World Journal of Soil, Water and Air Pollution
Vol. 1, No. 1, January 2014, pp. 1- 20
Available online at http://www.wjswap.com

Research article

Assessment and Management of Municipal Solid wastes for Kombolcha City

S. Yimer and O. P. Sahu

Department of Chemical Engineering, KIOT, Wollo University, Ethiopia
Correspondence E-mail:ops0121@gmail.com, Tel:+251-933520653

Abstract

For any city the solid waste management study information, its characteristics and rate of generation is among the core studies to find sustainable solution and to handle it easily for the generated wastes in specific region. The assessment of solid waste in Kombolcha city includes all 11 sub-cities of it with the major objective of assessing the characteristics of solid waste generated at the household level and composting for sustainable management of solid wastes in the city by accounting economical, environmental and social attitudes. According to the data analysis food waste was high (52.61%) followed by ash and dirt (20.9%); the average generation rate was determined to be 179 gm/cap/day with the average density of 302 kg/m^3. The survey analysis also showed that illegal solid waste disposal in open spaces is common practice in the area and some of the main reasons raised were the inappropriate placement and insufficient number of transfer stations and communal containers. The compositional analysis as well as the result of proximate and ultimate analysis clearly showed that the materials generated from Kombolcha city are ideal for the preparation of compost as a result of the largest proportion of organic wastes.

Keywords: Analysis; Compost; Generation Rate; Sustainable; Solid Waste Management

1. Introduction

The rapid urbanization that has been taking place during the 20th century virtually transformed the world in to communities of cities and towns facing similar challenges on environmental issues in which most of them have to be addressed at international level [1]. Among those environmental issues solid waste management is a critical one because as long as humans have been living in settled communities, solid waste generation has been an unavoidable and critical issue both in developed and developing nations [2]. As a result, solid waste management became a worldwide agenda at united nation conference on environment and development in Riodejieneiro in 1992 with a great emphasis on reducing wastes and maximizing environmentally sound waste reuse and recycling at first step in waste management [3].

Solid waste management is defined as the collection, transportation, processing, recycling, and disposal of solid waste materials so as to reduce their effect on health, environment and aesthetics. It is highly related with urbanization and industrialization. For instance in early societies, solid waste management consisted of digging pits and throwing garbage into them [4]. When cities began to be more concentrated; however, solid waste management became a serious and complex issue. Houses that did not have room to bury their garbage would throw it into the streets. In response, many cities started to set up municipal garbage collection teams which would dispose of unusable garbage. This is mainly because modern societies generate far more solid waste than early humans ever did. As a result, recent events in major urban centers both in developed and developing countries have shown that municipal solid waste management has become a big challenge [5].

In developed countries the daily life of people can generate greater quantity of solid waste than developing countries, but most parts of developed nations are efficient in handling waste when compared to developing countries because of their technologically complex, institutionally efficient and cost effective solid waste management systems [6]. On the contrary compared to developed countries, developing countries produce less per-capita solid waste. But the capacity of developing countries to collect, process and dispose waste is limited due to inadequate infrastructure, finance, political instability, inefficient institutional capacity and structure, and low level of awareness. Similarly the current condition of the municipal solid waste management service in different towns of the Ethiopia is less efficient and not properly managed.

Ethiopia is also becoming a challenge for municipalities. For instance, the municipal solid waste management practices of 15 regional cities of Ethiopia, a controlled solid waste disposal system were practiced in only two of them. That means small proportions of the urban dwellers are served and a large quantity of solid waste left uncollected. In addition, a study conducted revealed percentage of solid wastes which are left uncollected and disposed anywhere without due attention regarding their consequences in different towns of Ethiopia [7]. Kombolcha is an industrial city in north central Ethiopia, located in the South Wollo zone of Amhara region with elevation between 1842 and 1915 meters above sea levels. It is the only industrial zone of Amhara regions as well as one of the industrial cities among four cities in the country. It have the population of 91,290 by door to door count in 2011 from which 62,733 is live in 5 sub-cities and others i.e. 28,557 live in 6 outskirt parts of Kombolcha city [8].

