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Assessing Potential and Characterizatio n of Solid Waste of Jimma Town

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Abstract: *This research was conducted in Jimma town on randomly selected 120 households that are estimated to represent all classes of income levels; low, middle and high. Daily waste generations from those households were collected and separated into its components; weight and volume of each component were recorded. This has been conducted for nine consecutive days to determine the average daily household waste generation rate and per capital daily generation rate.*

The study showed that solid waste generation rate has direct relationship with level of family's income. The findings of this study showed that low, middle and high-income level households (HH) generate 0.563kg/HH/day, 0.661kg/HH/day and 0.801kg/HH/ day, respectively; and on average, a household generates 0.775kg/HH/day. Similarly, generation per capital per day from low, middle and high-income level was 0.129kg/cap/day, 0.136 kg/cap/day and 0.149kg/cap/day, respectively, and average of 0.143kg/cap/day. The daily, weekly, monthly and yearly solid waste generation rate of Jimma town was estimated to be 22.74, 159.17, 682.15 and 8,299.47 tons respectively. Results of experimental analysis of waste compositions showed high contents of food waste (36.03%) followed by miscellaneous waste (35.67%) and yard waste (17.87%).

The result of the proximate analysis showed high moisture content and this directly related to the trend of high consumption of kitchen waste, fresh vegetables and fruits. And this ultimately lowers the calorific value of the material 3213.36 Btu/lb (7497.84KJ/Kg).

Key words: Solid waste, calorific values, generation rate, ultimate analysis, proximate analysis and calorific value

1. Introduction

Humans and animals have used the resources of the earth to support life and to dispose of waste. In early times, the disposal of human and other waste did not pose a significant problem, for the population was small and the amount of land available for the assimilation of waste was large. Problems with the disposal of waste can be traced from the time when humans first began to gather together in tribes, villages, and communities and the accumulation of waste become a consequence of life [1, 29].

The increasing of population in the universe, in another way, is increasing the solid waste generated daily and makes difficulties to manage. Many developed and developing countries have different solid waste management system.

In Ethiopia the increase of solid waste generation is resulted from rapid urbanization and population booming [3, 20]. According to Dawit and Alebel (2003) the amount of solid waste in Addis Ababa, capital of Ethiopia, and other fast growing areas in the country has been increasing over time, largely attributed to rapid population growth rate. Recently the municipality of Addis Ababa has increased its coverage to about 85 % [1,].

Jimma, as one of rapid urbanizing town, is far from satisfying the infrastructure demand of its population. Its solid waste management is poor. This in-adequate solid waste management in the town has resulted in the accumulation of waste on open lands, in drains and in the residential areas, causing a nuisance and foul-smelling pools, environmental pollution through leachate from piles (water and soil pollution) and burning of waste (air pollution), clogging of drains. This situation is believed to result in poor environmental conditions, which in turn present a formidable threat to health. There is thus a need for improved waste management system of the town. Information on the characteristics, the composition, the volume and weight of waste generated and collected in Jimma town is limited. Very limited surveys and studies have been carried out in early 1980s and mid 1990s by the Department of Environmental Health, Jimma University and in 2008 by Melaku Tegegn.

In the case of performance and characterization, no research has been taken place on the Jimma solid waste, so that such study is required and taken place for further study and well organized management options. This research aimed to assess the performance and characterizing the solid waste of the Jimma town.

