

Quantification, Characterization and Recycling Potential of Solid Waste: Case Study Bahir Dar Institute of Technology

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Abstract: Various activities in university generate solid wastes that can pose environmental and human health threat. They can be reused, recycled or composted, if managed properly. However, solid waste management brings significant problem for universities as their collection, transportation, characterization and disposal requires intensive investigation. This study design as minimized cross-sectional study provide sufficient data for appropriate decision making and integrated solid waste management formulation. It was initiated to quantify, characterize and determine the recycling potential of solid wastes from Bahir Institute of Technology. Two study periods, November 1/2015 to December 30/2015 and January 31/2016 to February 14/2016 were set by assuming as academic and administrative activities were consistent (except during vacations). 50 samples from buildings, dormitories, cafeterias, laboratories and clinics were collected, separated, sorted and characterized. Weight percentage for each category and sub-categories were determined. Under each analysis, average values of triplicate measurements were used. The result of the study reveals that of the average total solid waste generated per day, 57.4% is compostable, 38.9% recyclable and 3.6% non-recyclable wastes. Finally, for effective solid waste management in Bahir Dar Institute of Technology, integrated solid waste management strategies; solid waste generation rate reduction, reuse, recycle, and composting of organic wastes through providing proper training and incentive was recommended.

Keywords: Characterization, Integrated Solid Waste Management, Quantification, Recycling, Solid Waste

1. Introduction

Integrated Solid Waste Management (ISWM) systems are one of the greatest challenges for sustainable development (De Vega *et al.*, 2008). ISWM can be defined as the selection and application of suitable techniques, technologies management programs to achieve specific waste management objectives and goals (Tchobanoglous *et al.*, 1993). A hierarchy in waste management can be used to rank actions to be implemented programs within the community. The US Environmental Protection Agency (EPA) (1989) has defined this hierarchy as source reduction, recycling, waste combustion and land filling. For any ISWM system to be successful, the first step is to carry out waste characterization studies (De Vega *et al.*, 2008). Because of the heterogeneous nature of solid wastes, determination of the composition is not an easy task. Strict statistical procedures are difficult, if not impossible, to implement. For this reason more generalized field procedures, based on common sense and random sampling technique have evolved for determining composition (Tchobanoglous *et al.*, 1993).

Solid waste production and their disposal has become a matter of great concern in developing countries (Das *et al.*, 2013; Hossain *et al.*, 2013). This is mainly due to population growth and unplanned urbanization. Due to rapid population growth and uncontrolled urban expansion urban environment is degrading severely (Salam *et al.*, 2012). For most of the cities in developing countries mass production and disposal of solid waste is an obvious cause for the environmental degradation (Asraf, 1994).

Reducing the quantity of wastes that have to be handled, transported and disposed in a landfill could lead to two main results in a reduction of the institutional expenditure dedicated to waste management and an increase of the useful life of the sanitary landfill (if there is). Besides these benefits, a reduction in the amount of waste produced by universities would also have environmental and social benefits (WWF, 1991). Because colleges and universities have the moral and ethical obligation to act responsibly towards the environment, they would be expected to be leaders in the movement for environmental protection. Specifically, it would be expected that universities would drive the efforts towards responsible waste management. It would set an example to the students and the community besides cost reduction for the management of waste.

Waste management programs in higher education institutions in industrialized countries began more than 20 years ago and vary from voluntary and local efforts to institutionalized programs (Armijo *et al.*, 2003). Some of the higher education initiatives focused on recycling and waste reduction have been very successful.

Bahir Dar Institute of Technology is resides nearer to the Lake Tana, which is ecologically sensitive environment, meaning that any kind of pollutant released towards the lake may leads to disastrous environmental and public health consequences. Significant amount of solid wastes have been generated in a daily bases at Bahir Dar Institute of Technology. Yet there were no integrated solid waste management practice employed by the institute to prevent the potential pollution treat. The extent and severity of water pollution problems can be described as "each year over five

million people die from water-related diseases, two million of the annual deaths are of children, in developing countries 80 % of all illness is water-related, at any one time half of the population in developing countries will be suffering from one or more of the main water-related diseases, a quarter of children born in developing countries will have died before the age of five, the great majority from water-related disease” (WHO, 1993).

