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# End-of-pipe Waste Analysis and Integrated Solid Waste Management Plan

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**Abstract**

A ten-year integrated solid waste management plan was established for the University of the Philippines Los Baños which complies with the provisions of RA 9003. An end-of-pipe Waste Analysis and Characterization Study (WACS) was performed to identify the classification of wastes in UPLB. Waste generation was found to be 593.67 kg/day on the average and is expected to increase by 2% per year which is 709.49 kg/day on the year 2027. The waste composition by weight of the non-biodegradable wastes are as follows: plastic (55.68%); paper (35.77%); glass bottles (5.22%); metal (2.77%); and residuals (0.55%). A large portion of the wastes, which is 99.45% by weight, are recyclables. The loose density of wastes is 131.93 kg/ $m^3$. Feasible collection points were assigned to improve efficiency of the collection of wastes in the university. Building units inside the campus were clustered and was assigned to dispose wastes to a single temporary storage facility per cluster. There are 181 units of 240-L garbage bin needed for the 39 clusters in UPLB. Two sets of dimensions of a proposed temporary storage facility were provided for the temporary storage facility; 5×2×2.2 m and 3.5×2×2.2 m. Conceptual design and structural plans of the materials recovery facility were provided. Mass balance was performed, and the theoretical diversion efficiency of the materials recovery facility is 99.445%.

*Keywords:* Solid Waste Management; WACS; Loose Density; Collection Points; Temporary Storage Facility; Conceptual Design; Mass Balance.

## 1. Introduction

Solid waste management pose a wide variety of administrative, economic, and social problems that must be managed and solved [1]. The production of solid waste has increased from 0.64 kg/capita/day to 1.20 kg/capita/day in the past 10 years due to the urbanization of rural areas [2]. It is expected to increase to 1.42 kg/capita/day of municipal solid waste since continuous increase of the population logically correlates to the increase in waste generation. Moreover, the Philippines is part of the East Asia and Pacific Region where the annual waste generation recorded for the year 2005 is approximately 270 million tons per year with an average of 0.95 kg/capita/day [1]. On the other hand, the waste generation of the Philippines is 40,000 tons/day with a per capita generation of 0.32 to 0.71 kg/day; with a collection efficiency of 40% to 85% [3]. Municipal solid waste generated in 2016, 2.10 billion tonnes, may grow to 3.76 billion tonnes by 2050 [4].

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In 2016, it was reported that the population in the Philippines is approximately 100.98 million [5]. The province of Laguna recorded 3,035,000 and is expected to increase by 1.72%, based on the 2005 Census of Population. Logically, as people increase in population, waste generation also increases. Since the Philippines is a developing country, the continuous manufacture of products results into production of more wastes which contributes to environmental degradation [6]. The classification of wastes generated would be necessary for collection and handling purposes; solid waste management as a whole. If one could segregate wastes properly, it would create a big impact in the preservation of our environment; reusable and recyclable items will not be disposed, instead serve other useful purpose; food wastes is used as fertilizers; paper wastes, plastic wastes and other combustible materials could be incinerated. The Ecological Solid Waste Management Act of 2000 (RA 9003) along with other resolutions and Municipal Administrative Orders, protects the public health and the environment. RA 9003 under the law adheres to the *"systematic administration of activities which provide for segregation at source, segregated transportation, storage, transfer, processing, treatment, and disposal of solid waste and all other waste management activities which do not harm the environment."* However, open dump sites are still being used in the country which pose threat and issues affecting public health. Moreover, the problem with solid wastes aggravates since there are limited land disposal sites.

Local government units (LGUs) are responsible for solid waste management of their respective municipalities. The enactment of the Ecological Solid Waste Management Act mandated the Department of Education (DepEd) and Commission on Higher Education (CHED) academic institutions including state universities and colleges (SUCs) to incorporate ecological waste management in the school system. In pursuing the advocacy of UPLB to have a sustainable development through environmental protection, university policies on solid waste management must be intensified [7]. Progress towards environmental sustainability will be hindered if solid waste is not managed properly [8]. However, the change in the attitude and behavior of people on waste management shall not be overlooked [9].

The Municipal Solid Wastes (MSW) in the Philippines is composed of 52.31% biodegradables, 27.79% recyclables, 17.98 % residual, and 1.93 % special wastes [4]. Since the wastes are comprised mostly of biodegradable wastes, then, composting will significantly contribute to the reduction of wastes that are thrown out to disposal sites of the municipality. Furthermore, recyclables which can be processed in a Materials Recovery Facility (MRF), can also contribute to the reduction of disposed solid wastes.

Due to the closure order imposed by the Department of Energy and Natural Resources (DENR) to the Waste and Resource Management, Inc. (WARM) controlled dumpsite, which facilitates the waste of UPLB, the handling of waste management was transferred to the University Planning and Maintenance Office (UPMO). The waste processing at the current materials recovery facility is done by sorting wastes and then selling it at a Junk Shop afterwards. However, UPLB does not receive the profit from selling the wastes but rather the sorters, which the UPMO has a verbal agreement with, are the ones who benefit from this. This verbal agreement was made so that UPLB would not compensate the sorters, however, they can recover wastes from the MRF as much as they can, and these wastes are for them to sell or benefit with. Since they are not employed by the University, their efficiency in sorting wastes varies with their own personal reasons. On the other hand, the University can't afford the wastes to be piled up since this will be non-compliant to RA: 9003, regarding proper solid waste management, and will result to consequences if the DENR conduct a visit to the facility.

If wastes are not properly handled and disposed, it can be a source of vector carrying diseases and can pollute air and water; a contaminated water has a risk of having waterborne diseases such as gastro and cholera. By imposing a proper solid waste management in the university, this study poses a great impact in preserving the environment and health of the public.

In this study, characterization of waste composition is used for the design of the appropriate materials recovery facility which aims to result into an efficient handling and disposal of wastes. Also, temporary storage facilities are designed to promote segregation and efficiency in waste collection. The main objective of this study is to establish a Solid Waste Management plan for the University of the Philippines - Los Baños (UPLB) in compliance with RA 9003. The specific objectives of the study are:

- Estimate waste generation and identify the characteristics of wastes;
- To identify the collection scheme of UPLB and establish feasible collection points; and
- Design the Materials Recovery Facility (MRF) for the processing of recyclable wastes and as temporary storage of residual wastes.