Significance of the study

- It will be a base line for the further study of solid waste management.
- Characterization of solid waste will pave the way for those interested to compost, recycle or land fill or reprocess the waste generated in the town.
- It will be cooperative to decide appropriate Technology for the Waste conversion.
- It gives values for the control of municipal solid waste management.
- It can be useful whenever there is a need to construct landfill for Jimma town as basic engineering data for the design purpose.
- It enables one to know about the properties and types of waste in the town

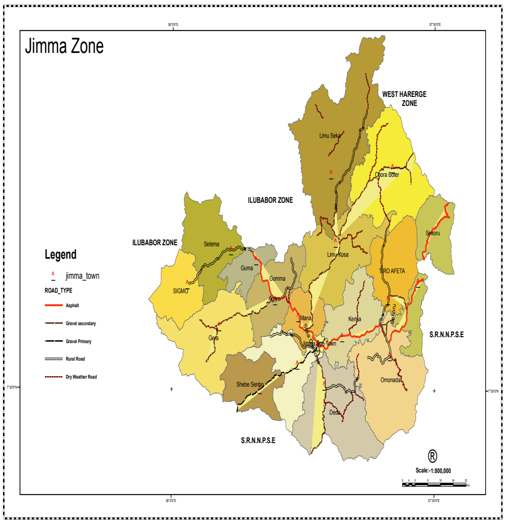
2. Description of study area

This study was conducted at Jimma town, Southwestern Ethiopia. Jimma, which has been founded in the late 1830s, is one of the biggest and dominant political, economical, cultural and historical towns in the southwestern part of the country. Jimma is locally known as the town of Abba Juffar. It is located 354kms far from Addis Ababa on the high way of Mettu - Gambella at an altitude of 1620 m.a.s.l. geographically, the town is located at 7^0 40'N latitude and 36^0 60'E longitudes. According to the master plan of the town, the total area of land of the town is 4623 (46.23km^2) hectares.

Topographically, the Jimma area is divided in to escarpment and alluvial plains. Elevation with in the town boundary ranges from the lowest 1620 m.a.s.l. of the airfield – Kitto to the highest 2010 m.a.s.l. of Jiren. The mean annual rain fall in the town is 1332.1 mm. The temperature of the town is high at March (30.4^{o}C) where the average at this season is 27.5^{o}C and low at January (8.5^{o}C) where the average is 12.5^{o}C. with mean daily temperature of 19.5^{o}C [9].

The information on zoning of the town indicates that 25.7% of the total area is covered by residential buildings, 2.65% by commercial activities, 10.6% by social and public services, 2.6% by administrative zone, 15.4% is land reserved for constructions of roads and the proportion of the land left for other infrastructures is about 39.1%.

The population of Jimma town was estimated to be 159,009 (CSA, 2007) with annual population growth rate of 4.9%. The town had 21 kebeles, but recently after restructuring some kebeles were merged and by now the town has 13 administrative kebeles. River Awettu is crossing at the center of the town [9, 21].



Source [21]
Fig. Map of the Jimma Zone

3. Methods and materials

3.1.1. Methods

This study was conducted following the review of relevant literatures, interviews and questioners were prepared and used for data collection, training of groups of data collectors, measurement of collected samples, household daily solid waste generation and waste classification by type, processing of the survey data, analysis of the data and evaluation of findings, assessment of sustainable management options.

3.1.2. Questioner Preparation

The simple and relevant questioners were prepared and organized in simple language for the local communities. The questioners were prepared in English language and then translated to Amharic and Afan Oromo for the understandings for the respondents. Then, the selected households filled the questioners before sample collection was started.

3.1.3. Determination of sample size

For higher statistical accuracy and confidence level, the number of samples would be more. There are statistical procedures to calculate the number of samples at each confidence level. Usually for solid waste data, the confidence level (C.L) is set at 80% or 90% [31].

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 with a 95% confidence interval and a 1% error as a desired reliability. 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 [34].

According to the central limit theorem the size of sample determined using the following equation.

$$n = \frac{z^2 x \delta^2}{\epsilon^2} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

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

$\delta =$ Standard deviation, $\epsilon =$ Standard error

Therefore, according to the above formula the number of household that considered in this study was estimated to be:

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

3.1.4. Household Identification

In this study 120 households were considered for the collection of samples. These 120 households were selected randomly from the Ginjo guduru kebele which is one of 13 kebeles of the study area in Jimma. This kebeles was selected because of its proper place for the study. It is located in the center of the town and also number of activities is taking place here in Ginjo guduru. It is also one of business running area than the others and so that all level of the residences i.e high, medium and low income individuals are living here.