The city generates large volume of waste from households, public institutions and industries. Among all waste, solid waste is a major visible source of environmental pollution in the city, which in turn, is the cause of pollution of air, water and soil. As a result, it is seriously affecting human health, the quality of life and natural resources [9]. Thus the solid waste littering the city is becoming one of the major areas of apprehension. With the current growth rate of urban population in Ethiopia, it is estimated that the population of most urban areas is doubling every 15-25 years [10]. As solid waste generation increases with economic development and population growth, the amount of solid waste generated in the cities and towns will be expected to double in an even shorter time span. Hence the city's solid waste management cost will increase accordingly [11]. Although solid waste is the serious problem of Kombolcha city there is no research made on solid waste management. According to the Kombolcha city Beautification sector plan document the collection and disposal of solid waste is stated as a persistent problem of the city. In the document, the current solid waste generation / day in this city is estimated to be $35.5m^3$ out of which about 73% is being collected and disposed in controlled disposal sites [12]. The remaining large proportion of the solid waste is littering open spaces, ditches and rivers near the source of waste generation.

As a result, municipal solid waste management in Kombolcha has not been carried out in a sufficient and proper manner. The environmental and sanitary conditions of the town have become more serious from time to time, and people are suffering from living in such conditions [13]. So that urgent need of efficient MSWM on one hand and steady growth of solid waste problem on the other side are still the main features of the town.

2. Material and Experiment

To study the assessment of solid waste management in Kombolcha prefer visual observation and field survey by waste management indicator method rather using 2nd hand information. The methodology followed for the preparation of this study involves review of related literatures; preparation of the interview survey; establishment and training of crews for the collection and measurement of sample household daily solid waste and waste classification by type; processing of the survey data; analysis of the data and evaluation of findings; assessment of sustainable management options. The followings are the major methodological steps followed during the study.

2.1. Preparation of a structured questionnaire

A simple structured questionnaire was designed to collect household level data on the socio-economic and daily waste traits. In addition the questionnaire included a number of attitudinal questions aimed at examining household awareness and attitudes towards the problem of urban solid waste. All the households randomly selected for this study filled the questionnaire prior to collection of samples.

2.2. Sample size determination

To determine the number of households that are going to be analyzed to obtain a reasonable and reliable result a method that was designed based on central limit theorem was used (Weiss, 1989) with a 95% confidence interval and a 1% error as a desired reliability. Our study encompasses the 8 sub-cities of Kombolcha only (population size was 62,733). For sample size determination it is possible to use standard deviation of similar study such that a standard deviation of 0.056, which was determined in the Arada sub-city (Addis Ababa) was used [16]. According to the central limit theorem the size of sample determined using the following equation.

$$n = \frac{\sigma^2 Z^2}{SE^2}$$

$$n = \frac{1.96^2\, 0.056^2}{0.01^2} = 120$$

Where Z= value of Z that corresponds to 95% confidence interval and equal to 1.96.

σ = Standard deviation

SE = Standard error

2.3. Identification of study households

In order to get a representative and reliable result, the total numbers of sampling houses that are going to be analyzed are determined from each kebele based on their total number of houses. The study area has eight sub-cities from kebele 1- kebele 8, but most of the population has lived in the first 5 sub-cities as a result I used the data of the five sub-cities only. The study was carried out based on housing number of kebele with a total number of houses of 912 in kebele 1, 2467 in kebele 2, 2559 in kebele 3, 1993 in kebele 4 and 1571 in kebele 5. From each kebele the number of residential housing units was identified with their numbers and sampling units, as a proportion of total housing units were determined. Then for each Kebele the sample houses are selected based on their housing number using a simple random number table. After the house numbers of the housing units of each kebele randomly selected, the housing units were identified using their housing number.

2.4. Data collection

One day before collecting the samples from each household the plastic bags of blue and green colors distributed for every household with the instruction that the organic waste (moist) should be kept in the blue plastic bags and the non-organic (dry) ones in the green bags. And the identification number was assigned to each household and corresponding level is given for each and every bag distributed for each household. On the next day early in the morning the collection of samples began. For the quality of the data the first day waste collected from each household was discarded taking into account that these wastes may not be generated on a daily basis. Right after the second day up to the eleventh day (10 day) sample was collected on a daily basis.

