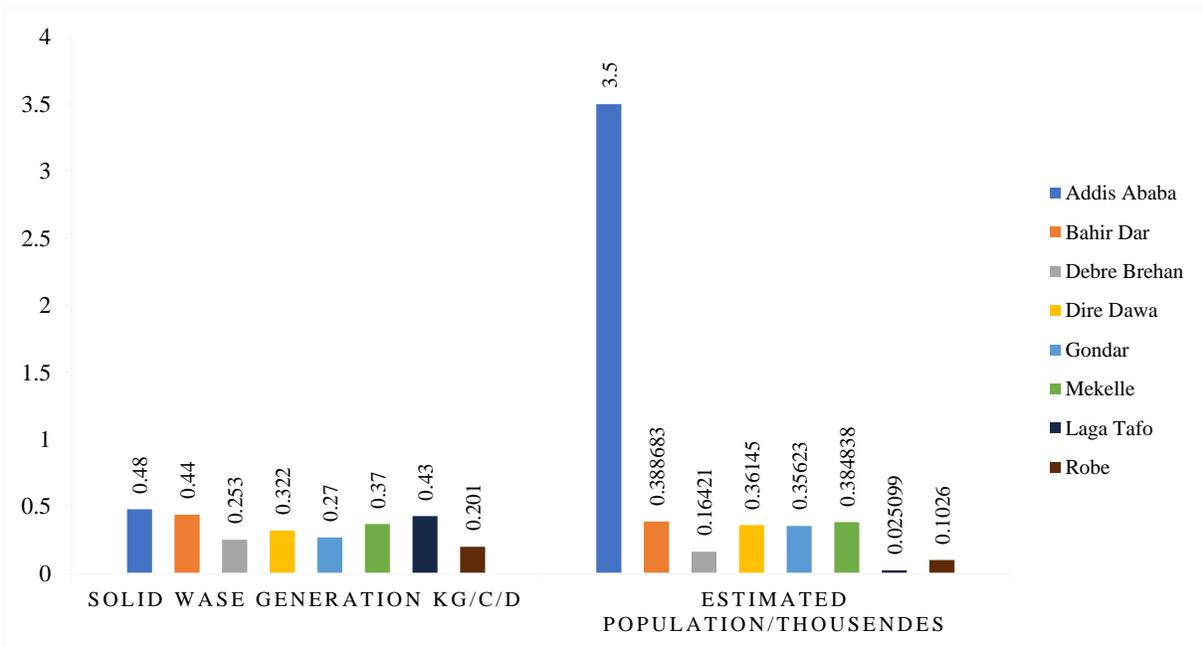


Fig. 1 Compares the per capita MSW generated by different cities of Ethiopia

Citation:- Addis Ababa [27], Bahir Dar [28], Dabre Brehan [29], Dire Dawa and Mekelle [30], Gonder [31], Lada Tafo [32] and Robe [33]

### 3.2 Household Survey

Waste generated from households varies according to income, food habits, numbers of family members, life style, educational and occupational status[34, 35]. 424 households took part in the survey. The majority of respondents (75.7 %) are females. The average family size is around 5. Almost all of the respondents live in the city of Bahir Dar. In terms of income, most households have a monthly income of less than 100.77 USD (62.97%) and only 12% of them obtain over 167.95 USD on the monthly basis.

The current solid waste collection fee is 8 Birr (\$ 0.27) per month. Based on the results, 59.2% of households would be able to pay 15 Birr (\$0.5) their payment per month for a better waste management service (at least 3-day interval waste collection). 40.8% of the households would be able to pay around 21 Birr (\$0.7) dollars in the monthly basis for daily waste collection service. The majority of households is not satisfied with the current services provided. Most of the community use sack for storage of the waste. It is interesting to note that 75% of respondents show willingness to volunteer in public campaigns. Regarding to the current waste

disposal practice of respondents, disposing waste at road sides and open fields, burry inside of compound and burn in their surroundings, has a present share of 7%, 1.8% and 9.5% respectively and mostly men are more responsible for such action.

