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Solid Waste Quantity and Composition Analysis in a Private University within an Urban City: Basis for an Improved Institutional Solid Waste Management System

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ABSTRACT

Voluminous solid waste negatively impacts both the environment and human health. Despite the laws on proper solid waste management (SWM) that have been promulgated, solid waste dumps remain a problem in the Philippines, especially in urban cities. In the selected private University in Western Visayas, Philippines, an SWM is in place, properly executed, and the surroundings are visibly clean. However, there is a need to determine whether or not such currently adopted SWM is appropriate and supportive of the universal call for proper solid waste management and environmental protection. Thus, this study investigated the current SWM of a private university in an urban city, completely gathered the disposed waste on an entire day's operation, analyzed the primary waste data through standard solid waste characterization and analysis procedures, and investigated the possible causes of a significant volume of waste generation and disposal. The research aims to provide the University's administrators with the necessary data and observations to improve the institutional SWM. Findings revealed that although cleaning and collecting waste for disposal are properly done, a considerable volume of waste is sent to the City's dumping site. Furthermore, the institutional SWM does not include the important management aspects of higher hierarchy - prevention, minimization, reuse, recycling, and recovery before final disposal. While the study revealed that solid waste is an untapped resource in the University, the amount of waste can still be reduced through minimization at source applying better administrative directives, especially in the University's canteen - the main source of waste.

Keywords

pollution prevention, environmental protection, solid waste management, waste analysis and characterization, Philippines, Asia

INTRODUCTION

Waste characterization provides a better understanding of waste generation and helps create a better sustainable waste management plan (Adeniran et al., 2017; Gallardo et al., 2016; Kumar & Goel, 2009).

The failure of solid waste management in urban areas was determined to have been caused by the lack of sustainable strategies (Ferronato & Torretta, 2019; Yukalang et al., 2017) in environmental education, which gives a vital role to the educational institutions, like schools and universities, in strengthening environmental awareness and upholding community practices (Galarpe & Heyasa, 2017; Mendez-Fajardo & Gonzalez, 2013; Ojeda-Benitez et al., 2003). In an urban city where garbage disposal is a consistent problem, the strategy "no segregation, no collection" policy has been repeatedly urged by the city government (Pedrosa, 2017; Santillan, 2009; SunStar Bacolod, 2019). In similar cases, educational institutions may help in strengthening the solid waste management projects as well as in a city's programs related to environmental awareness (Coertjens et al., 2010; Moh & Abd Manaf, 2017; Zhongguo, 2004) as they may play a role in channeling information and raising local participation among their students, faculty, employees, and nearby communities (Akil et al., 2015; Barloa et al., 2016; Desa et al., 2012), thereby minimizing ignorance of and poor compliance to the law.

Currently, several laws and ordinances govern solid waste. Republic Act No. 9003 or the Ecological Solid Waste Management Act of 2000 provides a comprehensive, organized, and ecological solid waste management program of the country. This national policy gives importance to local government units in managing their respective wastes. As a response to the mandate, the City of Bacolod strengthens the implementation of its "No Segregation, No Collection Policy" (SunStar Bacolod, 2019) to cover more areas. In addition, provisions of the Act covers NGOs and private sectors as well as educational institutions, whether formal or non-formal, to support the integration of environmental concerns in school courses and programs at all levels emphasizing the theory and practice of waste management principles (waste minimization, resource conservation, and recovery, segregation, reduction, recycling, re-use and composting) for the promotion of environmental awareness to the common public. Furthermore, there is City Ordinance 531 s. 2011 – an ordinance in the City of Bacolod forbids littering of plastics, paper, or garbage of any form in public places and waterways and provides penalties for violation. Additionally, City Ordinance 596 s. 2012 is likewise an anti-littering policy in the City banning disposal or throwing any kind of wastes in public places. This regulation also mandates households and commercial establishments to maintain the cleanliness of their premises, in which non-compliance has subsequent penalties.