## 2. Materials and Methods

The general methodology is summarized below, shown Figure 1. The following are the methodology applied for the study and are elaborated further on the succeeding part of this chapter:

- Total waste collected in the month of September 2017, one per each week, was unloaded to the existing MRF;

- Waste collected was weighed by portions of 50 kilograms;
- Total weight for the collection was recorded;
- Wastes were classified and separated according to the 31 waste classifications;
- Total waste per classification was computed;
- Waste density was computed;
- Data acquired was sorted and analyzed.


**Figure 1. Methodical framework of the study**

### 2.1. Waste Generation

Total waste generated in UPLB was measured by weighing four truck collections in a week of waste generation. The average of all four truck loads was computed using Equation 1.

$$WG_n = \frac{D_1 + D_2 + \cdots + D_n}{N} \quad (1)$$

Where; $WG_n$ is the total waste generated for n days (kilograms); $D_n$: is the weighed waste for the day (kilograms); N: is the number of days.

Population was projected at target year n and exponential growth Equation 2 was used.

$$P_n = P_o(1 + r)^n \quad (2)$$

Where; $P_n$: is the waste generation at n years later; $P_o$: is the initial waste generation; r: is the annual growth rate of wastes.

### 2.2. Waste Composition

In this study, waste composition was based from the end-of-pipe analysis performed by the researcher. Wastes are divided into 31 categories. Amount of waste per category was computed using Equation 3.

$$W_a = WG \times \%A \quad (3)$$

Where; $W_a$: is the amount of waste in category a; WG: is the total waste generated; %A: is the fraction of category a based from WACS.

Waste stream is further categorized into five categories: plastic, paper, metal, glass bottles and residuals using Equation 3. Specific information on the behavioral aspects and local conditions shall be generated within the analysis [12].

### 2.3. Waste Density

The density of wastes was computed by dividing the waste generation (kg/day) by the volume of the truck, as shown in Equation 4.

$$Density\ of\ wastes\left(\frac{\frac{kg}{m^3}}{day}\right) = \frac{Waste\ Generation\left(\frac{kg}{day}\right)}{Volume\ of\ truck\ (m^3)} \quad (4)$$

### 2.4. Dimensions of Temporary Storage Facility

Each building unit is clustered by considering its waste generation. The UPLB campus map was used as a basis for the measurement of the distance of the feasible temporary storage facility to each of the building unit. On-site inspection was performed to identify available land areas. The dimensions of the temporary storage facility are dependent on the number of dumpsters required per cluster and is shown in Equation 5.

$$D_a = \frac{W_a \times P_n}{\rho_a} \quad (5)$$

Where; $D_a$: is the number of x-Liter dumpsters required for waste category a; $W_a$: is the amount of waste in category a (percentage); $P_n$: is the waste generation at n years later (kg/day); $\rho_a$: is the density of category a ($m^3$); x: is the capacity of the dumpster ($m^3$).

### 2.4. Waste Diversion

MRF starts with the registration, inspection and separation of biodegradable from recyclables. Recyclables were manually sorted and weighed. Furthermore, paper, carton, tin cans, metals, plastics, and glass were separated, weighed, and stored in designated bins. The total waste which can be diverted was computed using Equation 6.

$$W_d = W_t - W_r \tag{6}$$

Where; $W_d$: is the total diverted waste; $W_t$: is the total amount of waste generated; $W_r$: is the recyclable wastes.

### 2.5. Mass Balance

The mass balance equation incorporates generated waste, disposed waste, recycled waste and diverted waste. These parameters determine the efficiency of the facility being established. Mathematically, the mass balance equation is shown in Equation 7:

$$\mathrm{G} = \mathrm{Ds} + \mathrm{R} + \mathrm{Dv} \tag{7}$$

Where: G: is the generated waste (kilograms); $D_s$: is the disposed waste (kilograms); R: is the recycled waste (kilograms); $D_v$: is the diverted waste (kilograms).

Moreover, the efficiency is computed using Equation 8.

$$Diversion\ Efficiency(\%) = \frac{Weight\ Diverted}{Weight\ Generated} \times 100 \tag{8}$$

Finally, the MRF was designed based on the amount of waste per category.

## 3. Results and Discussion

The process of UPLB's solid waste management as of May 2018 starts from the collection of wastes in the lower grounds and upper grounds, separately, by means of two separate dump trucks. It is then transferred to a materials recovery facility located in Pasong Kipot, Bay, Laguna, where the wastes are segregated. After segregation, residuals and unsorted wastes are transported to a disposal facility located at Barangay San Antonio, San Pedro, Laguna.

### 3.1. Waste Composition and Analysis

An end-of-pipe Waste Analysis and Characterization Study (WACS) was performed to identify the classification of wastes in UPLB. It was conducted on the first week of September 2017 and four waste collections were measured. The collected wastes per garbage truck was weighed to identify the density of the wastes. However, only one week of waste collection was considered, and it is assumed to be a good representative of the classification of wastes in UPLB. Furthermore, only non-biodegradable wastes are collected in UPLB which is the focus of this study.

As seen from Table 1, waste type represented the different classifications used in the current MRF of UPLB. In this study, these waste classifications are further subdivided into different waste material types patterned on a Junk Shop's classification of recyclable wastes. The weight of each waste type was listed and its total weight was 631.7 kg. This is relatively close, with a 0.11 percent error, to the initial weighted value of the wastes from the dump truck which is 631.0 kg.

**Table 1. Summary of end-of-pipe wastes of UPLB on September 2017**

| Waste Type | Weight (kg) | Composition (%) |
|---|---|---|
| Paper | 351.75 | 55.683 |
| Plastic | 225.95 | 35.769 |
| Glass Bottles | 33 | 5.224 |
| Metal | 17.5 | 2.770 |
| Residuals | 3.5 | 0.554 |

Since the waste collected in UPLB are only non-biodegradable wastes- special wastes and biodegradable wastes are handled differently- the wastes are only composed of recyclables and residuals. As shown in Figure 2, only 0.55% are residuals, and the remaining 99.45% of the wastes are recyclables which can be sold to Junk Shops. These recyclables are composed of plastic, paper, metal, and glass bottles. However, the current MRF still disposes wastes on the dump site.