3.1.5. Data Collection

Before collecting the samples, the plastic bags with different colors has been distributed for each selected households one day before. And the identification number was assigned to each household and corresponding level is given for each and every bag distributed for each household. During distributing the plastic bags all households were informed how and when the sample collectors come back. On the next day early in the morning the collection of samples began. Sample collectors collected all the distributed bags, with solid waste kept in, early morning and brought to the specific place prepared for sorting purpose using hand push cart and horse cart. 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 tenth day (9 days) sample was collected on a daily basis.

Immediately after the waste collection, sorting of waste into different components was made for each household after measuring the total weight and volume of each household wastes. The sorted components then weighted and their volume was determined using different sized wood boxes with a known volume. Finally, the size distribution of the waste was determined using a 25mm and 20mm sized mesh wires and then the weight and volume measurements were done for both size ranges.

3.1.6. Proximate Analysis

Proximate analysis is the analysis of wastes to determine moisture content, ash content and fixed carbon.

Moisture content

Moisture content is a very important factor that influences the decisions for converting organic waste into compost and biogas, using solid waste as a fuel, and designing landfills or incineration plants. Currently there are various types of moisture meters available to check the moisture content. However, the traditional test could also be done on certain types of materials. For the specific study, the moisture content was measured by heating the sample at 105^{o}C in an oven until the weight loss stabilizes. The weight of the sample before and after gives the moisture content. The different fractions of the waste stream shall have their moisture content measured separately. 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 civil engineering lab, Jimma Institute of Technology, just after the collection and analyzed using oven dry set at 105^{o}C for 24 hours.

The ash content of each component of waste was also determined using the same sample and equipment that was kept at 750^{o}C for three hours by using open crucibles [29]. Subtracting moisture content, ash and volatile matter from the initial sample determined fixed carbon.

3.1.7. Ultimate Analysis

Ultimate analysis (elemental analysis) is the analysis of waste to determine percent of C, H, O, N, S and ash. The elemental(C, N and S) analysis of waste components was done at the JIJE Analytical Testing Service Laboratory, Addis Ababa. The analysis involves the determination of sulfur, nitrogen and carbon. The determination of total nitrogen was carried out using the standard Kjeldhal method where loss on ignition is used for Carbon determination. 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 [3]. 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. For the specific case both loss on ignition and stop gap methods were used and the result obtained was approaching each other. The formula for is as follows:

$$\%\text{Carbon} = \frac{100 - \%Ash}{1.8} \quad ....2$$

Calorific Value

The calorific Value of the sample collected was determined at the Geological survey (GS), Hydrocarbon Laboratory analysis lab using adiabatic bomb calorimeter.

Bomb Calorimeter, in this experiment, was used to determine the heat of combustion/calorific value of a sample. A bomb calorimeter is a sealed container capable of holding several atmospheres of gas pressure. A weighed sample of substance is placed in contact with an ignition wire inside the bomb. The bomb is filled to about 30 atm of pressure with O_2, sealed, and placed in a known amount of water. An electric current is passed through a wire to ignite the mixture. As the combustion takes place, the heat evolved raises the temperature of the calorimeter and its surrounding water, as measured by a thermometer. In order to prevent heat loss from the calorimeter system, some calorimeters are surrounded by a second water bath, whose temperature is continuously adjusted (by the experimenter) to match that of the calorimeter.

3.1.8 Data analysis

For the analysis of the sampled solid waste and survey questionnaire the statistical package for social studies (SPSS.20) and Microsoft excels 2007 were used. In the data analysis the compositions of waste was analyzed and per capital generation rate and per household generation rate were determined.

3.1.9 Ethical Consideration

Official letter was written to Jimma Municipality and concerned bodies to communicate about the research and for required data.