After collecting the waste from each household then brought to the place prepared for sorting into different components was made for each household .The sorted components then weighted and their volume was determined using different sized wood boxes with a known volume [15]. Finally the size distribution of the waste was determined using a 50mm and 10mm sized mesh wires and then the weight and volume measurements done for both size ranges.

2.5. Proximate analysis

The proximate analysis includes the determination of moisture content, volatile combustible matter (VCM), ash content and fixed carbon. In order to reduce the magnitude of error arising from the moisture change and from decomposition the analysis of the sample was started within two to three hours after collection. Care was also always taken to make the samples well mixed for this purpose each waste component were randomly taken and then chopped to reduce the size and then the well mixed sample finally was taken for laboratory analysis. Regarding the determination of moisture content a sample from each component of the waste was daily taken to the chemical engineering lab just after the collection and analyzed using oven dry set at 105^{0}c for one hour [16]. The VCM and ash content determination was made at the last date of the collection program .The VCM was determined using a digital oven dry set at 950^{0}c for six minutes using a closed crucible. The temperature reaches 950^{0}c gradually in order to avoid flaming and protect the crucible from strong drafts to avoid mechanical loss of the specimen. The ash content of each component of waste was also determined using the same sample and equipment that was kept at 750^{0}c for three hours by using open crucibles. Subtracting moisture content, ash and volatile matter from the initial sample determined fixed carbon.

2.6. Elemental (ultimate) analysis

The elemental analysis of waste components analysis involves the determination of nitrogen and carbon. The determination of total nitrogen was carried out using the standard kjeldhal method. Regarding the determination of carbon due to the unavailability of analytical equipment and appropriate skill on the part of the analyst in developing countries UNEP recommends a ‘stop gap’ approach suitable for composting in SWM is an estimation based on a formula developed in 1950s [17]. The assumption is that for most biological materials the carbon content is between 45 to 60 percent of the volatile solids fraction. Assuming 55 percent is carbon.

The formula is as follows

$$\%\ \text{Carbon} = \frac{100\ \%\ Ash}{1.8}$$

And this study took this formula for the determination of carbon.

Total Carbon

Total carbon (C) is a direct measurement of all organic and inorganic carbon in the compost sample. Unless the sample has a high pH (> 8.3) or is known to contain carbonates, essentially all carbon will be in the organic form. Compost organic matter typically contains around 54 % organic carbon by weight. The carbon content of individual feedstock may vary from this ratio.

Compost 0rganic Carbon=0.54 Organic Matter

OM = TC x 1.72

2.7. Data analysis

For the analysis of the sampled solid waste and survey questionnaire the statistical package for social studies

(SPSS.10) was used. In the data analysis the composition of waste was analyzed and per capital generation rate was determined. In the correlation analysis the generation rate was cross-examined with the socio economic background and educational status.

3. Result and discussion

3.1. Survey results

Both survey data and observation indicate that self-occupied dwelling are less dominant in the area and renting houses to individuals is a norm in the study area. **Table 1** shows that 50.8 % of the households surveyed owned their houses followed by 44.2 % rented from individuals and the rest rented from kebele.

Table 1: Housing characteristics

S.No	**Characteristics**	**Frequency**	**Percent**
1 2	Owned	61	50.8
2	Rented from kebele	6	5.0
3	Rented from individual	53	44.2
4	Total	120	100.0

Household size ranges from 1- 12 with the average of 6. The large family size is because of the extended family members. The average number of years of education of the most educated member of the household varied between uneducated and second degree. Out of the 120 households surveyed 49.17 % of the most educated member of the household varied between eight and twelve grade.

Table 2: Educational background of the most educated member of the household

S.No	Educated Member	Frequency	Percentage
1	uneducated -8 grade	42	35
2	8-12 grade	59	49.17
3	12 grade >	19	15.83

The average monthly income of households per adult as computed from the survey data was Birr 323.20 for low-income groups, Birr 898.82 for middle-income groups and Birr 1817.43 for high-income groups. The average monthly income of households per adult for the entire sample was Birr 841.87. In the following **Table 3** the socio-economic status of the households surveyed is presented.