Requisite to any management endeavor is the measurement of the initial condition so that when the management strategy is implemented, its outcome can be properly measured against a baseline (Carayannis, 2004; Kerzner, 2002; Watt, 2014). Effective solid waste analysis and characterization hold the key to a successful solid waste management plan (Desa et al., 2012; Jibril et al., 2012; Smyth et al., 2010). Republic Act (RA) 9003, otherwise known as the Ecological Solid Waste Management Act - Section 17, defines waste characterization as «the identification of constituent materials which comprise solid waste generated and disposed of within an area. It identifies constituent materials by volume, weight percentage or volumetric equivalent, material type, and generation source. Waste Analysis and Characterization is an approach utilized by the local government units in preparation for their long-term solid waste management plans. The standard procedure for this Waste Analysis and Characterization Study (WACS) is provided by the Department of Environment and Natural Resources through its EcoGov Project 2011 (Espino-Yap et al., 2011).

In the subject private University, a considerable volume of waste is generated. However, despite the garbage segregation and collection bins at

strategic locations, the population does not seem to notice the labels and dispose of their trash without discrimination. Thus, this study deals with analyzing the quantity and composition of that part of the solid waste that is sent for disposal to the City's waste dumpsite. This stream directly adds to the increasing volume of Municipal Solid Waste (MSW) and contributes to environmental and health issues (Alam & Ahmade, 2013; Ana et al., 2011; Dery et al., 2018; Parvez et al., 2019).

Furthermore, this study identifies the underlying causes of neglectful waste generation, the absence of segregation, and the improper utilization and abandonment of an existing materials recovery facility (MRF). Consequently, the results may be used as the basis for the appropriate planning and design of an improved MRF and an effective solid waste management system for the institution (Ayvaz-Cavdaroglu et al., 2019; Das et al., 2019; Dinglasan & Duenas, 2018; Gequinto, 2017; Kofoworola, 2007; Shekdar, 2009).

METHODOLOGY

An initial assessment of the waste segregation system was conducted by the Chemical Engineering Department of the subject University, following the strategies presented in the literature (Galarpe & Heyasa, 2017). On-site inspection of the waste bins was performed; the number, types, labeling, and location of solid waste bins were inspected. This descriptive assessment also included qualitative observation and investigation of the possible factors affecting solid waste management.

Solid waste characterization is normally conducted within a period of seven days, but based on the WACS Manual (Espino-Yap et al., 2011), a shift from 7 days to a shorter period of 3 days statistically showed no significant difference in the results. Considering that the Manual is intended for general use, including communities with largely variable activities and the expected waste quantity and composition variation, the shortening of WACS duration has been valid. For simplicity and economy, the waste quantity and composition analysis in this study is conducted on the totality of the entire day's collected and disposed waste. Therefore, the data may be limited since the analysis is even shorter than the standard 3-day WACS; however, the amount of the waste that was analyzed was the whole amount and not just a sample of waste. In addition, the population and the activities in the University may be considered nearly constant day by day; thus, the data may still be a good representation of the averages within a certain duration of time. In the context of the limitations, the term 'waste characterization' is limited only to waste quantity and composition analysis but is still guided by the general WACS procedure.

The procedure of the waste characterization activity was patterned after existing protocols (Espino-Yap et al., 2011) with few modifications. Several meetings with the collaborators – Property Custodian's Office, Janitorial Services, Chemical Engineering Department - were made before the actual data gathering. The data collectors underwent crash-course training on Proper Waste Characterization under the Chemical Engineering professor. Necessary materials for the activity such as protective gears, weighing scales, garbage bags, laminated sacks, tongs, and blank forms for documentation were distributed to the data collectors. A temporary segregation site within the University's premises was also selected and prepared.

The data gathering was conducted for two days. On Day 1, entire-day garbage that represents the regular-day trash was gathered by the garbage collectors at their two assigned schedules: (1) at 2 PM for the morning/noon wastes, and (2) at 7 PM for the afternoon/evening wastes. On Day 2, waste quantity and composition analysis was performed under the guidance of the team leader – a Chemical Engineering

professor.

The steps taken were as follows: (1) collection of garbage and delivery to the waste segregation site; (2) sorting the solid waste among the following: recyclable, biodegradable, hazardous (special), and residual; (3) weighing of each solid waste type and recording of results; (4) gathering of reports and analysis of data.