3.2 Materials and Instruments

During the study time the following listed materials and equipments were used

1. Hand protective plastic gloves;
   - To protect hand from direct contact with dirt.
2. Mouth & Nose Mask;
   - To protect one from bad smells and inhalation of any fumes.
3. Wood boxes (with different types of volumes)
   - For volume measurement
4. Balance scale
   - For weight measurement of collected sample waste
5. A 25 mm and 20 mm wire mesh
   - For particle size determination
6. Plastic sheets
   - To ensure no loss of waste during sorting
7. Different type and color plastic bags
   - For the collection of solid waste from each household
8. Trash bags
   - For handling the collection of plastic bags
9. Audio and Video Cameras
   - For recording capturing pictures of the working process
10. Bomb calorimeter
    - For the determination of heating value
11. Digital and non-digital oven
    - For proximate analysis (including moisture content, VCM and ash content)
12. Open and closed crucibles
    - Used during the determination of ash and VCM(volatile compostable materials)

4 Results and Discussions

4.1 Results from the survey

During the study time selected households were conducted for different purpose. From the survey the researcher found out that the communities are living in owned, rented and kebele's house. Table 4.1 shows that the housing ownership of the study area.

Table4-1 House ownership of study area

	Frequency	Percent	Valid Percent	Cumulative Percent
Private	66	55.0	55.0	55.0
Rental	28	23.3	23.3	78.3
kebele	26	21.7	21.7	100.0
Total	120	100.0	100.0	

Table 4.1 shows that out of the conducted households 55% , 23.3% and 21.7% are living in private, rental and Kebele's house respectively.

Table 4-2 Income per Month of the respondent

Income level per month	Frequency	Percent	Valid Percent	Cumulative Percent
<500 birr(Low Income)	28	23.3	23.3	23.3
501 - 1000 birr(Medium Income)	26	21.7	21.7	45.0
>1000 birr(High Income)	66	55.0	55.0	100.0
Total	120	100.0	100.0	

According to the data surveyed and Table 4.2, three different income levels are found as 66(55%) individuals are in high income level where 26(21.7%) are in medium income following to 28(23.3%) of which are in low income level. These data are from the questioner as per need of the researcher as it was assigned for those whose income is less than Birr 500 are low income and those whose income is between Birr 501 and 100 are medium income where those whose income is greater than Birr 1000 are high income level. In this study, the researcher concludes that, most of the randomly selected respondents' income is more than Birr 1000. This is due to the additional income they can get from different fruit products and coffee plantation at their compounds. The income level of the household has the correlation with waste generated at the household level which is discussed in Table 4.6.

As per data collected from the respondents, the average level of education of the most respondents of the household varied between 5th grade and college degree. Out of the 120 households surveyed most of the respondents are above grade 12 and some of them are in between of grade 1 to 8. Academic rank of the respondents has negative correlation to the solid waste they generate. Most of the solid waste generated from the study area was from those who are in higher academic level and living in good life standards.

Table 4-3 Energy Availability at household level

Items	Frequency	Percent	Valid Percent	Cumulative Percent
Firewood and cow dung	8	6.7	6.7	6.7
Firewood, cow dung and charcoal	42	35.0	35.0	41.7
Firewood, charcoal, kerosene, electricity	70	58.3	58.3	100.0
Total	120	100.0	100.0	

The researcher found out that, out of the conducted households 58.3% of the total respondents use firewood, charcoal and electricity as an energy source for cooking and making their day to day food. Only 8 (6.7%) households out of 120 respondents use firewood and cow dung as an energy source where 35% of the total respondents use firewood, cow dung and charcoal. In general these figures made the researcher conclude that the as dust and ash waste from the household is high.

4.2 Solid waste handling in the study area

Most of the solid waste at the study area is not collected properly because of lack of proper management. Most of the respondents are facing the problem of waste collection and storage before disposal. For the integrated solid waste management, the six stages of the solid management should be addressed. These are collection, storage, transfer, processing waste, transportation and disposal. According to the data from the municipality of the town, the administration allocates only 1% of the total budget for solid waste management which is not highly recommended by the researcher. The following table shows how the respondents collect and keep the solid waste before disposal in temporarily storage tank at their home.