Table 2 Demographic Characteristics of Respondents

Variables	Response Rate	Percentage
<b>Sex</b>		
Male	112	26.42
Female	312	73.58
Total	424	100
<b>Family size</b>		
1 - 3	116	27.36
4_7	256	60.38
8 and above	52	12.26
Total	424	100
<b>Monthly in come in Dollar</b>		
Less than 100.77	267	62.97
100.77 - 167.95	93	21.93
Greater than 167.95	51	12.03
Not mentioned	13	3.07
Total	424	100
<b>Level of satisfaction for SW service provided by municipality</b>		
Fair	108	25.47
Unsatisfactory	237	55.90
Very unsatisfactory	79	18.63
Total	424	100
<b>Waste disposal practice</b>		
Door to door collection service		81.7
At the road sides and open fields		7
Burry inside the compound		1.8
<b>Burn in the compound</b>		<b>9.5</b>

### 3.2.1 MSW Service Provider

SW cooperation's provide weekly collection services in residential areas, and daily services a for institutions, commercial and some industrial sectors. The collection rate has been increased to 82% compared to 71% in 2010. However, the uncovered collection area leaded to illegal waste disposal and water pollution in lake tana as well as Blue Nile river.

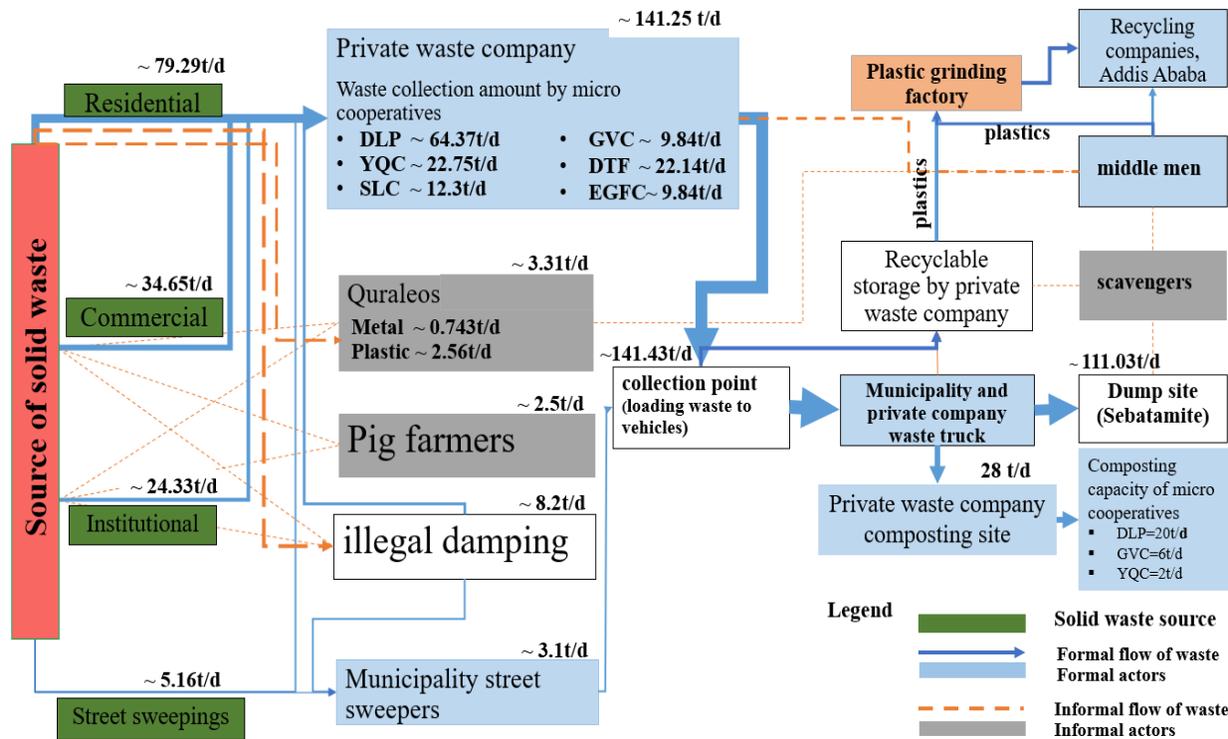


Figure 2: - The current solid waste system Process flow chart of Bahir Dar City.