The input was based on the four solid waste types (Espino-Yap et al., 2011, pp. 25–27): Biodegradable Waste – waste that decomposes under natural conditions; Recyclable Wastes – «any waste material retrieved from the waste stream and free from contamination that can still be converted into suitable beneficial use or for other purposes;» Residual Wastes – waste that cannot be used for other purposes, thus, directed for transport to the disposal site; and, Special Wastes – household hazardous waste, bulky waste, consumer electronics, white goods, and yard waste.

To determine the potential of recyclable wastes for specific recycling purposes, the team further segregated the recyclable waste stream into several components, namely glass bottles, dry paper, tin cans, metals, rubber, textile trimmings, and plastics. The plastics are further identified based on the composition, namely Polyethylene Terephthalate (PET or PETE), High Density Polyethylene (HDPE), Polyvinyl Chloride (PVC), Low-density Polyethylene (LDPE), Polypropylene (PP), and Polystyrene (PS).

Data from the preliminary observations conducted by the Chemical Engineering students, as well as investigations through interviews with important stakeholders - the janitors, the canteen concessionaires, the maintenance staff, and some students and faculty members - were also analyzed to explore the possible reasons behind the quantitative results of the waste analysis.

A report was submitted to the Office of the President, through the VP for Academics, copy furnished to the Property Administrator's Office for presenting the current waste condition and conveying some recommendations for improving the institutional SWM system.

RESULTS AND DISCUSSION

The preliminary investigation through observation and interviews revealed that the canteen is the primary source of solid waste in the University. The wastes collected in the canteen were mostly plastic bottles, plastic cups, and paper cups. Furthermore, biomass from fallen leaves and grass cuttings also formed a large fraction of the waste generated in the University's premises.

The University has a considerable number of janitors to maintain cleanliness and waste segregation bins to hold the waste at different locations temporarily. Table 1 presents the information on the number and type of

Table1
Current Number and Type of Waste Bins in the Campus

Waste types designated for the trash bin/net	Quantity of trash bins/nets
Plastic	32
Non-Biodegradable	46
Biodegradable	38
Residual	11

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Figure 1
Same-colored bins are assigned for two different waste types

waste bins on the campus.

For trash bins, proper labeling is adopted, but color-coding was not consistently implemented. As a result, some similarly colored bins were assigned for two different waste types (Figure 1), which might have confused the students. A color association could have been a good strategy to help students segregate their wastes correctly.

It was also observed that wastes were mixed up. Trash nets are assigned for non-biodegradables, especially recyclables, but it is common to find a trash net assigned for non-biodegradables to contain biodegradables and garden wastes. On the other hand, some plastic wastes were also found in waste

Figure 2
Mixed-up trash.

bins assigned for biodegradables. Some pieces of evidence are shown in Figure 2.

The non-biodegradables were collected and accumulated for discharge to the City's dumpsite. The biodegradables were accumulated at a certain area in the campus and left to decompose in that assigned area. The food wastes from kitchen and dining residues were collected by the canteen concessionaires and used as animal feed; these do not add up to the University's waste generation.

The Materials Recovery Facility of the University is currently not used for its purpose. The Property Custodian's Office provided the reason is the lack of an administrator to manage the facility. On the other hand, the hired janitorial services personnel emphasized that segregation in the MRF is not practical since the City's garbage collector collects unsegregated waste and even mixes up everything, including the already segregated wastes. These practices contradict the published City Ordinance "No Segregation, No Collection" Policy (Samillano, 2017). These also explain the researchers' observation that the janitors mix up the segregated waste from the different garbage bin types during collection.

The two-day Solid Waste Characterization Activity started with the waste collection and accumulation of the waste on Day 1 in a temporary collection site near the man-made mini-forest at the back portion of the University, around 100 meters from the back perimeter fence. Figure 3 shows the temporary collection site. Day 2 is the waste segregation schedule that was participated by the Chemical Engineering Students data collectors and some volunteers, with the assistance of the Property Custodian's Office and the Janitorial Services. The activity lasted for around eight hours.

Figure 3
Temporary waste collection site for the purpose of waste characterization only.