In Ethiopian universities there is little or no study has been done regarding waste characterization and quantification for further analysis of recoverable potential of wastes. No reliable data on solid waste characteristics and generation rate within the Bahir Dar University. The lack of characterization studies suggests the need to research and to document waste composition in order to have the necessary data to propose better handling and management alternatives for solid waste. In this sense, the main objective of this study is to reduce the gap between the need for this type of study.

The overall objective of the study is to determine the quantity, quality and recycling potential of the solid wastes generated from Bahir Dar Institute of Technology.

2. Methodology of the Study

2.1 Overview of the Study Area

Bahir Dar University comprises five campuses, which are the university main campus (“Peda”), the College of Business and Economics campus, the College of Agriculture and Environmental Science campus (“Zenzelima”), the Institute of Technology campus (“Poly”) and the Institute of Law and Land Administration campus (“Yibab”). The present study, however, was conducted at one of the five campuses, Bahir Dar Institute of Technology. This campus was selected as it situated at the center of Bahir Dar city near to Lake Tana, meaning that any waste generated have a potential to pollute the lake’s ecosystem as well as to pose public health treat, especially, if it is not handle properly. Currently, according to human resource office data, Bahir Dar Institute of technology had a total of **1,416** workers hired as academic and administrative staffs and the from registrar office data the total number of students in the campus undergraduate , postgraduate and extension programs are about **3421**, **442** and **2493**, respectively.

2.2 Study Period

As the period of the year varies the people’s activities as well as the amount, type, composition and the rate of solid wastes they generate also varies. For example, different wastes are generated during hot and cold or rainy and non-rainy periods. Hence, seasonal variations heavily influence the nature (the type, amount, composition and rate) of solid wastes generation. For this study, however, academic and administrative activities performance in the campus has assumed to be consistent throughout the year (except during vacations).

The study was started by defining suitable period and specifying the time boundaries to investigation solid waste

generated at Bahir Dar Institute of Technology. Two study periods were identified and selected. The first study period was at the term-time, from November 1/2015 to December 30/2015, during which the campus had maximum number of student and staff populations. Whereas, the second period was at the semester break time, from January 31/2016 to February 14/2016, during which undergraduate students were leave the campus. However, the number of postgraduate students and staffs remained relatively unchanged.

2.3 Sample Collection

Solid waste samples were collected from five different sampling sites that were entrusted as they could represent the entire solid waste generators found in the campus. Sampling sites were academic/administrative building (B-01), Students dormitory (“Taye Block”), Students cafeteria (the main café), Laboratory (food process lab-I) and the student’s clinic. In doing so, a total of **50** homogenous solid waste samples were selected randomly across different solid waste generation sites for unbiased statistical investigations. During the first study period a total of **40** homogenous solid waste samples were collected, which were one sample from each of the five representative sampling sites for two months. During the second study period a total of **10** solid waste samples were collected, which were one sample from each of the five sampling sites for the two weeks.

2.4 Sample Quantification and Characterization

There are a number of possible methods that can be used for solid waste investigation. These can be divided into two categories; the first one is quantification or measuring the amount of waste and characterization of waste. This can be further divided into characterization through visualization and through hand sorting. Quantification of solid wastes can be done with one of the methods: quantification by measurements at the point of generation, by examination of records at the point of generation, by examination of records at the disposal facility, and/or through use of a vehicle survey method (UNEP, 2009). As there were no recorded document found in the campus regarding to the quantity and rate of generation of solid waste land as the solid wastes were disposed-off within the campus or as there were no need for transportation of solid wastes outside the campus, the ultimate approach used in this study were by measuring at their point of generation and characterization through visualization and through hand sorting.

From each of the selected sampling sites, a total of **50** solid waste samples were collected directly at their point of generation and characterized visually and sorted by hand into their respective categories as recyclable and non-recyclable, compostable and non-compostable organics, papers and cardboards, construction/demolitions, metals, plastics, glasses, hazardous and other wastes. The sorted wastes were quantified by determining the amount of solid wastes disposed during the given period of time at their source. Investigation was carried out every day at **5:00** throughout the study.