Table 4-4 Temporary storage available at household level

Availability of storage	Frequency	Percent	Valid Percent	Cumulative Percent
Available	102	85.0	85.0	85.0
Not available	18	15.0	15.0	100.0
Total	120	100.0	100.0	

Table 4.4 shows that from the total respondents, 102 households have temporary storage tank where 18 have no temporary storage. Of these storage tanks, plastic bag, plastic dust bin and wood container are used.

Storing the waste at household level before transferring to the transfer station is one of the management options. The above Table 4.4 indicates that 15% of the total respondents have no temporary storage at the household level. This implies that their first choice to through the waste is either on the street or in the nearby play stations.

From the collected solid wastes, tins, scrap metals and glasses are sorted and sold to the private collectors commonly known as *Kura-lie* for the purpose of recycling and reusing final products before throwing it as a wastes. This contributed that, the actual volume of waste to be disposed of outside the house would be decreased and this reflected in the compositional analysis. 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.

For proper management of solid waste, composting organic matters at household level is highly recommended, but this is not practiced in Jimma as all. From the study findings, only 22.8% of the households compost organic matters at their home. The rest 77.2% are not practiced. The following table shows the practice of composting organic wastes at the households.

Table 4-5 Practice of Composting wastes at household level

	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	29	22.8	22.8	22.8
No	91	77.2	77.2	100.0
Total	120	100.0	100.0	

On the other hand incineration of solid waste may be considered as one of the options to reduce the waste generated during disposal, but incineration has its own environmental impact. Most of the households are practicing incineration at the house hold level. From the data gathered about 54.4% of the households incinerate the solid waste.

4.3 Waste generation rate

Waste generation rates are affected by socioeconomic development, degree of industrialization, and climate. Generally, the greater the economic prosperity and the higher percentage of urban population, the greater the amount of solid waste produced.

4.4 Per capita generation rate

To calculate overall average per capita generation rate, contributions of households in different income groups (which is discussed in Table 4.2 above) is taken in to account. Because as it was discussed earlier, the mean household generation rate of one income group is different from the other groups.

The total waste generation rate survey of households' of Jimma town is estimated depending on the data collected from the selected households. Results of 120 households were analyzed. The generation rate per day per capita of the conducted area is estimated as total waste collected within nine days divided by total population of the conducted area as shown in table 4.6 below.

Table 4-6: Generation per day per household and per day per capital.

Level	Low	Medium	High	Total/average
Total Kg	141.9	154.76	475.58	772.24
No. of HH	28	26	66	120
Population	122	126	354	602
Kg/HH/day	0.563095	0.661368	0.80064	0.675034
Kg/ca/day	0.129235	0.136473	0.149272	0.138326

4.5 Total generation rate

Total generation rate per household per day is equal to total weight of sample in nine days divided by the total house hold conducted. This sample size is comparable with that of similar studies conducted at different areas of developing countries. Households are categorized in to three groups depending on their monthly income. It is well known that per capital income level and solid waste generation rates have direct relationship [33]. Households that have better life standard use more consumption materials than low-income households do, through which they generate higher wastes.

Therefore, the total generation rate of solid waste which is expressed as the amount of waste (kg) generated by one person on a daily basis will be the total waste collected in nine days divided by total population of the study area in general and it will be 0.143Kg/ca/day.

It is known that the total population of the town is about 159,009. Taking this figure into account, the daily, weekly, monthly and yearly solid waste generation rate of Jimma town is estimated to 22.74, 159.17, 682.15 and 8,299.47 tons respectively. There is some variation in figures when it is compared with other studies. For example the annual generation rate of Jimma according to Lem Ethiopia (2005) and Melaku (2008) was 11,897 tons and 9,125 tons respectively. It is highly recommended by the researcher that similar study should be taken place with considerable factors, i.e. season, budget and number of participants.