Table 2
Characteristics of Solid Waste for Final Disposal (1 whole day)

A. BIODEGRADABLE	Mass (kg)	%
A1. FOOD WASTE		
A2. AGRICULTURAL WASTE (mostly dry leaves and some twigs)	58.9	23.21%
A3. WET PAPER & CARTON (mostly paper plates, bowl, and cups, with some wet test papers and notes)	51.9	20.45%
A4. FRUITS & VEGETABLES (rotten, peelings, seeds, etc.)	33.4	13.16%
A5. ANIMAL WASTES & BYPRODUCTS (eggshells, fish/chicken cleaning)	0	0.00%
A6. others (aggregate of food waste and other small-sized biodegradables)	17.9	7.05%
SUBTOTAL	162.1	63.87%

B. RECYCLABLE	Mass (kg)	%
B1. DRY PAPER (test papers, old notes, cartons)	8.2	3.23%
B2. TIN CANS	1.6	0.63%
B3. METALS (steel, iron, copper, aluminum, etc)	0	0.00%
B4. BOTTLES & BROKEN GLASS (bubog)	0.7	0.28%
B5. RUBBER	0	0.00%
B6. TEXTILE TRIMMINGS (handkerchief, hand towel, id chord)	0.3	0.12%
B7. PLASTICS (45.1 kg)		17.77%
B7.a. PETE/PET bottles (soft drinks, mineral, sports drink, etc.)	18.9	7.45%
B7.b. HDPE (shampoo, milk, yogurt, margarine tub, etc.)	1.1	0.43%
B7.c. PVC (clear non-food packaging, wire, insulation, pipes)	0	0.00%
B7.d. LDPE (food bags, cellophane)	5.4	2.13%
B7.e. PP & PS (mostly plastic cups and plastic utensils)	19.7	7.76%
SUBTOTAL	55.9	22.03%

C. RESIDUAL	Mass (kg)	%
C1. Food wrappers, candy wrappers. Tetra packs, foil chips packaging material	34.5	13.59%
C2. Tissue paper and disposable diaper	0.5	0.20%
C3. Tattered/ contaminated styro	0.5	0.20%
SUBTOTAL	35.5	13.99%

D. SPECIAL WASTES	Mass (kg)	%
D1. TOXIC & HAZARDOUS WASTES	0	0.00%
D2. BULKY WASTES (furniture)	0	0.00%
D3. WHITE GOODS (appliances, electronics, e-wastes)	0	0.00%
functional scientific calculator	0.3	0.12%
SUBTOTAL	0.3	0.12%
TOTAL	253.8	100%

Table 2 summarizes the characteristics of the solid waste collected. A total of 253.8 kg of waste was collected in one day. Waste from the clinic (mostly soiled) and solid waste from the chemical laboratories (mostly hazardous) were not part of this waste collected by the janitors because they are not disposed of on a daily basis. Rather, they are accumulated in specially labeled and properly sealed containers or bags before proper disposal or turning over to third-party treaters.

Twenty-three percent (23%) of the waste, with a mass of 58.9 kg, is agricultural waste from plants and trees, including dried leaves and some small branches. This stream is accumulated in a certain area near the perimeter fence of the University and is left to decompose; thus, it is not included in the bulk of waste sent for collection and disposal to the City's disposal site. Subtracting this from the total collected waste, a total mass of 194.9 kg or approximately 200 kg of waste is sent by the University for final disposal daily.

Biodegradables accounted for 64% of the total waste collected. The bulk of the biodegradables consist of dry leaves (58.9 kg), attributed to the presence of a considerable number of trees inside the campus. Following it is the wet paper and carton (51.9 kg), which is mostly composed of wet paper plates, bowls, and cups used by the canteen concessionaires in selling food. Fruit and vegetable waste (33.4 kg) is mainly a byproduct of food preparation in the canteen. There was no food waste separable and identifiable as purely food waste in the waste stream; thus, the little remaining food waste is classified under "Others," including leftovers mixed with other very small biodegradables like wet paper and dirt. Its separation was done last during the activity; thus, it was very hard to separate and identify them.

The agricultural waste collected (110 kg) is not utilized for composting. The Agriculture Department of the University has a vermicomposting facility, but they do not use the daily collected waste for their composting. On the other hand, the waste paper stream, which is classified as part of the biodegradables, will take longer to degrade because of its mixed composition. These paper food containers are not mere plain paper but rather composites of paper and either wax or plastic sheet. Unless the outer polymer cover is degraded, the inner paper will not start to degrade. Also, even the paper material used for this purpose cannot easily be recycled for the same reason – being composite with plastic. Thus, these disposable paper containers are single-use and non-recyclables and are all bound to the dumpsite to stay there for longer periods.