The sorters working at the facility are not employees of the University. A verbal agreement was made that they sort the wastes without salary, but everything that they can recover, which can be sold to Junk Shops, are theirs to keep and/or dispose. Since they are not employed by the University, their efficiency in sorting wastes varies with their own personal reasons. On the other hand, the University could not let the wastes to be piled up since this will be a non - compliance to RA 9003 regarding proper solid waste management. Consequently, this will result to consequences if the Department of Environmental and Natural Resources conduct a visit to the facility.

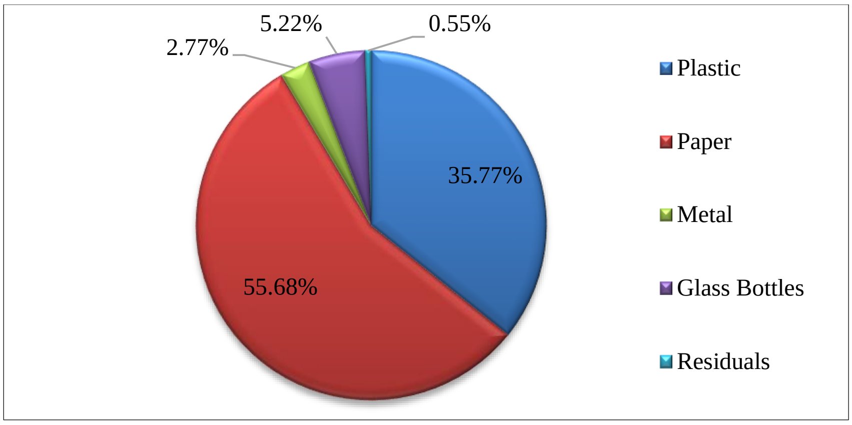


**Figure 2. Percentage composition per waste**

It can be seen from Figure 2 that the waste generation of the University is generally paper which 55.68% of the total wastes. This is greatly affected by the *No Plastic Policy* of the local government since the means of carrying goods from a store is through a paper bag rather than plastic ones. Furthermore, students and faculty often use paper for their reading materials, lectures, examinations and other academic matters. Paper wastes is also composed of cartons, food container and paper cups; all of which are profitable.

Plastic wastes are generally composed of bottles of water which is separated from its caps. It is also worth noting that the University doesn't collect biodegradable wastes in the campus. The residuals consist shampoo sachets which are not sold in junk shops.

The paper wastes of UPLB is composed of three classifications: paper, carton and assorted paper. As shown from Figure3, the paper wastes are generally composed of cartons with 48.54% of the total paper wastes. Assorted wastes, which rank second with 29.85%, are composed of food containers, paper cups and other papers with other colors aside from white. Moreover, white papers, which are composed of old handouts and scratch papers, rank least with 21.60%.

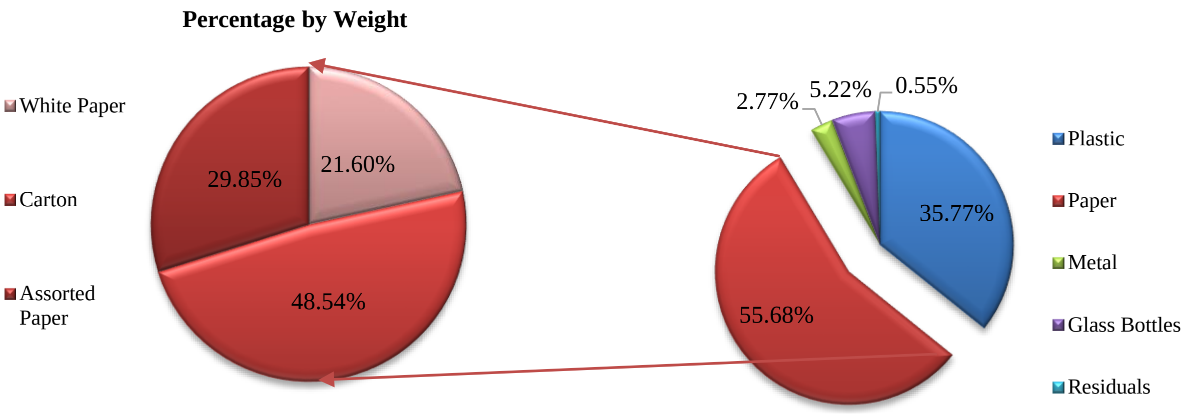


**Figure 3. Classification of paper wastes in UPLB**

Although the use of plastic straws and plastic bags have been prohibited, plastic wastes are still present in the composition of wastes in UPLB which occupies 35.77% of the total wastes. As shown in Figure 4, plastic bottles compose 89.84% of the plastic wastes. The typical container for beverages, which are sold in and out of the campus, are plastic bottles. Consequently, its abundance and availability in the market is logically the reason for the huge amount of UPLB's plastic wastes. It follows that polypropylene caps from the plastic bottles are the second most abundant plastic waste classification which is 4.51% of the plastic wastes. The type of plastic, weight and percentage are summarized in Table 2. LDPE plastic bags, most commonly known as "sando bags" are still present despite of the prohibition because the Municipality of Los Baños allows the use of sando bags for wet goods; i.e. fish and meat. Furthermore, the knowledge of the type of plastic will determine the appropriate recycling process that can be applied on a certain plastic waste.

