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RESEARCH ARTICLE OPEN ACCESS

Optimization of the Utilization of Material Recovery Facility in Don Honorio Ventura State University in Bacolor Pampanga Using Solid Waste Management Plan as a Guide Tool

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Abstract:

The population of the university continues to increase, which has led to a corresponding rise in waste production that has an impact on the environment, public health, and society. Different volumes of waste were collected every day in the university, which made the Material Recovery Facility (MRF) unable to accommodate. MRF serves as a drop off point where the waste was sorted, cycled and composted before disposal to landfills. Solid Waste Management (SWM) entails proper waste segregation, recycling, and management, and is a crucial component required to help reduce waste through out the campus in order to optimize the MRF. In order to obtain data, Waste Analysis and Characterization Study (WACS) and a survey that was intended for the target participants around the campus to determine the most generated waste in the campus. After a thorough analysis of waste, they were able to determine that waste under the Recyclables category is the most generated type in Don Honorio Ventura State University(DHVSU),with a total of 43.1% in terms of weight and 61.1% in terms of volume. The most common recyclables waste types are straws, spoons, forks, cardboard, dry paper, plastic containers, plastic cups and water bottles, which is the most consumed waste type with a percentage of 35.7%.Thisledtheresearcherstoproposea comprehensive SWM program and awareness campaigns for DHVSU based on the accumulated results. Conclusively, it was known that implementing SWM programs will yield substantial benefits across financial, academic, and environmental domains of the whole university today and in the future.

Keywords—**Material Recovery Facility, Solid Waste Management, Waste Analysis and Characterization Study, Segregation, Recyclables and RA 9003**

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I. INTRODUCTION

Waste disposal is an essential component of an integrated solid waste management system, wastearedetrimentaltohumanhealthandthe where recycling and trash reduction programs should be prioritized. The implications of current dumping techniques on public health, the environment, and society may also be addressed ina realistic and feasible manner. One of the best methods to properly dispose of waste is by optimizing a Materials Recovery Facility (MRF) which acts as a drop-off location station where the solid waste is sorted, recycled, and composted before disposal to landfills [1]. Generated solid waste is recycled and employs mechanical and manual methods forseparationandprocessing.This includes plastics, tin cans, bottles, paper, fooditems, and other biodegradables but excludes industrial and hazardous waste. After being temporarily stored, the recovered materials, which include plastic, paper,glass,andmetals,arecrushed and baled before being sold to recycling and manufacturing businesses.

The Philippines' fast population growth and economic progress have increased garbage generation, which has accelerated thedestructionof the environment [2]. Theamountandcomplexityof waste produced by the modern economy are increasing, endangering both human health and ecosystems. The Secretary of the Department of Environment and Natural Resources (DENR)stated that the Philippines produce at least 61,000 million metric tons of waste each day, of which 24% is plastic waste [3]. Poor waste management, which includes inefficient disposal, results in the contamination of the air, water, and land. Unclosed and dirty garbage dumps have the potentialtoharm individuals through the spread of diseases and the contamination of drinking water.

Littering damages ecosystems, and dangerous compounds from technology or industrial environment.

Nowadays, there are various proposals to effectively manage solid waste by adopting the Republic Act 9003 or the Ecological Solid Waste Management Act, which ensures the preservation of the environment and public health, and ecological waste management program. Solid waste management is defined as the discipline of waste management that is concerned withtheregulationof solid wastecreation,storage,collection,transfer,and transportation, as well as processing and disposal. The Philippines has worked to improve solid waste management and to establish solid waste management plans. These plans set rules for solid waste related activities like collection,transport,and disposal [1].

However, despite the laws and regulations, and waste diversion programs like recycling, incineration, and composting have been put into place, said efforts remain futile as they still resulted in the shortage of landfill space for the continually growing amounts of municipal solid waste. To handle the growing volume of trash generated daily, relatively few new sanitary landfills had been constructed,andtheonesthatdocurrentlyexistwere rapidly filling up. As of 2021, 245 sanitary landfills were in operation, according to the Commission on Audit (COA). These barely sustain 478, or 29.25%, of the 1,634 Local Government Units (LGUs) inthe country, and they were scarcelysufficienttomanage the 12,091 tons of waste generated everyday in the country, roughly equivalent to 600 garbage trucks [4].

Due to insufficient sanitary landfills around the country, some cities and municipalities are required to pay in order to dump their waste in different landfills. Solid waste management is a challenge for city authorities primarily due to the financialstrainthathighmanagementcosts place on the municipal budget, the ignorance of numerous factors influencing the various stages of waste management, and the linkages necessary to enable the entire handling system to function. By directing wastetoMRFs,wastesegregationcanhelplowerthe amount of landfill waste and costs. However, due to the practice ofimpropersegregation,wastematerials like food scraps, paper, plastic, or liquid are all mixed together inlandfillstodecompose.Itcouldbe dangerous for both human health and the environment as a resultoftherun-offthatisreleased into the soil and harmful gas into the atmosphere.