The recyclables (55.9 kg) compose 20% of the collected waste. Plastics contribute not just the greatest mass (45.1 kg) of these recyclables but are also responsible for the great volume of waste collected and disposed of daily. Most plastics are bulky and of low density, like plastic bottle containers and plastic cups. Based on composition, the PETE tops the list (18.9 kg), followed by the PP and PS (19.7 kg), LDPE (5.4 kg), and HDPE (1.1 kg). Though the combined mass of PP and PS is greater in mass than PETE, it is ranked second because it is hard to distinguish and separate the plastic cups and utensils made of either PP and PS.

A good portion of the recyclable waste is PETE plastic bottles, which are commonly bought by recyclers. However, they are mixed with other waste types because of the lack of segregation. An alarming bulk of the recyclable wastes are plastic utensils and plastic cups, and these all came from the canteen. Plastic utensils total to almost 20 kg, which denotes the excessive use disposables in the canteen. Though this is a considerable amount, the selling and recycling of PP and PS kinds of plastic are not common. Moreover, small efforts such as melting to produce composite materials may pose health hazards due to the generation of poisonous gas during the heating

process (Jittabut, 2015).

Another portion of the recyclables is dry paper and cardboard, mostly test papers and old notes (8.2 kg). This disposal is, in fact, a very small portion of the paper used in the University, which could be the product of effective paper recycling habits. The University practices paper recycling as offices use both sides of the paper for printing or reuse the scratch papers for back printing. Some offices donate their used papers to the library to print the call slips and borrower's receipts. Other offices implement strategies to lessen the use of paper, like the Research and Development Office, which previously uses a considerable volume of paper for evaluation purposes but has shifted from a manual paper evaluation to an online evaluation system through the UNIVERSITY's information system. This has saved thousands of pages of paper from printing evaluation forms for four years now. The rest of the recyclables are tin cans (1.6 kg) and a few glass bottles (0.7 kg), accumulated and sold to junk shops when a certain marketable mass is reached.

The residual waste (35.5 kg) is still a considerable portion of waste generated and disposed of. It comprises mostly food wrappers, candy and chips foil wrappers, tetra packs, and tattered and soiled thin food/grocery plastic bags. Interestingly, styrofoam food containers are minimal. This could be caused by a shift in disposable container composition from styrofoam to lined plastics. Though paper is biodegradable, the benefits of this material change are still unclear, as utilization of paper which are not reusable also equate to the cutting of trees and the generation of a large volume of wastewater, which is equally of serious concern to the environment just as the styrofoam waste (Guedez & Püttmann, 2014).

No toxic nor hazardous waste was found in the garbage collected. Bulky wastes are collected in the Maintenance Office for possible reuse of valuable equipment or furniture parts and not sent for final disposal unless evaluated of no value anymore. Unexpectedly, a fully functional scientific calculator was found in the garbage together with the other residual wastes. Indeed, waste is a resource!

CONCLUSION AND RECOMMENDATIONS

The waste management system in the University focuses only on the provision of a sufficient number of strategically located waste segregation bins and the regular collection of wastes which results in a clean and healthy environment. However, this segregation scheme does not serve its purpose; the waste collected is all mixed up during collection, and the City's collectors also mix up all the waste on their collection and retrieval from the University. Moreover, the existing MRF is currently non-functional as it has become a part of the construction area for the currently constructed new building. Very soon, it will be demolished for the clearing of the grounds surrounding the building.

Furthermore, waste is still an untapped resource in this University. The amount and characteristics of waste revealed considerable revenue that may be gained from the recyclable waste stream. However, institutional efforts to reduce or recycle these wastes are minimal. Everyone depends on the janitors to manage the waste they dispose of. Despite the significant amount of marketable plastic bottles generated daily, nobody has shown interest in utilizing them for monetary benefits. Biodegradables are left to decompose despite the presence of a small vermicomposting facility at the Agriculture Department. Waste paper is not processed despite the constant supply of this resource that could be a constant feedstock for a sustainable recycling effort in an academic institution.