Table 3: ***Income of households***

S.No	Income group	No. of house hold	Percentage (%)
1	Low income	39	32.5
2	Middle income	64	53.33
3	High income	17	14.17

3.2. Solid waste management in the study area

Like other big cities of Ethiopia, Kombolcha's city solid waste problem is getting a little attention, but due to the economic inability of the households in the area to afford collection services, inappropriate placement and insufficient number of communal containers together with the area's undulating nature, the problem of solid waste littering around rivers and roadside is still one of the major environmental problems of the area. According to the survey data, 72.5 % of the households are getting solid waste collection services by the primary collection schemes established by the small and micro enterprise groups and the rest of the households disposed their waste either on a communal container and/or open spaces like river Borkena.

Table 4: Households receiving a collection service

S.No	**Collection**	**No. of house hold**	**Percentage**
1	Have collection	87	72.5
2	No collection	27	22.5
3	No information	4	3.3
4	No specified	2	1.7
Total		120	100

All easily transportable valuable waste materials (glass, tins, scrap metals etc) are collected and sold, by private collectors who visit households regularly for this purpose (commonly known as *kuraliyo*), for waste recycler (individuals or companies). Thus, the actual volume of waste to be disposed of outside the house is decreasing and this reflected in the compositional analysis. High residential densities result in the generation of considerable amount of total waste in most neighborhoods. The waste consists primarily of organic matter from the kitchen which necessitates frequent disposal because of spoilage but most of the households getting the collection service only once in a week and this revealed in the disposal of some of the waste in the nearby open spaces.

World Journal of Soil, Water and Air Pollution
Vol. 1, No. 1, January 2014, pp. 1- 20
Available online at http://www.wjswap.com

Table 5: Frequencies of collection services

S.No	Collection	Frequency	Number of Household	Percent
1	Valid	Twice a week	3	2.5
		Once a week	69	57.5
		Less frequently	43	35.83
		Don't know	5	4.16
Total			120	100.0

Transport of waste from households is a growing problem. The city municipality employs communal collection points. However, the primary collectors, who are a member of small and micro enterprises, are responsible for transporting the waste to the collection point and the municipal transports the waste from the point to kombolcha landfill. Individual households who receive the collection service do not have standardized containers used to store waste prior to pick up. The survey analysis, as well as observation, shows it is up to the individual residences to designate some sort of collection container. Frequently, these are plastic bags or trash bags; however, the majority of the households simply place the trash bags full of waste on their gate to await collection.

Table 6: Containers for storing solid waste

S.No	Item		Frequency	Percent
1	Valid	Metal or plastic container	21	17.5
		Basket, carton or wheat bag container	82	68.3
		No container	16	13.3
		Don't know	1	0.83
	Total		120	100

World Journal of Soil, Water and Air Pollution
Vol. 1, No. 1, January 2014, pp. 1- 20
Available online at http://www.wjswap.com

The municipality of Kombolcha city claims that 75% of the solid waste generated is collected. Survey results indicate somewhat lower coverage might by the mismatch between the perception of the municipality and households as to what constitutes acceptable service or due to the skewed service provided by the municipality. As a result of the coverage, households disposed solid waste over a variety of sites with-in the neighborhood. These include throwing the waste in to the street or in riverbanks.

3.3. Environmental impacts

3.3.1. Human health Risks

There are some health risks associated with solid waste handling and disposal in the study area. The main problems can be classified into the following categories:

1. Presence of human fecal matter
2. The decomposition of solids into constitute chemicals which contaminates air and water systems and
3. The air pollution caused by consistently burning solid waste.

Table 7: Main problem of the household

S.No		**House hold**	**Frequency**	**Percent**
1		Inadequate disposal of human excreta	9	7.5
2		Inadequate disposal of residential wastewater	39	32.5
3	Valid	Drinking water shortage	3	2.5
4		Flooding and inadequate drainage of storm water	42	35
5		Inadequate solid waste collection service	7	5.83
6		Presence of litter and illegal piles of solid waste	14	11.66
7		Water quality problem	6	5.0
Total			**120**	**100.0**

3.3.2. Environmental issues

The thorough observation of the study area showed that the disposal of waste in open spaces and river banks decreased the aesthetic value of those areas .The decomposition of waste into constituent chemicals is also a common source of local environmental pollution. Since the collected wastes are disposed in the only open disposal Kombolcha landfill site it is wise to see the environmental issues concerned with this open disposal site. The major environmental concern is gas released by decomposing garbage. Methane is a byproduct of anaerobic respiration of bacteria, and these bacteria thrive on landfills with high amount of moisture. Methane concentration can reach up to 50 % of the composition of landfill gas at maximum anaerobic decomposition [19]. In well-designed and well sited landfills there is a potential for methane recovery; few landfills in the developing world are designed to capture and make use of methane (UNEP, 1996).