Table 1: Data sheet for the collection of solid waste categories (CURC, 2001).

Code: Weight of bag (g): Sample site: _____ Date: _____

<u>Paper and cardboard</u> (g) - White - Colored - Newspaper - Magazines - Other cardboard <u>Metals</u> (g) - Aluminum cans - Metal mixed <u>Construction/demolition</u> - Gravel and Sand - Rocks - Wood - Others	<u>Plastics</u> (g) - Containers 1 - Containers 2 - Containers 3–7 - Other containers - Plastic mixed - Bags - Foam <u>Glass</u> (g) - Bottles clear - Bottles green - Bottles amber <u>Other</u> (g) - Sanitary waste - Other (describe) - E-Waste	<u>Organic</u> (g) - Food waste - Leaves and grass - Trees and branches - Harvest waste - Organic mixed <u>Hazardous</u> (g) - Cleaner - Batteries - Reactive agents - Insecticides - Rocks - Other (describe)
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Containers 1 = PET, Containers 2 = HDPE, Containers 3–7 for the rest of the recyclable resins

Data Analysis and Recording

For data analysis and recording, the important considerations are to produce the results, which are representative with high confidence levels with minimum costs (UNEP, 2009). Therefore, triplicate measurements were employed during each investigation and average values were taken. The weight percentage for each category and sub-categories were estimated and recorded. The weight percentage for each subcategory was calculated using:

$$PS = \frac{PL}{PT} * 100 \text{-----Eq 1}$$

Where: PS - is the sub-category percentage, PL - is the amount of sub-category in kg, and PT - is the total weight of sample in kg.

Differentiating the solid wastes among recyclable and non-recyclable categories was done after obtaining the weight percentage of each subcategory. The recycling potential of each solid waste sub-category were determined by categorizing them according to: Waste for which there exists a recycling market, Recyclable waste for which there does not exist a local market, and Non-recyclable wastes.

Moisture content is a very important factor that influences the decisions for converting organic waste into compost and biogas, using as a fuel, and designing landfills or incineration plants (UNEP, 2009). The moisture content of solid wastes under each subcategory was determined by oven drying at 105 °C until the weight loss stabilizes (for 1 to 3 hours). The moisture contents of the solid wastes can be calculated as follows:

$$\text{Moisture Content (\%)} = \frac{\text{Wet Weight} - \text{Dry Weight}}{\text{Wet Weight}} * 100 \text{-----Eq-2}$$

3. Result and Discussion

Generation rate

Several day-to-day activities was executed at Bahir Dar Institute of Technology while providing different services generate substantial amount of solid wastes, however, the generation rate is predominantly associated with the number of peoples encompass in the campus. The study reveals that

the solid waste generation rate at Bahir Dar Institute of Technology is considerably affected by the seasonal variation. The campus generates an average total of 1,280 kg/day solid wastes during the first study period (during term-time), and 672 kg/day in the second study period (during “semester-break”). The solid waste generation rate of the selected sampling sites are average total of 397 kg/day during the first study period (31.02%) of the average total solid wastes generated by the entire campus, and 105 kg/day during the second period (15.63%) of the average total solid waste generated by the entire campus.

During the break times, at the middle and at the end of the year, the number of students as well as the activities performed at the campus is small number. However, significant numbers of students are present at the campus and the activities become steady for the rest of the year. The institute has neither solid waste reduction measures nor recycling, composting or properly disposing mechanisms. Rather, the institute has been done some sort of solid waste management practice. This is simply collected from their sources, transported to a specific location and burns it in an open atmosphere.

Waste Characterization

Knowing the composition of solid wastes enables to make sound decisions over solid wastes collection, separation and recycling strategies. From the average total of solid wastes generated during the first study period, 397 kg/day, an average weight of 125 kg/day (31.49%) is from the main café, 105 kg/day (26.45%) from the dormitory (“Taye block”), 97 kg/day (24.43%) from the B-01 academic/administrative building, 42 kg/day (10.6%) from food process lab-I and the rest 28 kg/day (7.05%) from the clinic. Considering the entire campus, from 1,280 kg/day of average solid wastes generated in the first period, an average weight of 403.03 kg/day is from cafeterias, 338.56 kg/day from dormitories, 312.7 kg/day from buildings, 135.68 kg/day from laboratory and the rest 90.24 kg/day from clinics.