The waste characteristics further connote that the University's canteen is the main waste generator for both biodegradable and non-biodegradable waste. Food preparation byproducts, plastic bottles, food

containers, food wrappers, and disposable eating cutleries – plates, cups, bowls, spoons, and fork – constitute around 75% of the mass of the waste collected. Thus, the canteen concessionaires play a very important role in waste management, especially in source reduction, which is the best way to diminish waste. It is also a fact that the concessionaires are bound to follow the administration's conditions to continue their business inside the University. However, until this SY, the school administration has not prescribed any condition related to waste reduction for the canteen to observe.

The published "No segregation, No collection" Policy of the urban city where the University is located is not implemented as far as the University is concerned. The University's garbage collectors mix up the segregated waste that they collect because there is no place for the temporary storage of segregated waste and mainly because the City's waste collecting unit also mixes up everything during collection. Therefore, there is no provision for collecting segregated waste, and there was no hint of implementation of the said policy (at the time of writing.)

The activities related to this study have opened the minds and hearts of the Chemical Engineering students in their role as initiators of change and agents of a good solid waste management practice. These were also a learning experience for the janitors and garbage collectors who showed increased knowledge about the different types and characteristics of the waste and expressed willingness to cooperate in any future effort to manage the solid wastes in the University.

It is said that "You can't manage what you don't measure" (Peter Drucker) and "If you can't measure it, you can't improve it" (Lord Kelvin). In this regard, an assessment of the current condition of any system is a prerequisite for good management. Thus, this study has determined the amount and characteristics of waste collected and disposed of. The administration must realize that by disposing of around 200 kg of waste daily, the University contributes significantly to environmental pollution and greenhouse gas emission. Nonetheless, the number 200 kg is not the end; it is just the baseline where all solid waste management efforts and outcomes will soon be measured against with. This way, a valid and reasonable assessment of the success of any environmental management, in this case, solid waste management, can be made.

This study has also identified a number of factors that caused the failure of the current segregation system but can be used as the basis for improving the system of waste management. A system, as it is defined, must have all components must work for the common goal. Therefore, to promote better waste management in the University, all components must function properly – the community of students, teachers, employees, janitors, garbage collectors, canteen concessionaires, and most importantly, the Administrators. This promotion must be coupled with proper facilities, policies, and educational programs. Most of all, being an academic institution, the University must ensure integrating the value of solid waste and environmental management in the curriculum.

Moreover, it is recommended that a qualified administrator be appointed to head the waste management unit and provide proper direction. In addition, the results of this study must be utilized by the University in (a) designing a new MRF capable of handling the amount of waste it generates, (b) exploring and selecting a suitable recycling technology that will utilize the waste generated as feedstock to the recycling plant, (c) plan out the marketing of recyclables with economic value, and (d) draft effective policies to reduce the waste generated at source – the University's Canteen. All of these serve as support that the waste administrator can utilize to effectively implement the waste management

system.

The most effective way to deal with the volume of waste generated is "source reduction," which the University can control or regulate. For example, the use of disposables in the canteen may be prohibited. The students may be required to bring their own reusable containers to be used when buying food. A value-added fee may also be collected from the concessionaires to recompense the burden and expenses of the University for the collection and disposal of this waste. This fee is in accordance with the directive "the polluter pays," as it must be their responsibility as waste generators to manage and dispose of their waste (Cordato, 2001; Khan, 2015; UNEP, 2002).

A deeper study of managing and utilizing waste as a resource must be conducted. The Chemical Engineering Department is seeing many opportunities in this area. First, they can study and plan a better and well-functioning MRF for more effective waste segregation. Second, they can find ways to recycle the waste and produce several products, such as fertilizer and briquettes from agricultural wastes, recycled paper products and paper briquettes from paper waste, and floor mats and tiles from plastic wastes. Third, the generation of around 19 kg of PETE recyclable bottles may be marketed, and the proceeds may be used for the management of some of the endeavors for effective waste management. Nevertheless, education and information drive are very important, and any effort promoting this must be supported, but this must be done scientifically and systematically for a more productive result.

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