Source: - 2019 survey.

Abbreviations: - DLP dream light SW plc, YQC Yifestemal Qalu SW Cooperative, SLC Sira Lehiwote SW cooperative, GVC Green Vision SW cooperative, DTF Diresse, Tigiste and their friend SW cooperatives, EGFC Emenat, Guadie and their friend's SW cooperatives

The municipality SW office provide all the vehicle for solid waste collection and transportation. Around 10 trucks and trickles are deployed. In light of this, all the vehicle used currently are not standard for the operation of SW transportation. They have no any cover and any facility to contained the flued generated from waste. Moreover, most of the vehicles and equipment are in need of replacement for the quality of service, for the health of SW collection workers, to the community and to minimize the environmental damage.

### 3.2.2 Waste Sorting

The major drawback of the MSW management system in Bahir Dar is the weak waste sorting stage. 42.6% of the respondents sort the waste in to bio degradable and non-bio degradable categories. It was observed that some of the waste collectors segregate recyclable wastes at source or temporary waste transfer station. Some street rag pickers segregate recyclable material such as plastics, glass and metallic items from illegal dumping areas and Sebatamite disposal site for their living income.

### 3.2.3 Waste Recycling

According to the data from Bahir Dar SW municipality office, less than 28 tonnes per day (19.8%) of waste are used to produce compost. There are 3 micro-cooperation's participated in compost production, Dream Light PLC, Yifestemal Qalu and Green Vision

treat 20t/d, 6t/d and 2t/d bio degradable city wastes respectively. In addition, recyclable material is mostly (metal, plastic, old shoes and clothes) collected by Quraleos and Liwach with door to door services. The recycled materials are sold to the recyclers, agencies or directly to plastic grinding factory.

### 3.2.4 Disposal System

Waste disposal is also an important problem. The Sebatamite dumpsite is the only legal site and it is around 6 Km from the center. The site is an open area of around 150,000M<sup>2</sup> with the following issues:, formal cell creation for the daily fill of waste dumped, there is no leachate containment or protection at the bottom like a geo-membrane nor any required infrastructure, leachate management pond, landfill gas management(vent), final soil cover and compaction process conducted in a very limited range, drainage for controlling the rain water, and fenced with a gate.

Due to lack of awareness and control, dead animals and hazardous waste such as battery are also disposed into the site. In the rain season, flood with leachate may contaminate the river, and the downstream communities' activities, such as farming, washing and basing are significantly affected. Such poor management resulted in socio-economic problems and ecological damage. Recently the SWM office has been working with different governmental and nongovernmental organization to addresses the environmental impact caused by this site. There are a series of actions to be undertaken within the frame work collaborations of UN-Habitat supporting for the improvement of the current disposal site and the design of a new sanitary landfill. World Bank is planning to provide financial support for the construction. In light of this, the municipality SW office should encourage citizens to compost the biodegradable waste at community level to reduce the overall volume of waste to be disposed at dumpsite.

### 3.3 Household Solid Waste Generation

**Table 3**, shows household waste generation rate by different days of a week, total waste generated and by waste fractions. Total weekly SW generation amount was found 349.4 kg/week and average daily solid waste generation was 49.91 kg/day. Based on 30 sampled households, the average family size was around 5. A total sample of 147 persons used for the analyzing per capita daily generation rate. Per capita/day waste generation rate was computed. The household waste generation rate of the city was 0.34 kg/person/day, which is within the estimated range of 0.09-3 kg/person/day in the African region [36].