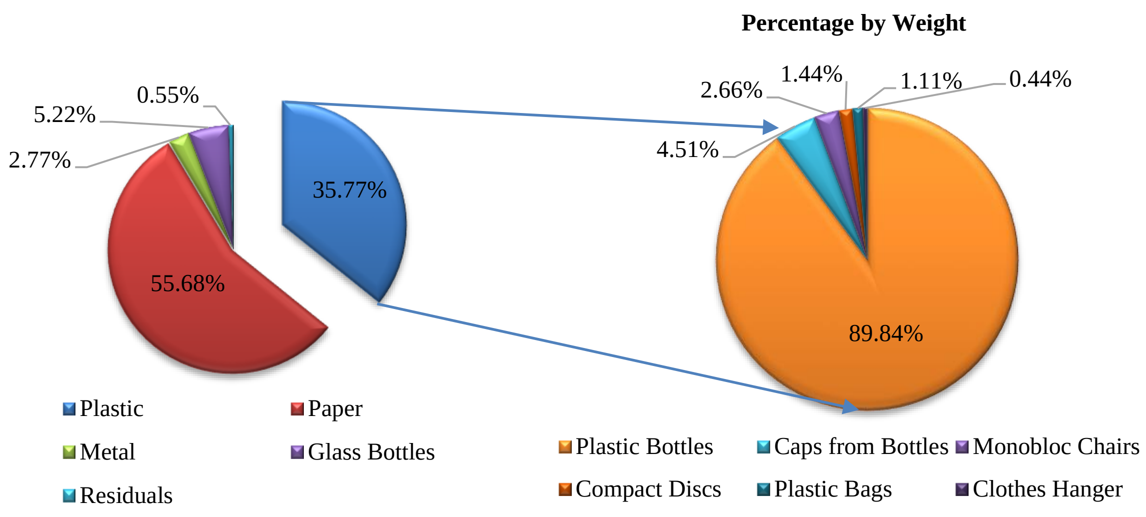


**Figure 4. Classification of plastic wastes in UPLB**

**Table 2. Percentage and types of plastic wastes in UPLB**

| Classification | Type Of Plastic | Weight (kg) | Percentage |
|---|---|---|---|
| Plastic Bottles | PETE | 203 | 89.843 |
| Caps from bottles | PP | 10.2 | 4.514 |
| Monoblock Chairs | PP | 6 | 2.655 |
| Compact Discs | PS | 3.25 | 1.438 |
| Plastic Bags | LDPE | 2.5 | 1.106 |
| Clothes Hanger | PP | 1 | 0.443 |
| | **Total** | **225.95** | |

The abovementioned classification of wastes is the main result of this study but having only considered non-biodegradable wastes of UPLB. There is a need to estimate biodegradable wastes in order to design an MRF which includes all type of wastes. Hence, the assumption that the total wastes are composed of 60% non-biodegradable wastes and 40% biodegradable wastes was acquired [10]. In addition, the percentage of food waste and yard waste was computed which is 28.60% and 7.18% of the total wastes, respectively [10]. The total percent composition of wastes was then summarized in Table 3.

**Table 3. Percentage composition of wastes including estimate of biodegradable wastes**

| Waste Type | Weight (kg) | Composition (%) |
|---|---|---|
| Paper | 351.731 | 34.88% |
| Food waste | 301.110 | 29.86% |
| Plastic | 225.959 | 22.41% |
| Yard Waste | 75.593 | 7.50% |
| Glass Bottles | 33.000 | 3.27% |
| Metal | 17.498 | 1.74% |
| Residual | 3.500 | 0.35% |

The loose density of wastes is 131.93 kg/m$^3$ and is shown in Table 4; it is close to the United Nations Environment Programme's (UNEP) estimate on density of wastes on academic institutions in Latin America and the Caribbean which is 150 kg/m$^3$ [11]. It is worth noting that the second week truck collection, with a total weight of 427 kg, was excluded since the waste collected did not reach the full capacity of the truck. In this study, the truck which collected the wastes has a dimension of 3×2×0.75 m. Identification of the density of wastes was then used to determine the appropriate size of the materials recovery facility.

**Table 4. Density of wastes of UPLB**

| | Truck Load (Kg) | Volume of Truck (m$^3$) | Density of Wastes (kg/m$^3$) |
|---|---|---|---|
| (Week 1) | 612 | | 136.00 |
| (Week 2) | 631 | 3.0×2.0×0.75 | 140.22 |
| (Week 3) | 538 | | 119.56 |
| | | **Average** | **131.93** |

### 3.2. 10-Year Projection

UPLB is an academic community and the population of the students doesn't vary greatly every year and is averaging 10,000 students [13]. Hence, UPLB will be independent of the population trend of Los Baños. Moreover, Table 5 shows the summary of the population of each dormitory by the time of WACS.

**Table 5. Estimated population of dormitories in UPLB**

| Dormitories and Buildings | Population |
|---|---|
| Women's Dormitory | 360 |
| Men's Dormitory | 544 |
| Veterinary Medicine Dormitory | 376 |
| New Dormitory | 294 |
| ATI | 126 |
| Foreha | 148 |
| New Foreha | 160 |
| Mareha | 112 |
| Acci | 128 |
| International House | 100 |
| Searca &YMCA | 200 |
| Commercial and Institutions | 500 |
| Households | 1264 |
| **Total** | **4312** |

The commercial institutions are comprised of various canteens, PCC, SEARCA, IRRI and the contractors of UPLB. The households inside UPLB are composed of 316 units with approximately 4-5 people per household. Hence, there are 1,264 persons in total. On the other hand, the 4,312 total population doesn't comprise the entire of UPLB. An assumption is made that the average student spends 4 hours a day in the University. Therefore, the total population of students which goes in and out of the campus throughout the day is 2,500 ppl/day. Hence, the total population of UPLB by the time of WACS was performed is about 6,862. Therefore, it is calculated that the waste generation of UPLB is .0132 kg/capita/day.

The 10-year projection of waste generation is modeled using the assumption used by Asian Development Bank which has a 2% increase every year [14]. The10-year projection of waste generation in UPLB is shown in Figure 5. Waste generation acquired from the study was 593.67 kg/day on the average is expected to increase to 709.49 kg/day on the year 2026.