Generally, the required capital for methane recovery installation is lacking, and the low price of commercially produced gas does not make methane recovery an economically viable enterprise. Carbon dioxide is a second predominant gas emitted by landfills. Although less reactive, carbon dioxide build up in neighborhoods could be a cause of asphyxiation [20]. The second problem with these gases is their contribution to the so-called green house gases (GHGs), which are blamed for global warming. Both gases are major constituents of the world's problem of GHGs; however while CO_2 is readily absorbed for use in photosynthesis; methane is less easily broken down, and is considered 20 times more potent as GHG [21].

Every metric ton of unsorted municipal solid waste, 0.2 Mt is converted to land fill gases. Of these gases, CO_2 and CH_4 each comprise 0.09 Mt, since it is believed that landfill gases supply 50% of human- caused methane emission and 2.4 % of all worldwide greenhouse gases, this is clearly an area of concern in global environmental issues.

3.4. Municipal service

The local and international standards set to control the location of containers shows that the distance between containers should not exceed 200m [22]. Observations at the study area show that in addition to the insufficient number, the placement of the communal containers is not appropriate and also user population size is not given due consideration. As seen from field observation and survey analysis, the long distance required covering to dispose their waste to communal containers and poor settlement seems the main cause for households and some of the primary collection crews to dispose their waste in the nearby open spaces, riverbanks and plantation areas.

Regarding the collection of communal containers and wastes from open piles, the city has a responsibility to deliver its trucks. As seen, the city deploys two trucks. Survey analysis, field observation and opinion of the experts at all kebeles showed that the collection system is not functioning regularly and sometimes the garbage stays more than a week before being disposed at the final destination.

3.5. Solid waste generation rate

Globally, per capital amounts of municipal solid waste generated on a daily basis varies significantly. Economic standing is one primary determinant of how much solid waste a city produces in the correlation analysis performed on the data, both the sign and the relative magnitude of the correlation coefficients conformed to expectations. The household daily solid waste was positively correlated with the income. This means that households with higher incomes generated larger quantities of solid waste per day.

Table 8: Generation rate vs. income

S.No	Income status	Generation rate (gm/cap/day)	Density (gm/cm^3)
1	Low income	176.9	0.384
2	Middle income	231.3	0.282
3	High income	320.7	0.231

The statistical analysis result of the 120 sampled households listed in the following **Table 9**.

Table 9: Statistical analysis results

S.No	Analysis	Results
1	Mean	195.5
2	Std. Error of Mean	9.6984
3	Median	173.20
4	Mode	121.91
5	Std. Deviation	104.34
6	Skewness	2.867
7	Std. Error of Skewness	0.231
8	Kurtosis	13.768

The educational level of the family head was negatively correlated with the quantity of daily household solid waste. This indicates that households whose head was highly educated generated less solid waste each day, reflecting the fact that individuals with higher level of formal education exhibit higher levels of general environmental and health awareness.

When computing the weekly and monthly generation rate per capital the results would be: 1.253 Kg/cap/week and 5.37 Kg/cap/month, respectively. The total solid waste generated from households of the studied area can be calculated by multiplying the total population and it would be: 11,229.2 Kg /population/day. The weekly generation of the study area is: 78,604.45 Kg /population/week. When taking the average density of 302 kg/m^3 the total volume of waste expected in one -week time is around 260.28 m^3. Currently the potential of the city to collect the wastes from the studied area is not more than $190m^3$ per week.

3.6. Solid waste compositions

Although countries sometimes use different categories for the physical characterization of solid waste, the categories listed in **Table 10** can usually be distinguished in the various waste characterization studies. Not only wealth, but also consumer patterns significantly influences waste composition [24]. According to survey analysis the following percentage composition and moisture content by weight of the different types of waste was found.