In the Philippines, landfill clustering is common due to natural area constraints. Metro Manila and Central Luzon are served by three Sanitary Landfills (SLF) in the province of Rizal, which are situated at Montalban, San Mateo, and Morong. Metro Clark Waste Management Corporation (MCWMC) and Bulacan signed an agreement for the transportation of their garbage to the landfill located in Barangay Cutcut II, Capas, Tarlac. One component of SLF clustering that is often overlooked is the expense. The average transportation charges and tipping fees for Pampanga Local Government Units (LGUs) to MCWMC is estimated at PhP 660 per metric ton[5].

The majority of the garbage produced in Barangay Cabambangan, Bacolor, Pampanga has been obtained from Don Honorio Ventura State University (DHVSU), according to the Municipal Environment and Natural Resources Office (MENRO). DHVSU had an average of 20,000 population per semester. Today, Barangay Cabambangan has a total population of 791, while DHVSU has 35,444, which proves that the university produces themajorityofthewastewithin thearea.Wasteinthebarangayisalsoaresultofthe several businesses and food vendors surroundingthe university. Since most of the consumers are DHVSU students, improper garbage disposal has been caused by a variety of waste materials, including plastic bottles, cups, sticks, and other items.Furthermore,asignificant percentage of staff members and students come from different municipalities and cities outside of Bacolor, and some of them add to the garbage produced in the campus.

The researchers determined the various factors incorporating MRFs into a Solid Waste Management System that present a workable substitute for attaining Don Honorio Ventura State University's sustainable development objectives. This is achievable not only through the installationof MRFs butmostimportantlythroughoptimization. It also encompasses information on the financial effects of recycling income and waste management cost components. This was the reason why the researchers were driven to look into the several aspects that would improve proper waste disposal and offer strategies and programs to reduce risk and related problems today and in the near future.

II. METHODOLOGY

Research Design

The researchers employed a bottom-up approach in the study. According to Asana, Inc. (2023), this type of research involved everyone ona team,regardlessofposition,tocollaborateonproject decisions. This approach built open communication, feedback, and creative participation from all team members,resultinginbetteroutputsandacloser-knit team [6]. Through a collaborative and participative approach, the goal was to deepen connections and improve the outcomes of the project. This included collaborative decision-making, in which those directly involved in the project contributed to the decisions that were made. This method strove to build a cooperative and inclusive environmentwithin the team by encouraging cooperation in decision-making and project planning.

Research Locale

Don Honorio Ventura State University (DHVSU), established in 1861 and situated in BarangayCabambangan,Bacolor,Pampanga, Philippines, holds the distinction of being the oldest vocational school in Far East Asia. With apopulationexceeding35,444individuals,comprising students from various levels (LHS, SHS, College, Graduate School, Juris Doctor), as well as faculty and staff (totaling 34,251 students and 1,193 employees), the DHVSU Main Campus generates a substantial amount of solid waste. Because of its large population and considerable amount of wastes which it generates, DHVSU was determined to bethe research site for this study.

The study was aimed at achieving optimal efficiency for the existing Materials Recovery Facilities (MRFs) in this specific setting, thereby providing valuable insights for institutions with similar characteristics. Through comprehensive analysis and strategicinterventions,thestudyaimed to enhance waste management practices and sustainability initiatives at DHVSU and potentially serve as a model for similar educational institutions.

Fig.1MapofMaterialRecoveryFacilityinDHVSU

Research Instrument

In this study, the researchers extensively employed the Waste Analysis and Characterization Study (WACS) as a primary method for data acquisition. Through WACS, they gathered crucial information regarding the quantity andcomposition ofgeneratedwaste,enablingthemtoidentifythe predominant types of waste produced.Additionally, the researchers conducted a feasibility analysis, utilizing interviews and surveys as supplementary data gathering techniques.

The interviews conducted followed a structuredformat,whereintheresearcherspreparedaformal set of questions to be posed to the respective participants. Furthermore, a questionnaire was created and distributed using Google Forms, allowing for efficient data collection from a broader audience. These methodologies facilitated comprehensive data collection and analysis, contributing to a robust understanding of waste management dynamics within the study context.

Data Collection Methods

To gather data, the researchers requested information from theStateUniversitiesandColleges (SUCs) Land Use Development and Infrastructure Plan, specifically regarding any future plans concerning the existing Materials Recovery Facility (MRF), if available. They conducted computationsto assess the capacity of the MRF to accommodate waste and determine the amount of waste generated by the university per day.