Table 3  
 Household waste generation rate and composition in different day Kg/week

Days	Total SW	SD	Food and yard	SD	Paper and card board	SD	Plastic	SD	Glass	SD	Metal	SD	Others	SD
Monday	47.70	0.35	38.64	3.65	3.77	0.36	1.91	0.18	1.05	0.10	0.38	0.04	1.96	0.18
Tuesday	48.40	0.36	38.24	3.68	3.68	0.36	2.13	0.20	1.11	0.11	0.44	0.04	2.81	0.27
Wednesday	48.10	0.36	38.96	3.71	3.85	0.37	1.97	0.19	1.44	0.14	0.34	0.03	1.54	0.15
Thursday	47.90	0.36	37.88	3.60	3.98	0.37	2.16	0.21	1.44	0.14	0.43	0.43	2.01	0.19

Friday	48.50	0.37	38.80	3.88	4.37	2.32	1.94	0.19	0.97	0.10	0.44	0.44	1.99	0.20
Saturday	53.00	0.33	43.99	4.22	3.07	2.36	2.17	0.21	1.11	0.11	0.32	0.32	2.33	0.22
Sunday	55.80	0.44	46.78	4.43	2.90	2.38	2.28	0.22	1.11	0.11	0.50	0.50	2.23	0.21
Sum	349.40		283.28		25.61		14.56		8.24		2.84		14.86	
Average	49.91		40.47		3.66		2.08		1.18		0.41		2.12	
% share			81		7.33		4.17		2.36		0.8		4.25	
ANOVA(F)	0.01		0.11		0.29		0.07		0.38		0.37		0.50	

### 3.3.1 Waste Generation in Groups with Different Socio-Economic Status and Family Size

In the random selection of household survey, 16 low income, 8 middle income and 6 high income households were approached. There were no high variations among the three groups in terms of the waste generation rate (Kg/capita/week, ANOVA,  $F = 0.01$ ,  $p = 0.92$  check). The whole sample shows that food waste was the major component (80.4–82.77%) followed by papers and card board and plastics respectively. Table 4 describes household waste generation and composition of different socioeconomic groups. In the low-income class, the population is 85 and waste generated per week was 154.3Kg with the average waste generation rate of 0.259kg/c/d. food waste were take the major composition of SW share (82.77%) the rest are paper and card board waste (6.02%), plastic (3.89%), glass and ceramics (2.33%), metals (0.84%), and others (4.1%). The middle-income class has a population of 39 and the average waste generated were 93.9Kg with a generation rate of 0.583kg/c/d. The compositions were food waste (79.13%), paper and card board waste (9.3%), plastic (4.15%), glass and ceramics (2.37%), metals (0.79%), and others (4.25%). The high-income group has 23 persons in total and the total waste generated were 93.9Kg with the average generation rate of 0.583kg/c/d. Waste composition were food waste (80.4%), paper and card board waste (7.35%), plastic (4.58%), glass and ceramics(2.34%), metals (0.85%), and others (4.47%). The high biodegradable waste percentage suggests more frequent collection and removal services, and indicates a potentially booming bio-waste recycling industry.

Table 4

Generation rate and HH waster composition in different socio-economic groups in the city.

Socio-economic groups	Total population in each socio economy group	Total waste generated in Kg/week	Generati on rate kg/c/d	Food and yard %	Paper and card board %	plasti cs %	Glass and ceramic s %	Meta l %	Other s %	SD
low income	85	154.400	0.259	82.77	6.02	3.88	2.33	0.84	4.15	32.43
middle income	39	101.100	0.370	79.13	9.30	4.15	2.37	0.79	4.25	30.74