Table 10: Compositional analysis

S.No	Waste components	Composition by weight (%)	Moisture content (%)
1	Food waste	52.61	66.8
2	Ash and dirt	20.9	4.97
3	Yard waste	17.65	26.9
4	Paper	1.47	6.89
5	Plastic	2.1	1.64
6	Wood	1.49	14.1
7	Textile	2.03	5.2
8	Glass	0.77	0.054
9	Cardboard	0.69	7.5
10	Metal	0.24	1.6
11	Rubber	0.05	0.43

The above compositional analysis shows that the proportion of food waste takes the largest proportion and this is similar to many developing countries. The ash and dirt proportion of the domestic waste of the area is also high and this is seemingly due to the use of charcoal and wood as a major source of energy. This is directly related to the poor socio-economic condition of the households to utilize other energy sources like electricity as well as due to the poor housing conditions of the households. The analysis also showed that the generation rate of these components increase with the income of the households. The middle-income groups generate the highest level of plastic wastes followed by the high and low-income groups. In the case of paper waste the high-income groups generate the highest. The other waste show a lower proportion and this is likely related to the re-use behavior of the households together with selling of valuable materials. This might have resulted in decrease of waste from this category entering the waste stream.

As seen from the table the high content of food waste results in high moisture content consequently with high waste density. These physical characteristics significantly influence the feasibility of certain treatment options.

The high moisture content and organic composition of waste may lead to problems of increased decomposition rates in the area because of the high average daily temperature. The high rainfall would only compound these problems, presenting additional challenges with proliferation of insect population and conditions conducive to propagation of diseases. To mitigate these problems, much more frequent collection is needed to remove organic waste before they are able to decompose [26]. Although daily collection has proven unreliable or unworkable in many cities perhaps a twice-weekly collection of organic material would be sufficient to reduce decomposition. The city's solid waste management problems are different than those found in high income countries; indeed the very composition of our waste is different from that of developed nations.

3.7. Particle size

The particle size distribution analysis shows irregularity in the particle size distribution of the solid waste. Particles with a size larger than 50mm, between 50-10mm and less than 10mm are 62.8%, 25.5%, 11.7%, respectively.

3.8. Proximate analysis result

Results of proximate analysis are given in Table 11. The results of ash content show the amount of inorganic substance that would remain after burning.

Table 11: Results of proximate analysis

S.No	Waste component	Moisture Content (%)	VCM	Ash	Fixed carbon
1	Food waste	66.8	27.3	2.54	2.19
2	Yard waste	26.9	51	8.1	11
3	Cardboard	7.5	67.3	4.99	8.8
4	Paper	6.89	82.1	5.1	7.9
5	Wood	14.1	77.8	5.23	10.4

6	Plastic	1.64	89.4	2.3	4.6
7	Textile	5.2	86.5	15.7	1.08

In the following Table 12 typical proximate analysis data for materials found in residential wastes is presented. As can be seen from the table below, some of the results differ from the results of the studied area. The researcher thinks the variation of the result might have occurred due to the characteristic difference of the materials.

Table 12: Typical proximate analysis data for materials found in residential solid waste

S.No	Type of waste	Proximate analysis % by weight			
		Moisture	**Volatile matter**	**Fixed carbon**	**Ash**
1	Food waste	70	21.4	3.6	5.0
2	Paper	10.2	75.9	8.4	5.4
3	Plastic	0.2	95.8	2.0	2.0
4	Textile	10.0	66.0	17.5	6.5
5	Yard waste	60.0	30	9.5	0.5

3.9. Elemental (Ultimate) analysis result

The results of the ultimate analysis are used to characterize the chemical composition of the organic matter in the solid waste. They are also used to define the proper mix of the waste materials to achieve suitable C:N ratio for biological conversion processes. Data on the ultimate analysis of the individual waste components are presented in Table 13.

Table 13: Element analysis result of waste components

S.No	Waste components	Percent by weight (dry basis)		
		% Carbon	**% Nitrogen**	**C:N**
1	Food waste	46.7	2.4	19.45

2	Yard waste	41.9	2.2	19.04
3	Paper	46.2	0.2	231
4	Cardboard	46.3	0.21	220.47
5	Wood	52.0	0.43	120.93

In the following Table 14 typical data on ultimate analysis of the combustible components of residential solid waste are presented. The value of the ultimate analysis shows that the carbon content of all the waste components have higher percentage and lower nitrogen percentage compared with the typical value of domestic solid waste.