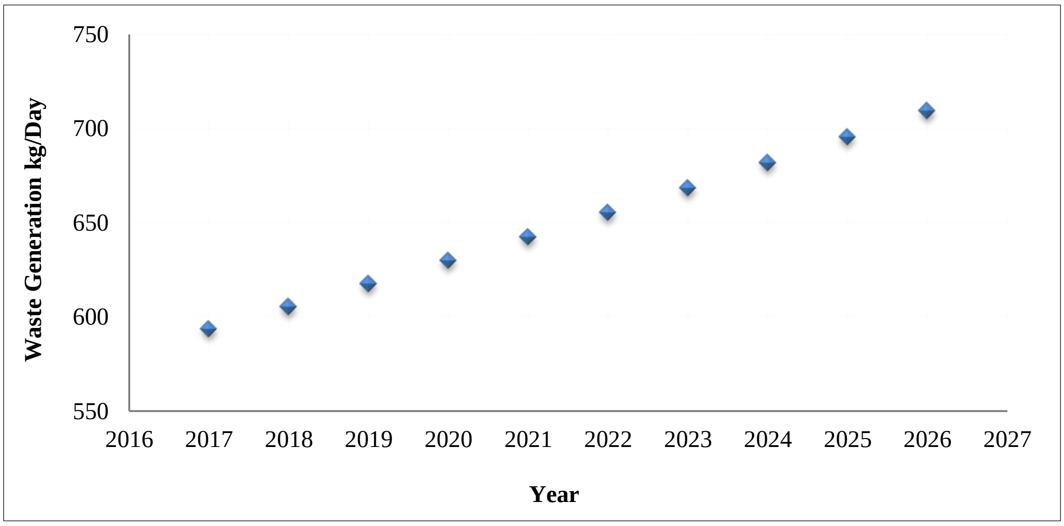


**Figure 5. Projected waste generation of UPLB in the next ten years**

Furthermore, considering that UPLB will eventually collect the biodegradable wastes for the continuous operation of the approved waste-to-energy facility to be constructed in the university, a ten-year projection of wastes including yard wastes and food wastes were considered. The total waste generation of UPLB is estimated to be 1008.4 kg/day in 2017 and will increase to 1205.13 kg/day in 2026, as per ADB's 2% increase per year, as shown in Figure 6.

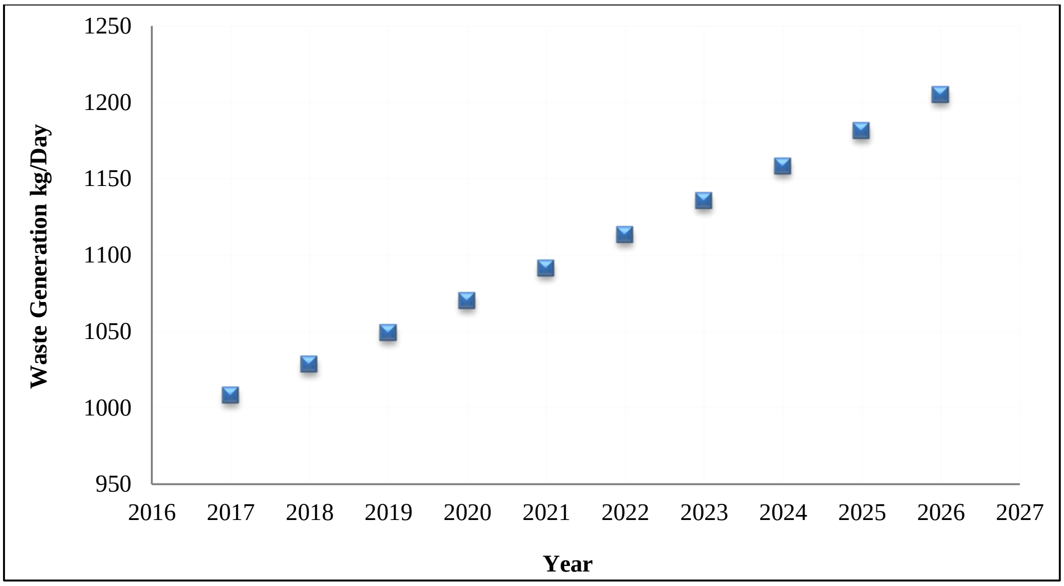


**Figure 6. Projected waste generation, including biodegradable wastes, of UPLB in the next ten years**

## 3.3. Collection Scheme

Temporary storage facilities promote segregation and efficiency in collection, hence, in this study, collection points are also idealized to improve efficiency of the collection of wastes. Collection points with improved strategical routing scheme for the truck loading are presented in Figure 7. The route of the truck is shown by the black and violet highlights on the road; the black highlights are the path where the truck passes the road once while the violet highlight is the path where the truck passes the road twice. By measuring the length of path of the existing truck route using AutoCAD, and comparing it with the proposed truck route, it was found that the proposed route is 29.36% shorter than the existing route, hence, more efficient. In addition, about 29.36% of fuel can be saved since there are only 39 idealized temporary storage facilities; the truck will only stop for 39 times which is 40% less than the existing collection scheme. This saves fuel budget at the same time improved the efficiency of collection of wastes. The distance from the road, convenience of staff to bring the collected waste to the collection point, and aesthetics of the building units -garbage is not by the entrance of the building- were considered to further ensure effectivity and presentability. The primary data which was used to estimate the generation of wastes of each building unit was based from Javier et al. study [16].