Additionally, the researchers obtained the total population of internal stakeholders within the university from varioussources,includingtheOffice of the University Registrar, Office of Human Resources, and previous studies conducted withintheuniversity.Thisdatacollectionprocessfacilitated a comprehensive understanding of waste management infrastructure, waste generation rates, and the university's internal demographics.

TABLEI
POPULATIONOFDHVSUFORFIVEYEARS(MAINCAMPUS)

School Year	Population (1stSemester)	Population (2ndSemester)
2023-2024	35,444	33,806
2022-2023	35,012	33,558
2021-2022	32,678	31,627

2020-2021	25,414	25,719
2019-2020	23,228	20,154

Table I presents the population of internal stakeholders at Don Honorio Ventura State University's Main Campus in Bacolor, Pampanga, for the past five years up to the current period. The population acquired was used for the 10-year projection of the population of DHVSU Main Campus.

A feasibility analysis was also conducted to assess the viability study and practicality of the study, to identifypotentialconstraintsandrisks,and to ensure its alignment with objectives. Survey questionnaires were distributed through Google Forms for easier dissemination.

Researchaboutexistingstudiesthatcouldbe utilized to propose a program for the optimizationof the MRF was also conducted and a Waste Analysis and Characterization Study (WACS) onthe waste of the university was performed.

Analysis of Existing MRF

The current Materials Recovery Facility (MRF) located at Don Honorio Ventura State University (Main Campus), positioned at Gate 8, boasts avolumetriccapacityof32,000liters.Acting as a central repository for collected waste, it serves as the primary collection point until it reaches full capacity, at which point, the Metro Clark Waste Management Corporation (MCWMC) undertakesits collection.

Under a contractual agreement between the Office of Grounds Improvement and Maintenance Unit and MCWMC, 37 trash bins are scheduledfor collection annually. Each collection incurs a costof PhP 21,000. However, this allocation often proves inadequate, necessitating early contract renewals.

The escalating student population each academicyearcontributes to a corresponding rise in waste generation,therebyaugmentingthefrequency of trash bin collections throughout the year.

Data Analysis

The Materials Recovery Facility (MRF)plays a critical role in receiving, sorting, and characterizing wastes. However, its capacity often falls short of the volume of waste generated, presenting a significant challenge. To address this issue, researchers adopted a bottom-up approach.

Figure 2 illustrates the flow of solid waste from its source to recycling. At the top of the inverted triangle lies the source of waste. Fully optimizing the MRF hinges on reducing waste generation. By curbing waste generation, theMRF's capacity can be better matched to the volume of waste it receives. Consequently, the downstream processes, extendingfromtheMRFtorecycling,can operate more effectively.

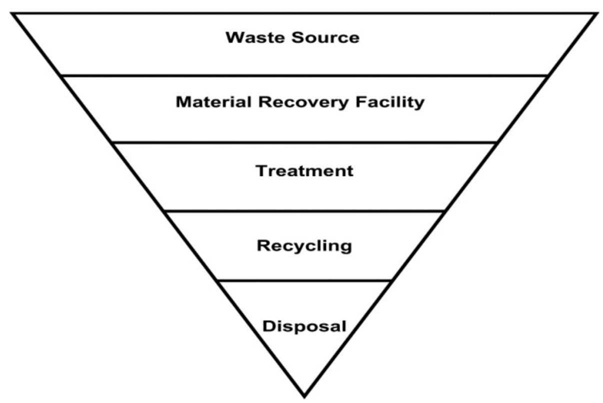

Fig.2WasteFlow

Feasibility Analysis

The researchers optimized their time utilization by employing the most efficient and convenient approaches for data collection. They employed a variety of approaches and techniquesto obtain information from the target respondents.Theyuseddifferentscalesthatwereusedto assess the program's effectiveness as well as the level of awareness and understanding among students, faculty, and other employees about solid waste management.

Sample Size

The total population of the university, inclusive of both students and employees,is35,444 individuals. The sample size was calculated using Slovin's Formula considering a 5% margin of error, resulting in a total of 396 respondents.

$$n = \frac{N}{1+Ne^2}$$

where:
n = sample size
N=populationsize e
= margin of error

WeightedMeanInterpretation

The initialphaseoftheanalysisinvolvedthe categorization, organization, and quantification of the descriptive data. These were subsequently presented in a structured format utilizing frequency distributions, percentages, and weighted means. To facilitate the interpretation of the weighted mean during data analysis, likertscalelevelofagreement, frequency, satisfaction, awareness and importance was employed,