4.6 Waste characterization

Solid waste streams should be characterized by their sources, by the types of wastes produced, as well as by generation rates and composition. Accurate information in these three areas is necessary in order to monitor and control existing waste management systems and to make regulatory, financial, and institutional decisions.

Because waste characterization studies are relatively expensive to conduct, the general "rules of thumb" provided in this paper should provide sufficient direction for the purposes of waste management planning.

4.7 Waste compositions and moisture con tents

The composition of the generated waste which is expressed as the percentage of different components of the generated waste (i.e. green/food waste, plastics, paper, glass, metals and etc), as well as the volume and density of the generate waste are highly required to determine, plan and design waste equipments (sizes of bins, size of rubbish trucks and etc); type of facilities and services (treatment plants, waste landfill sizes, collection and recycling services. The compositions and moisture contents of the waste from the study area are described in the Table 4.7 below.

Table 4.7: Compositional and moisture content analysis

Category	Percent composition by weight (%w/w)	Moisture content (%)
Food waste	36.03	68.7
Yard waste	17.87	62
Plastics	3.35	0.95
Paper	7.08	8.5
Others	35.67	48

As per the Table 4.7, the composition of the food waste is took the larger figure (36.03%) when compared with other waste composition where the next figure is other waste compositions which content ashes, dusts and other fine materials. The percent of the moisture content of the food, waste (68.7%) is also higher as shown in the table above. These figures are somehow related with other literatures for the developing countries. The ash and dirt proportion of the domestic waste of the study area is also high and this is on the face of it due to the use of charcoal and wood as a major source of energy as discussed in earlier in Table 4.3 above. 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 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. 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. [10].

4.8 Size and Density determination

The particle size distribution analysis shows irregularity in the particle size distribution of the solid waste. Size of the solid waste of the study area is categorized in to three parts as particles with a size larger than 25mm, between 25-20mm and less than 20mm are 58.37%, 10.53%, 31%, respectively. This figures indicated that particle in between 20mm and 25mm size less than those of which is greater than 25mm size. Whereas the bulk density of the solid waste of the study area is estimated to be 632.5kg/m^3.

4.9 Proximate analysis result

According to data obtained from the laboratory experiments, results of proximate analysis of selected samples are given in Table 4.8. The results of ash content show the amount of inorganic substance that would remain after burning.

Table 4.8: Proximate Analysis of the collected sample

Category	Moisture content (%)	VCM	Fixed carbon	Ash content
Food waste	68.7	20	3.8	7.8
Yard waste	62	33	10	2.1
Plastics	0.95	75	2.3	3.3
Paper	8.5	59	7.8	6.2
Others	48	-	-	57.75

VCM: volatile compostable materials

In the following Table 4.9 typical proximate analysis data for materials found in residential wastes for developing country 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 that, the variation of the result might have occurred due to the characteristic difference of the materials and accuracies of the data in addition to seasonal variation.

Table: 4.9 typical proximate analysis data for materials found in domestic solid wastes

Category	Moisture content (%)	VCM	Fixed carbon	Ash content
Food waste	70	21.4	3.6	5
Yard waste	60	30	9.5	0.5
Plastics	0.2	95.8	2	2
Paper	10.2	75.9	8.4	5.4
Textile	10	66	17.5	6.5

Source: extracted from Techobanaglous et al., 1993

4.10 Ultimate/ elemental Analysis results

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 commonly known as compost. Data on the ultimate analysis of the individual waste components are presented in table 4.10.

Table 4.10: Ultimate analysis of domestic solid waste

Waste components	Carbon content	Nitrogen content	C:N ratio
Food waste	51	0.68	51:0.68
Yard waste	54	4.2	54.9:4.2
Paper	52	1.1	52:1.1

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. The researcher can conclude that, the variation of lab results of the conducted sample and the ultimate value is due to the accuracy of the sample collected. Accordingly, the sample tested is more suitable for the production of the compost depending on result recorded. The standard carbon to nitrogen ratio of MSW to be composted is 25-50:1[6].