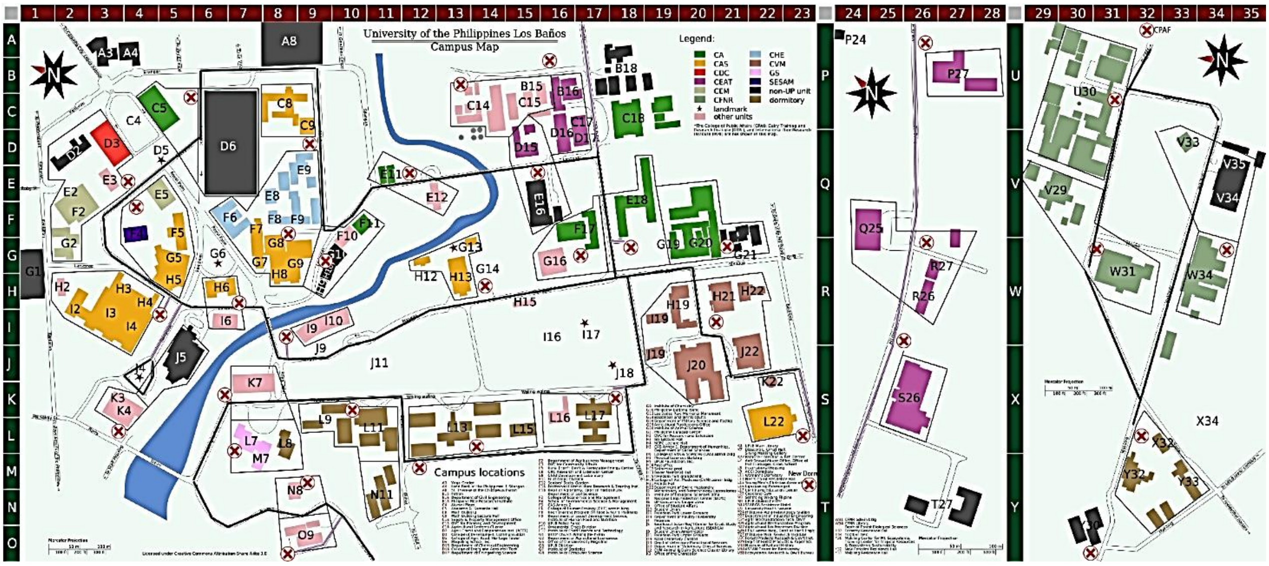


**Figure 7. Suggested location of feasible collection points**

## 3.4. Temporary Storage Facility

The temporary storage facility was designed by considering aesthetics and functionality. Its roof is shaped in an elliptical manner so that water will flow behind the structure, where drainage is located, and it is designed to have a natural ventilation. The 5×2×2.2 m proposed temporary storage facility, as shown in Figure 8, shall be composed of 2×1-inch tubular square tubes which serves as the main support of the whole structure while 3 inches diameter circular bars and H100 C-purlins, with 0.5 meters spacing, is used as the main frame of the roof. It is roofed by a frosted twin wall polycarbonate sheet. Its gate is located at the center of the storage with a length of 1 meter.

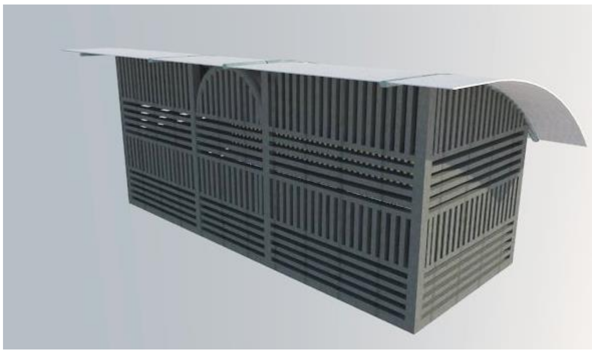

**Figure 8. Conceptual design proposed temporary storage facility**

The design of the temporary storage facility was determined by computing the total waste generation per day of each building unit for every cluster. However, the primary data from Javier et.al.'s study wasn't able to account for some building units. Hence, the data was completed by assuming that certain building units, with missing waste generation, are equal depending on its function as a building: administrative, institutional, residential/dormitory, or laboratories. Also, the waste generation was increased by using the 10-year projection so that the temporary storage facilities will have a design life of 10 years. The waste generation was multiplied by the percent composition, by weight, to get the waste generation per waste classification. Afterwards, the waste generation, per waste classification, was multiplied by its corresponding literature density: 76 kg/m$^3$, 72 kg/m$^3$, 120 kg/m$^3$, 411 kg/m$^3$ for paper, plastic, metal and glass, respectively. However, the density per waste classification was multiplied by a factor using the average density acquired from this study which was 131.93 kg/m$^3$ divided by the average of the literature density values which is 169.75 kg/m$^3$. Afterwards, the required number of a 240 liter- 1015×740×580 mm- trash bin wheeler was determined. The trash bin wheeler is available at different colors - yellow, red, green, blue, military green- and will be used to specify different types of waste classification. Clusters with fraction results were rounded up and then the total dimensions required were computed. The total number of wheeler trash bins is 181.

A standard height of 2.2 m was considered for uniformity and functionality purposes. From the acquired number of trash bin per cluster, the width and length required for each cluster was computed and spacing was added to each trash bin to ease the movement of the administrative staff which stores the trash bins. Figure 9 shows the location, in meters, of each 240-L trash bin inside the temporary storage facility.

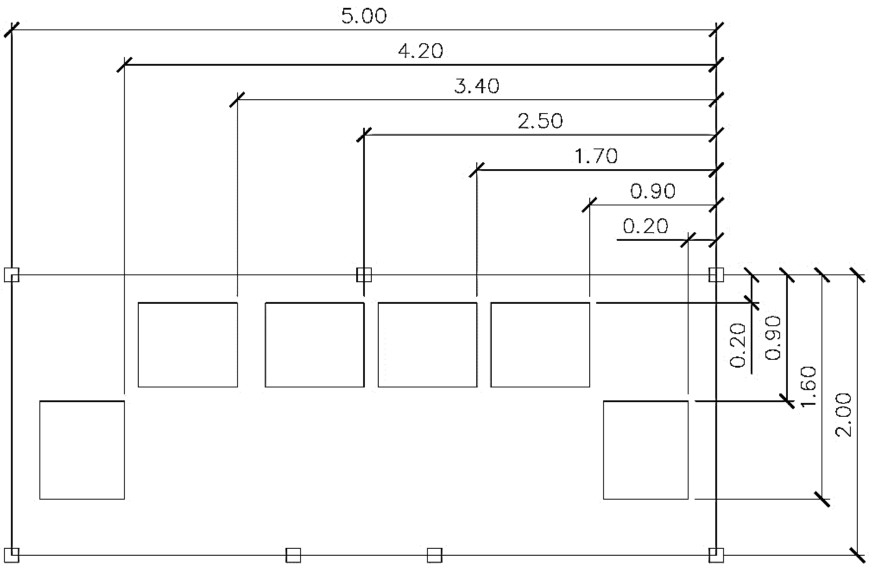


**Figure 9. Location of trash bins of Option 1, in meters**

The largest dimensions computed is 5×2×2.2 m which encloses six trash bins. If the administration of UPLB considers the uniformity of the temporary storage facility all throughout the campus, then, 39 clusters in the University will all have the 5×2×2.2 m design. However, only 16 out of 39 clusters requires the largest dimensions. Therefore, two options are provided for the dimension of the other clusters, as summarized in Table 6, since the clusters have different amount of waste generation from one another.