Table 14: Typical data on the ultimate analysis of residential SW

S.No	**Waste components**	**Percent by weight (dry basis)**	
		% Carbon	**% Nitrogen**
1	Food waste	48.0	2.6
2	Yard waste	47.8	3.4
3	Paper	43.5	0.3
4	Cardboard	44.0	0.3
5	Wood	49.5	0.2

3.10. Heating value result

The energy content of the waste components was determined using a laboratory bomb calorimeter. The results are listed in the following Table 15.

Table 15: Energy value for different composition

S.No	**Waste component**	**Energy content (Btu/lb)**	
		Dry	**As collected**
1	Food waste	5811	1977.4
2	Cardboard	6712.6	6208.3
3	Paper	8108	7542.6

4	Plastic	15617	15359.8
5	Yard waste	7901	5824.3
6	Wood	7800	6650.9
7	Textile	10522	10000.2

In ordered to determine the total energy content the compositional analysis result is essential. The necessary compositional are presented in Table 16.

Table 16: Total energy of waste sample

S.No	**Waste component**	**Composition**	**Energy (Btu/lb) As collected**	**Total energy, Btu**
1	Food waste	52.61	1977.4	104031.01
2	Yard waste	17.65	5824.3	102798.89
3	Plastic	2.1	15359.8	32255.58
4	Paper	1.47	7542.6	11087.62
5	Textile	2.03	10000.2	20300.4
6	Wood	1.49	6650.9	9909.84
7	Cardboard	0.69	6208.3	4283.73
Total				**284667.07**

The average energy content of the domestic waste as collected per lb of waste is:

$$\text{Energy Content} = \frac{284667.07\ Btu}{100Ib}$$

$$\text{Energy Content} = 2846.67\frac{Btu}{Ib}$$

A typical value of domestic solid waste has a total heating value of 5000 Btu/lb [26]. However, the determined total heating value of the sampled domestic solid waste shows above half of the results of the typical value. The high proportion of food waste associated with its high moisture content might be the cause for its lower calorific value.

In Table 17 the heating values of the different solid waste components from the different city (Arada sub-city, Addis Ababa-Ethiopia) are presented [27]. As can be seen, the results of each component doesn't show much difference but in calculating for the total heating value the study in Arada sub-city did not take into consideration the compositional differences of the various waste components.

Table 17: Calorific value of domestic solid waste from sub-city

S.No	Waste component	Energy content (Btu/ lb)
1	Textile	8079.54
2	Wood	7999.25
3	Yard waste	7457.95
4	Food waste	7316.22
5	Paper	6913.36
6	Cardboard	6704.11
Total		**44450.34**

4. Conclusion

During the study it was learnt that the area studied is facing environmental degradation and public health risk due to uncollected disposal of waste on the streets, burial areas and other public areas including the market places, drainage congestions by indiscriminately dumped waste and contamination of water resources near uncontrolled dumping sites. Based on the results of the analysis, the population in the study area generates on average a total of 11,229.2 kg of solid waste per day; the average rate per person is 0.179kg of solid waste per day. The distribution of daily household solid waste by type was: food waste 52.61%, ash and dirt 20.9%, yard waste 17.65% and other items which are recyclable amounts to 4.63%. Daily quantities of solid waste generated amounts were affected by families socio-economic and education status. The calorific value of the material is reduced to $2846.67\frac{Btu}{Ib}$ as a result of large proportion of food waste, which has high moisture content. Finally, it is recommended to do periodic research to update and modify the data and information regarding household solid waste of Kombolcha city to handle the solid waste management accordingly.

Reference

[1] Adams, R. C.; F. S. MacLean; J. K. Dixon; F. M. Bennett; G. I. Martin; and R. C. Lough(1951). The utilization of organic waste in N.Z.: Second interim report of the inter-departmental committee.

[2] Addis Ababa Chamber of Commerce (2002). Addis Ababa solid waste collection, Removal and utilization, Addis Ababa.

[3] Cointreau, S.(2002). Environmental Management of Urban Solid Waste in Developing Countries: A Project Guide. Washington, DC: Urban Development Department, World Bank.

[4] Jorge Jaramillo (2003), Guidelines for the Design, Construction and Operation of Manual Sanitary Landfills, Universidad de Antioquia, Colombia.