Table 4.11: Typical data on the ultimate analysis of domestic solid waste

Waste components	Carbon content	Nitrogen content
Food waste	48	2.6
Yard waste	47.8	3.4
Paper	43.5	0.3

Source: extracted from Techobanaglous et al., 1993

4.11 Calorific Value

The heat value/ calorific value of the samples were determined using adiabatic bomb calorimeter at the GS lab, Addis Ababa. According to the lab result, the total calorific value of the sample analyzed was 3213.36 Btu/lb where a typical value of domestic solid waste has a total heating value of 5000 Btu/lb [29]. However, the determined total heating value of the sampled domestic solid waste is less than 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.

5 Conclusion

From the study conducted, Jimma town has great environment pollution due to uncontrolled and improper solid waste management. The solid waste simply thrown to the uncontrolled open dump can pollute the river around and decrease the beauty of the town as well.

The study showed that the per capital and per household solid waste generation rate of the town is 0.143 kg/cap/day or an average of 0.775 kg/HH/day respectively. For the total population of the study area 22.74 tones of domestic solid waste is generated from the town in a day. This does not include other municipal solid waste streams.

The proximate analysis results showed that the moisture content of the food waste is 68.7% and yard wastes is 62%. This figure helps the researcher to conclude that, as the moisture content increases the energy value of the waste decreases. So incineration of such waste is not recommended. Rather it is highly recommended that the organic wastes are suitable for the compost to organic fertilizer as the finding results of carbon and nitrogen contents are 51% and 0.68% respectively and nearer to ultimate values. The finding of this paper indicated that 22.7% of the households in the study area are practicing composing household solid wastes at their compounds. This practice should be encouraged at the kebele and town level.

The survey analysis and visual observation show that the placement of communal containers is not appropriate and sufficient and this discourages peoples from disposing into the container. They rather preferred to dispose the waste nearby open areas and play stations.

To have a complete picture on generation rate and characteristics of the solid wastes, similar studies should be conducted on the other waste streams and periodic research is needed to update and modify the data and information regarding household solid waste at the kebele and city level and planning solid waste management accordingly.

6 Recommendations

- Solid waste data is largely unreliable. This research contains one of the most comprehensive compilations of municipal solid waste data in Jimma Town; yet, due to inconsistencies in data recording, definitions, collection methods, and seasonal variations, the data can only be considered approximate, albeit more accurate than most. For planning purposes, however, the data presented in this research should be sufficient.
- Municipalities should charge for waste management before disposal, and possibly collection, transferring, and transportation based on generation rates.
- Municipal governments are usually the responsible agency for solid waste collection and disposal, but the magnitude

of the problem is well beyond the ability of any municipal government. They need help. In addition to other levels of government, businesses (MSE) and the general community need to be more involved in waste management.

- The waste components requiring priority attention in Jimma are organics (food waste), yard wastes and papers.
- The municipality should encourage the community to participate on disposal fees based on the volume or weight of refuse generated in each household. If so the amount of refuse will be reduced.
- Solid waste reduction at the source is the preferable and crucial means to management system. But this will be done by educating and awarding the primary participants who are households.
- From the research conducted, the contents of carbon and nitrogen in food waste are 53% and 0.68% respectively. These values vary somewhat from the ultimate values which are 48% and 2.6% for carbon and nitrogen respectively. Even though the values vary, the finding shows that the solid waste at the study area is suitable for compost in general and food wastes in particular. So that composting is the primary conversion technology for the domestic solid waste of Jimma town.
- In the town there are about 54 containers which serving the communities for the purpose of waste transfer. This means one container serving for about 3000 individuals and not adequate to handle/ accommodate the all wastes generated. So increasing number of the containers is highly recommended.
- The town administration should think about the management options of the solid waste.

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