**Table 6. Variable design options of temporary storage facility**

| | | Dimensions (m) | | |
|---|---|---|---|---|
| | # of 240 L-Dumpsters | L | W | H |
| Option 1 | 6 | 5 | 2 | 2.2 |
| Option 2 | 4 | 3.5 | 2 | 2.2 |

As shown in Table 7, 23 clusters require 3.5×2×2.2 m while 16 clusters require 5×2×2.2 m. If there is a budget constraint for the University, each cluster can be different depending on its dimension requirement. Clusters are derived from Figure 7.

**Table 7. Allocation of design types per cluster**

| Option 1 | | | Option 2 | | |
|---|---|---|---|---|---|
| C5 | G19 | P27 | B16 | I9 | L9 |
| C14 | H13 | Q25 | C8 | J20 | M13 |
| D15 | H6 | S26 | D2 | L13 | M23 |
| E11 | K4 | U0 | F4 | L17 | O9 |
| E18 | K7 | U00 | G8 | L22 | Y32 |
| F17 | L7 | U30 | H2 | | |
| G10 | N8 | W31 | | | |

Furthermore, construction of temporary storage facility on seven clusters-C5, N8, P27, S26, U0, U30, Z32- are optional since these clusters have a low generation of waste because these clusters covers only one building. If the maximum number of required trash bin is considered, then 14 clusters will be overdesigned. Therefore, clusters F4 and Y32 must be split into two clusters because these clusters have a requirement of seven trash bins.

It is worth noting that the total number of bins needed, which is 181, doesn't include the private institutions including SEARCA, SEARCA Residence Hotel, Maquiling School Incorporated, Museum of Natural History, ASEAN Centre for Biodiversity and Ecosystems Research and Development Bureau, as they would be instructed to shoulder the costs of building their temporary storage facilities.

### 3.5. Mass Balance

The mass balance is summarized in Table 8. Theoretically, the diversion efficiency of the materials recovery facility is 99.445%. However, the time allowed for the sorter to segregate wastes is limited because the University can't allow the wastes to be piled up since this will be non-compliant to RA: 9003, regarding proper solid waste management, and will result to consequences if the DENR conduct a visit to the facility. Hence, diversion efficiency varies significantly depending of the efficiency of the sorters. The unsorted wastes become disposed waste which will lessen the amount of recycled and recycled waste. Figure 10 shows the diagram of the mass balance.

**Table 8. Diversion efficiency of the MRF**

| | |
|---|---|
| Weight Generated | 631.7 |
| Weight Recycled | 628.2 |
| Diversion Efficiency | 99.445 % |

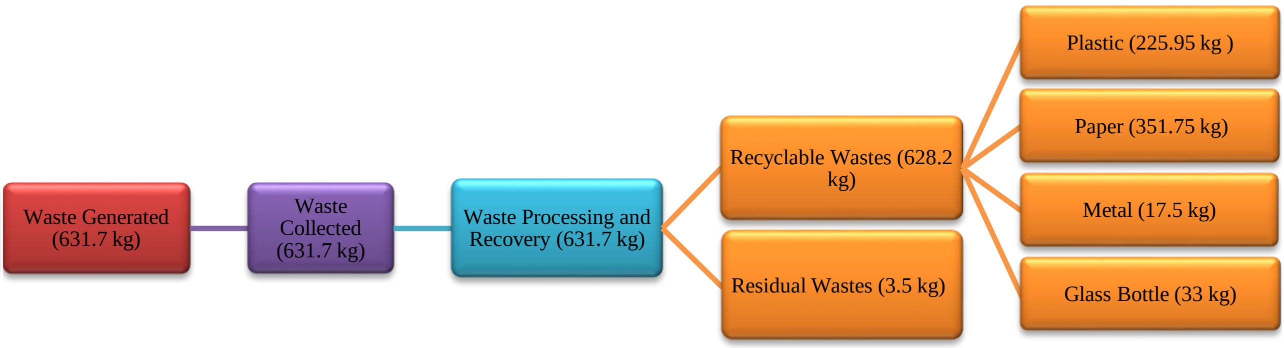


**Figure 10. Flow chart of the mass balance**

### 3.6. Materials Recovery Facility

The current MRF has existing partitions than can be utilized for the sorting of wastes. Proposals has been raised to rehabilitate and improve the facility. Instead of constructing another building, it is practical to retrofit the existing facility to be a fully functional Materials Recovery Facility. However, the proposals only include the structural layout of the building.

With the use of the waste characterization that have been acquired in this study, there can be an improvement for the rehabilitation of the said Materials Recovery Facility. Shown in Figure 11 is the proposed layout, with a 10-year service life, which accounts the classification of waste; allotting more space for plastic and paper wastes. Furthermore, a composter has been considered for the layout since there are still biodegradable wastes which are retrieved from the food wastes- specifically from the paper food containers. In addition to this, if the Memorandum No.005 of Series 2012 of OVCPD is lifted and UPLB decided to collect the biodegradable wastes of the university, then the MRF should be sufficient to process the wastes. Hazardous wastes generated by the University, including the Department of Chemistry and Department of Chemical Engineering, are disposed separately through private environmental service providers. However, the University may opt to centralize all type wastes in the MRF, including hazardous wastes. Therefore, special wastes, including hazardous wastes, were also considered in the layout.