High income	23	93.900	0.583	80.40	7.35	4.58	2.34	0.85	4.47	31.30
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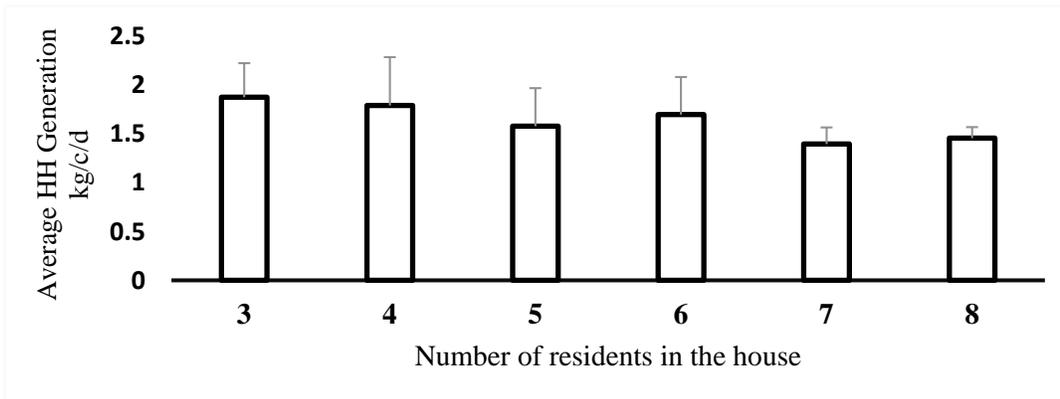


Fig. 3. The relationship between family size and per capita household waste generation rate.

In the statistical analysis of HH family size, most of the family were 4-6 person per households and household SW generation rate differs among households with different family size (Fig. 3). The highest amount of HH waste generation rate is recorded was 2.48 Kg/c/d in high socio-economic household with 4 family members. And the smallest amount of household SW was 1.29 Kg/c/d in the low socio-economic group with 5 family members. Families with 8 members and low income have the average quantity of 1.46 Kg/c/d and it ranges (1.3-1.6 Kg/c/d), In the group of household with 7 family members, the mean waste was 1.4Kg/c/day (range between 1.2-1.7 Kg/c/d), In the group of household with 6 family members, the mean 1.7Kg/capita/day and (range between 1.2-2.7 Kg/c/d). In the group of households with 3 family members, the mean 1.88 kg/c/d (range between 1.3-2.5 kg/c/d). Table 5 presents the statistical analysis of SW generation in groups with different family size. Families with 5 members generates the maximum 107.37 Kg/c/w household waste in a week. Households with 4 family members generate the maximum daily amount of waste (1.23-2.8kg/c/d). Correlation between household waste generation and family size was not too high ( $r = 0.318, p = 0.086$ ). The outcomes are in line with the findings of [37] who have find out correlation between waste generation rate and the family size in their studies.

**Table 5**

Waste generation rate in groups with different family size

Size of the household	Frequency	Total waste generated /family size/week	Range		Mean	SD	Variance	ANOVA (F)	95% Confidence level of mean	
			Min	Max					Lower bound	Upper bound
3	5	65.67	1.30	2.50	1.88	0.35	0.12	2.07	1.73	2.02
4	6	75.26	1.23	2.80	1.79	0.50	0.25	2.03	1.76	1.83

5	10	107.37	1.10	2.10	1.58	0.39	0.07	1.70	1.42	1.65
6	6	71.34	1.20	2.70	1.70	0.39	0.15	0.44	1.57	1.83
7	2	19.56	1.20	1.70	1.40	0.17	0.03	2.30	1.25	1.54
8	1	10.20	1.30	1.60	1.46	0.11	0.01		1.35	1.56

### 3.4 Waste Compositions

Understanding the composition of household solid waste is essential for good solid waste management (reuse, reduction, and recycle). Literature suggests that household waste composition is closely related to socio-economic status of households, cultural conditions, food habits, season, geographical locations, etc. [38, 39]. Figure 4 shows the household wastes composition and their percentages generated in Bahir Dar community. Food wastes account for main fraction of the household waste. 81.08% is organic waste (food and yard), the rest are paper, plastics, glass and ceramics, metals and other waste (7.3%, 4.2%, 2.36%, 0.8% and 4.25%, respectively).

The main fractions are biodegradable waste contains (food and yard, paper) having the share ranges between 84.3 and 90.4%. Non-biodegradable ranges from 9.6 to 15.6%. The percentage of other waste (old shoes, textiles, leather and ash etc.), and wastes less than 10 mm is around 4.25% in average. Moreover, MSW composition have been an organic content of 74.6% and 25.4% inorganic waste released by UNEP (2010a). All these results indicate a substantial potential for resource composting and biogas production. It will reduce the amount of landfill waste, and help local industries (agriculture) to do soil amelioration.