From the average total of solid wastes generated during the second period, 105 kg/day, an average weight of 25 kg/day (23.8%) is generated from main café, 55 kg/day (52.38%)

from the academic/administrative building, 20 kg/day (19.05%) from the dormitory, 4 kg/day (3.8%) from food process lab-I and the rest 1 kg/day (0.95%) from the clinic. Considering the entire campus, 672 kg/day of average solid wastes, an average weight of 159.94 kg/day is from cafeterias, 128.02 kg/day from dormitories, 352 kg/day from buildings, 25.54 kg/day from laboratory and the rest 6.38 kg/day from clinics. The findings of the study illustrates that

most of the solid wastes during the first study period is generated from the main café (31.49%) and from the dormitories (26.45%) together contributes more than half of the waste, whereas, during the second period their contribution reduced significantly. The presence and absence of students had a multiplied effect on the solid waste generation rate. The result for the subcategorized solid wastes is summarized as follows in Table 2.

Table 2: Solid waste Composition (kg/day) for subcategories

Waste category	Buildings		Cafeteria		Clinic		Dormitories		Laboratory	
	P ₁	P ₂	P ₁	P ₂	P ₁	P ₂	P ₁	P ₂	P ₁	P ₂
Papers and cardboard	165	179	7	7	40	3	125	12	55	15
Metals	---	--	11	2	1	---	---	---	---	---
Construction/demolition	23	19	49	20	6	2	57	68	25	10
Plastics	61	83	43	17	23	---	46	17	15	--
Glasses	---	---	5	1	13	---	33	---	11	---
Others	41	46	52	28	4	---	31	12	9	1
Organics	23	25	236	85	---	---	47	19	19	---
Hazardous	----	---	-----	-----	3	1	---	---	2	---
Total	313	352	403	160	90	6	339	128	136	26

P₁ - is the first study period P₂ - is the second study period

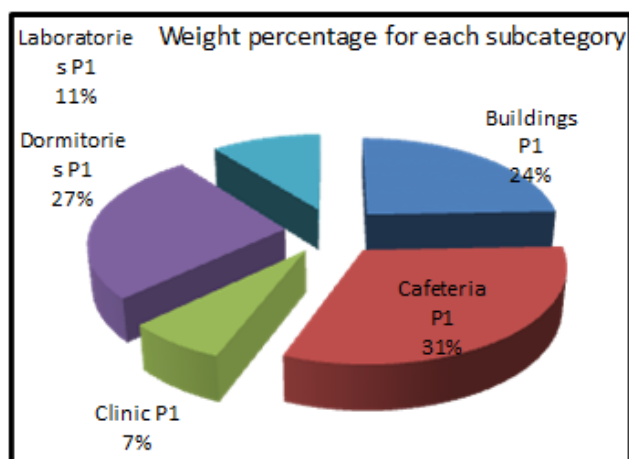


Figure 1: Average weight percentages of each representative solid waste generator, during first study period (November 1/2015 to December 30/2015)

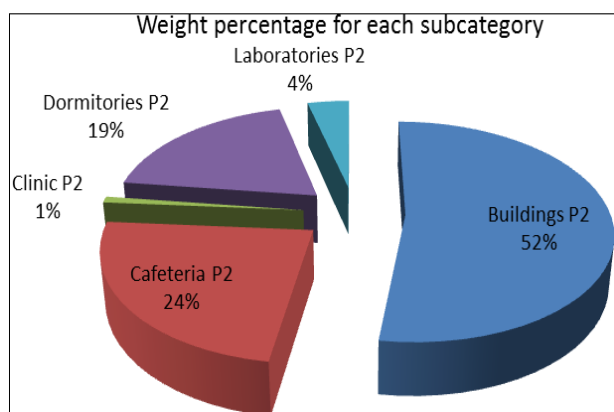


Figure 2: Average weight percentages of each representative solid waste generator, during second study period (January 31/2016 to February 14/2016).