[5] Johannessen, L.M. (2009). Observations of solid waste landfills in developing countries: Africa, Asia and Latin America. Urban and Local Government Working Paper Series No. 3, The World Bank, Washington, DC.

[6] Peter, S. (2006). "Urban Management And Infrastructure - Conceptual Framework for Municipal Solid Waste Management in Low-Income Countries'', UNDP/UNCHS (Habitat)/World Bank/SDC Collaborative Programme on Municipal Solid Waste management in Low-Income Countries.

[7] Cointreau, S.(2012). Environmental Management of Urban Solid Waste in Developing Countries: A Project Guide. Washington, DC: Urban Development Department, World Bank.

[8] Fitsum Haile (2003). Existing situations of waste management in urban areas of Ethiopia, ministry of Federal Affairs: National urban planning institute, urban development policy project, Addis Ababa.

[9] Helge Borattebq (2007). Emerging strategies and concepts – A Framework for the Future in Sustainable Industrial Production: the Baltic university programme, uppsala university, Sweden.

[10] Christian Zurbrugg (2002). Urban solid waste management in low-income countries of Asia: how to cope with the garbage crisis. Paper presented for scientific committee on problems of environment (scope) urban solid waste management review session, Durban, South Africa.

[11] P.A. koushki and A.L.Al-Khaleeti (2008). An analysis of household solid waste in Kuwait: Magnitude, Type, and Forecasting Models, technical paper. Department of civil engineering, Kuwait University, Safat, Kuwait.

[12] Regulatory and Institutional reform in the Municipal solid waste management sector (2004). Ethiopia base line Review of current waste management situation in Ethiopia, Final Report,Addis Ababa.

[13] Hoornweg, D.; Thomas, L. and Otten, L. (2009). Composting and Its Applicability in Developing Countries. Urban Waste Management Working Paper Series 8. Washington, DC: World Bank.

[14] World Resource Institute, United Nations Environmental Programme, United Nation Development Program, The World Bank, 1996, World Resources 1996-97 – The Urban Environment, Oxford University Press, Oxford.

[15] Pavoni, J., Heer, J. and Hagerty, D. (2005). Hand Book of Solid Waste Disposal: Material and Energy Recovery. Van Nostrand Reinhold Co. New York.

[16] Yitayal Beyene (2005). Domestic Solid Waste Quantity And Composition Analysis in Arada Sub-City, Addis Ababa, Addis Ababa University, Addis Ababa.

[17] Weiss, N.A. (2008). Elementary statistics. Addison-Weslesy Publishing Company.

[18] Olar Zerbock (2003). Urban solid waste management: waste reduction in Developing Nations. Micigan technological university.

[19] Zerayakob Belete (2002). Analysis and Development of Solid Waste Management system of Addis Ababa, Addis Ababa University, Addis Ababa.

[20] Arlosoroff, Saul (1982). "WB/UNDP Integrated resource recovery project: Recycling of Waste in developing countries." In: Appropriate Waste Management for Developing Countries, edited by Kriton Curi. New York: Plenum Press, 1985.

[21] Jorge Jaramillo (2003), Guidelines for the Design, Construction and Operation of Manual Sanitary Landfills, Universidad de Antioquia, Colombia.

[22] Johannessen, L.M. (2009). Observations of solid waste landfills in developing countries: Africa, Asia and Latin America. Urban and Local Government Working Paper Series No. 3, The World Bank, Washington, DC.

[23] Otoniel, B. (2011). forecasting generation of urban solid waste in developing countries, A case study in Mexico, air and waste management association.

[24] Yami Birke(2010). Solid waste management in Ethiopia. Paper presented on the 25th WEDC conference on Integrated Development for water supply and sanitation, Addis Ababa.

[25] Mir Anjum Altafa and J.R Deshazo (2006). Household demand for improved solid waste management: A case study of Gujranwala, Pakistan. Elsevely science Ltd.

[26] George Techobanaglous, Hilary Theisen and Samuel A. Vigil (2007). Integrated solid waste Management, Mc Grow Hill, New York.

[27] U.S. Environmental protection Agency of solid waste (1999). Characterization of Municipal Solid waste in the United States. Report No. EPA 530.