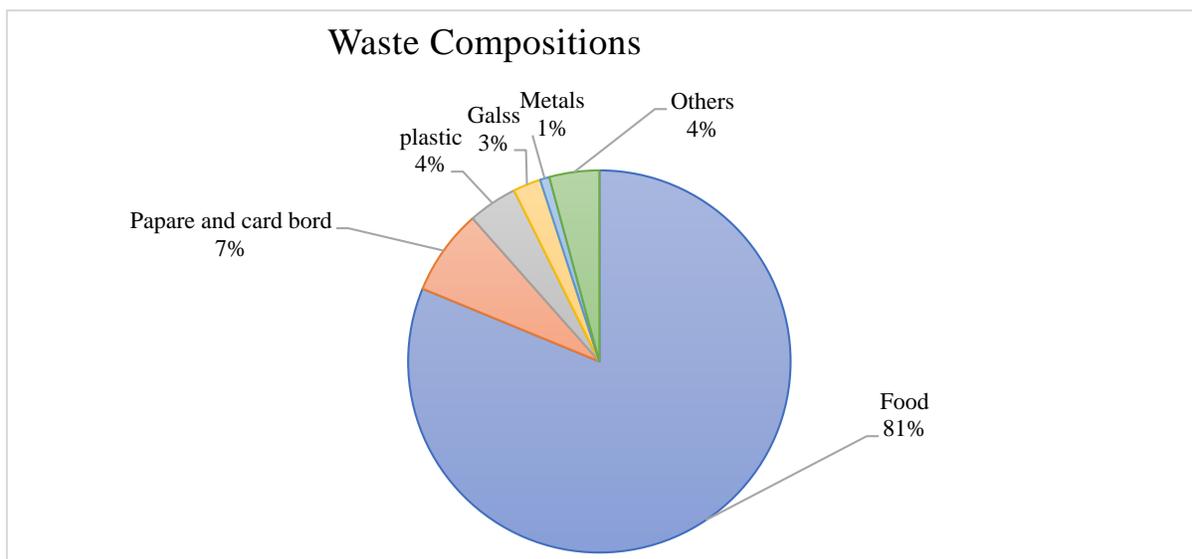


Figure 4: - household solid waste composition of Bahir Dar city.

Source: - 2019 survey

The composition and estimates of solid waste generated in Bahir Dar community could be considered representative for other cities of Amara national state communities with similar population. The generation and composition of solid waste changes with per-capital income, consumption habits, family, etc. Results showed that hazardous waste has a share of 0.2% and most of them are dry cells, fluorescent lamps and chemical contaminated containers for insect killers. Such waste has been collected and stored separately at household level and dumped separately in a specially designed landfill site. However, the management of this waste category has not been investigated thoroughly.

#### 4. Conclusion

This study carried out in the city of Bahir Dar, emphasized the existing situation of the SWM systems from the point of view of citizens and SWM program operators. Also, it investigates the residential solid waste and its components. The results show that solid waste collection, transportation, and disposal procedure is not standardized and environment friendly. The municipality generates 421.215M<sup>3</sup> solid waste per day. HSW generation rate is 0.33kg/c/d. 82% of the localities have access to SW collection service. 81% of household waste are organic which provides business opportunities for compost and biogas industry. Seasonal variations may also have a significant impact on analyzing waste components [40]. Therefore, the research in the future could be conducted in all seasons to give a comprehensive picture of the household.

In conclusion, waste sorting at source is vital for building a good waste management system. Understanding the current waste fraction is important for a better system. Apart from that, it is suggested to enhance the public awareness, build up necessary facilities, ensure a close collaboration with government other organizations, seek the worldwide technical and financial support. The ultimate goal is to help reducing ecological damage and health hazards drastically.

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## Abbreviations

ECBS	Ethiopian central Bureau statistics
HH	household
HSW	household solid waste
MSW	municipal solid waste
SW	Solid waste
SWM	Solid waste management

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