Recycling Potential

As shown the above table, paper and cardboard wastes (such as newspaper, magazines, rough papers, cartons, etc.) is dominant with 608 kg/day (31.13%) of the total solid waste

generated, organic wastes (such as food waste, trees, leaves and branches, etc.) are about 454 kg/day (23.25%) of the total solid waste generated. Plastics (such as plastic bags, plastic bottles, plastic packages etc.) constitute about 305 kg/day (15.62%), Construction/demolition (such as gravel, sands, woods etc.) constitute about 279 kg/day(14.29%),Glass (such as bottles, glass containers, broken glasses etc.) constitutes about 63 kg/day(3.22%), Metals (such as metal cans, metal containers etc.) constitute about 14 kg/day (0.72%),Hazardous (such as wasted chemicals, expired chemicals, expired drugs, clinic and laboratory wastes) constitutes about 6 kg/day(0.05%),and Other wastes constitutes about 224 kg/day(11.47%) of the total solid waste generated.

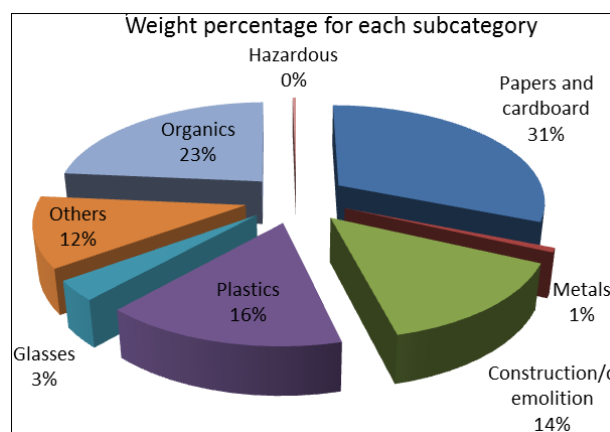


Figure 3: Weight percentages of each subcategory

The study elucidate that from total solid waste generated from the Bahir Dar Institute of Technology potentially recyclable solid wastes are an average of about 760 kg/day (38.93%), potentially compostable solid wastes are an average of about 1121 kg/day (57.43%) and non-recyclable solid wastes are an average of about 71 kg/day (3.64%).

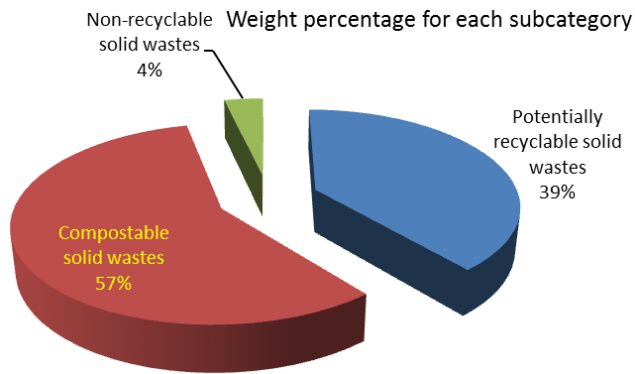


Figure 4: Weight percentages of solid wastes based on recyclability and compostability

Solid Wastes from Buildings

Solid wastes originated from the academic/administrative buildings have been found insensitive to the seasonal variations. It is because of, in most cases, students did not have significant interaction at these buildings, which resulted in the presence and absence of students had no potential effect over the solid waste generation rate at these buildings. In general, the majority of these wastes are potentially reusable, recyclable as well as compostable. The solid wastes collected from the buildings did not embrace metals, glasses, as well as hazardous wastes. Instead it defined as it is paper and cardboard wastes.

Solid Wastes from Cafeterias

The solid wastes originated from the cafeterias did not comprise hazardous wastes. Rather compostable organic wastes holds overpowering majority as shown the figure above. The paper and cardboards constituents are invariably 7 kg/day for both study periods, meaning that the papers and cardboards generated from cafeterias is not affected by seasonal variations. As the majority of these wastes, more than half of the total cafeteria solid wastes, are organics, there is ample prospect for composting, recycling and reusing of the wastes.