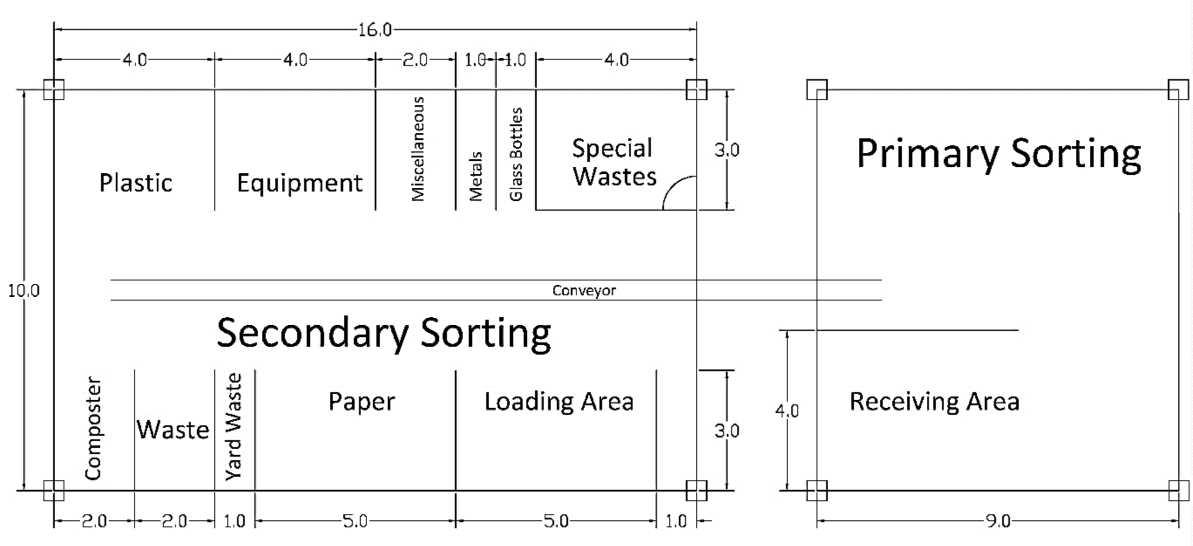


**Figure 11. Proposed layout for the Materials Recovery Facility (in meters)**

Primary sorting of wastes shall start with the unloading of wastes in Building 1 before wastes can be separated by a sorter. Afterwards, the sorted wastes shall be transferred to Building 2 by a conveyor. A conveyer system is an equipment that allows transfer of materials. Purchase of such equipment will increase the efficiency of sorting of wastes in the MRF as it will improve the transfer of the wastes from Building 1 to Building 2.

To ensure efficiency, one type of waste will be transferred at a time. In Building 2, two sorters will transfer the wastes on the designated area. An area for other equipment was assigned. Lastly, loading area in Building 2 was assigned for the maneuvering of the garbage truck and it is placed adjacent to the residuals which shall be ready for disposal. If landfill design shall be designed on future studies, the dynamic properties for safety shall be included and not only static conditions [15].

The present scheme of the existing MRF hires a pilotage for five times a month to transfer the residual wastes to Barangay San Antonio, San Pedro, Laguna for 14,000 pesos. There is an assumption that if the existing MRF continues to perform the same strategies as the present, UPLB will have to pay two violations per year which costs 50,000 pesos each. This totals to 940,000 pesos a year. The cost-benefit summary for the proposed MRF is shown in Table 9. The negative sign indicates cost while the positive sign indicates profit.

A minimum of three employees shall be hired so that the low efficiency of the present sorters can be addressed; the basic salary is 10,000 pesos per month, hence, the cost for the whole year is 360,000 pesos. The proposed layout for the MRF requires the purchase of a $52' \times 22'$ horizontal conveyor system, which costs 345,701pesos [13]. Also, installation of walls for partitions will cost around 19,000 pesos. The provided estimate includes the material costs; CHB 4'', sand and cement; the labor costs which is 50% of the material costs and the profit of the contractor which is 20% of the combined price of the material and the labor cost. Moreover, it is assumed that there is at least one pilotage per month to dispose the residual wastes which will cost 168,000 pesos a year. However, the recyclables, which is 99.45% of the wastes can be sold to junk shops which is approximately 2,500 pesos per day. Since there are four collections a week, the total profit from selling the recyclable wastes is 480,000 pesos per year.

The difference of the costs of the proposed layout and the present MRF is 527,377 pesos which is the total savings of the university for the first year. Afterwards, the university will only have to pay a net total of 48,000 pesos per year (including the salary of workers, the cost of pilotage per month, and the earnings from the recyclables). Instead of paying 940,000 a year, the university can save as much as 892,000 per year on the succeeding years.

**Table 9. Cost-benefit summary of the proposed MRF**

| | | Unit Price (php) | Annual Price (php) | Remarks |
|---|---|---|---|---|
| Present | Payment for Pilotage | 14,000 | 840,000(-) | (Five times a month) |
| | DENR's fine | 50,000 | 100,000(-) | (Twice a year) |
| | **Total Fees** | | **940,000(-)** | **(Cost)** |
| Proposal | Sorters' Salary | 10,000 | 360,000(-) | (Three sorters) |
| | Conveyor 52'x22'' | 345,701 | 345,701(-) | (Paid once) |
| | Retrofit | 18,922 | 18,922 (-) | (Paid once) |
| | Payment for Pilotage | 14,000 | 168,000 (-) | (Once a month) |
| | Resell | 2,500 | 480,000(+) | (Four times a week) |
| | **Total Fees** | | **421,623(-)** | **(Cost)** |
| | **Savings** | | **527,377** | |

## 4. Conclusion

An end-of-pipe Waste Analysis and Characterization Study (WACS) was performed to identify the classification of wastes in UPLB. Waste generation acquired from the study is estimated to be 1008.4 kg/day in 2017 and will increase to 1205.13 kg/day in 2027. The waste composition by weight is (55.68%); paper (35.77%); glass bottles (5.22%); metal (2.77%); and residuals (0.55%). Recyclables are 99.45% by weight and can be profitable. The loose density of wastes is 131.93 kg/ $m^3$.

Feasible collection points were suggested to improve efficiency of the collection of wastes in the university. There are 181 units of 240-L garbage bin needed for the 39 clusters in UPLB. Conceptual design and structural plans were provided. Theoretical diversion efficiency of the MRF is 99.445%.

A proposed layout, with a 10-year service life, was provided which thoroughly accounts the classification of wastes. A horizontal conveyor system was proposed to promote sorting efficiency. Biodegradable wastes, special wastes and hazardous wastes were considered and its location in the MRF was provided. The proposed layout for the MRF requires the installation of walls and will cost approximately 18,922.4 pesos. A cost-benefit summary, considering penalties, cost of retrofit, salary of workers, and reselling of recyclable materials was provided.

## 5. Acknowledgements

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## 6. Conflict of Interest

The authors declare no conflict of interest.

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