Solid Wastes from Dormitories

Dormitories waste is one of the major solid waste contributors in the campus, which is responsible for average solid wastes of 338.56 kg/day and 128.02 kg/day generated during the first and second study periods, respectively. It is recognized for 26.45% and 19.05%, respectively, of the total solid waste generated in the campus. Metallic and hazardous wastes are not found in the dormitory wastes. However, the dormitory solid wastes are incorporate significant amount of paper and cardboard. Furthermore construction/demolition, plastics, organics, and other wastes are identified as potential constituents of the dormitory solid wastes. Most of these wastes are compostable, recyclable, while some of them are reusable.

Solid Wastes from Clinics and Laboratories

Solid wastes arise from clinic and laboratory sources are share some characteristics. These wastes is contains hazardous wastes while wastes identified as paper and cardboards holds comparably the same (higher) position in both sources. Laboratories solid waste dominates a paper and cardboards of during the first and second study periods. This

portion of wastes could be compostable and recyclable; however, special care must be taken as they were.

4. Conclusion

Bahir Dar Institute of Technology is one of the oldest higher institutions in Ethiopia. Yet, it did not adopt an appropriate means for its solid waste disposal exercise. Solid wastes have collected from their sources and then moved to the place where they burned in inconsistent manner without any attempt to record, identify, quantify, sort or characterize them. For this reason, there is no documented information found about the quantity, quality or rate of solid wastes generated. In addition to this, solid wastes have been burned in an open atmosphere at the bank of a lagoon/wetland, which crosslink with Lake Tana, especially during rainy seasons. This designates that; the contamination of the lake by the solid wastes seems inevitable, which are calling for the institute officials to instate special attention.

The institute's solid waste rate of generation exchanges along with the season variations; found minimum at the break time, when the number of students absent, and found higher at the term-time, when the number of students increased. The study ratifies that inference should not be drawn or not acceptable if drawn based on the outcomes gathered from incomplete, short-term or one season solid waste examination, as they could not represent the whole and so misleading. However, sound decisions could be addressed if the solid wastes are intensively investigated for appropriate period of time, which covers the seasonal variations. The outcomes could be used as a base for comparison with other outcomes from the same or different educational institutions, but studied under similar condition.

Compostable (57.43%) and recyclable (38.93%) wastes, comprises chiefly paper and cardboards (31%), organics (23%), plastics (16%) and construction/demolitions (14%), are responsible for over whelming portion of total solid wastes originated from Bahir Dar Institute of Technology. Therefore, the study also advocates that, the majority of the solid waste generated by the campus could be useful in a number of ways, but it will be realized only if these wastes are coped properly. However, in viewing of the existent approach or due to the absence of apparent solid waste management methodology or proper means for the collecting, identifying, recycling, composting and/or proper disposal, the solid wastes generated from the campus signals a problem. Though some sort of movement towards assessing the possibility of using organic wastes generated from cafeterias for biogas production was under progress, it will be achieved only if the institute develops integrated solid waste management strategy, which necessitates a comprehensive investigation of all solid wastes raised from the campus to get a complete picture about it.

5. Recommendation

Bahir Dar Institute of Technology urgently needs to shift the location where its solid wastes are disposed-off and the entire means of solid waste handling. The institute also expected to develop and employ an integrated solid waste

management in order to minimize the rate of generation of solid wastes, to develop a better and effective mechanism of recycling, composting and disposal, and to generate energy from the solid wastes, thereby to minimize the public health and environmental impact while maximizing profit or generating income.

As some of the solid wastes are released because of the lack of knowledge and carelessness, the institute can reduce its solid waste generation by giving proper training to handle specific duty or activity and by assigning responsibility and taking some measure. In general, Bahir Dar Institute of Technology can significantly reduce the solid wastes rate of generation through, in addition to implementing integrated solid waste management program, minimizing or abandoning wasteful materials and activities, providing proper and consistent training, promoting reusing, recycling and composting of generated solid wastes. The ongoing study on the biogas production potential is promising step taken by the institute's authority. Furthermore, exhaustive investigation of solid wastes in consistent manner is important and advisable.

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