Statistical Procedure

The survey results collected by the researchers aimedtoascertaintheweightedmeanof respondents' choices for each statement outlined in the questionnaire. This involved assigning weights to each response option and computing the mean score to gauge the overall sentiment or opinion regarding the statements posed in the survey. The weighted mean was computed using the formula below:

$$\bar{x} = \frac{\sum_{i=1}^{n} wixi}{\sum_{i=1}^{n} w}$$

where:
X = Level
W=Weight
n=WeightofFrequencyofRespondents/ NumberofRespondents i
= interval

$$\sigma = \sqrt{\frac{\Sigma(x_i - \mu)^2}{N}}$$

where:
□=populationstandarddeviation
N = the size of the population
□□=eachvalueofthepopulation μ = the population mean

WasteAnalysisandCharacterizationStudy

In the pursuit of enhancing waste management strategies,theresearchersembarkedon a comprehensive Waste Analysis Characterization Study. This research entailed anin-depthanalysisof collected data, encompassing diverse aspects of waste,includingitscompositionandgenerationrate. The data collected was meticulously organized, tabulated, and subjected to analysis using ratio and percentage calculations.

Throughout the study, various WACS techniques were employed to comparatively assess their effectiveness and suitability. These methodologies were aimed at identifying the most suitable approach for waste analysis and characterization, thereby facilitating the development of optimized waste management strategies.

Technique

The researchers identified themosteffective sampling method for obtaining their data sample. They employed Slovin's formula to determine the sample size, considering a 5% marginoferror.This approach enabled them to refine their waste management strategies and gain a comprehensive understanding of garbage properties.

Formulas

The data obtained from the Waste Analysis CharacterizationStudy(WACS)wereinputtedand structured within a Google Spreadsheet to expedite andensureprecisecomputations.Variousformulas weredeployedbytheresearcherswithinthe spreadsheet to derivespecificresults.Thefollowing formulas were employed:

1. $TotalWofwasteCollectedperday = \sum Wofsampleofwasteperday$

   $W = Weight$

2. $TotalVofwasteCollectedperday = \sum Vofsampleofwasteperday$

   $V = Volume$

3. $AverageWofgeneratedwaste = \frac{\sum TotalWofwasteCollectedperday}{Numberofdays}$
4. $AverageVofgeneratedwaste = \frac{\sum TotalVofwasteCollectedperday}{Numberofdays}$
5. $TotalsegregatedWofwaste = \sum Wofsegregatedsampleofwaste$
6. $TotalsegregatedVofwaste = \sum Vofsegregatedsampleofwaste$
7. $AveragesegregatedWofwaste = \frac{TotalsegregatedWofwaste}{Numberofdays}$
8. $AveragesegregatedVofwaste = \frac{TotalsegregatedVofwaste}{Numberofdays}$

To project the total amount of waste generated for future years, Linear Regression was employed to calculate the expected population growth. This involves analyzing historical population data to establish a trend, which canthen be extrapolated to predict future populationfigures. Once the expected population figures for future years are determined, they can be used in conjunction with waste generation rates to estimate the total amount of waste generated for those years.

$$Px = A + Bx$$

where:

Px – population at x
A – population factor
B–growthfactor x
– time in years

Per Capita Generation (PCG) in L /person/day:

$$PCG = \frac{TotalVolumeperday(\frac{L}{day})}{Totalnumberofpopulation}$$

VolumeAnalysisofWasteGeneration

The waste volume in the trash binundergoes compression as newly collected waste is layered on top. The 32,000 L capacity of the bin cannot accommodate uncompressed wastes that are simply tossed over it. When the bin reaches full capacity,the Metro Clark Waste Management Corporation (MCWMC) is notified for collection. However, beforethecollectioniscompleted,wasteoften overflows from the bin, prompting its covering, which further compresses the waste. Usually, after being empty it reaches six days before the bin is collected again.

The researchers devised a formula to calculate the percentage by which the waste is compressed and to project the number of bin collectionsinoneyear.Todeterminethenumberof MRF collections in a year, thecompression percentage of waste is calculated using formulas:

$$ACRV = (1 - \frac{TotalVofWasteCollectedinaWeek}{TotalcapacityVofMRF})$$

where:

ACRV=Averagecompressionrateofthe volume of waste

$TotalVofWasteCollectedinaWeek = (TotalVofwasteinaday)(t)$
t=numberofdaystobeforethecollectionofwaste(6)

Then,computethecompressedvolumeof generated waste.

$$CompressedV = GeneratedV - (GeneratedV)(AverageCompressionRate)$$

Steps and Procedure

This section delineates the methodological framework employed for data acquisition and analysis derived from the Waste Analysis CharacterizationStudy(WACS).Theensuing procedures detail the systematic approach undertaken by researchers in gathering, organizing, and interpreting waste data within the study domain.

1. Inserted the weight (kilograms) and volume (liters) in the spreadsheet. Labeled the date when WACS was conducted including the unit of measurement used.
2. Created separate sheets in the spreadsheetfor the result of segregated waste per day.
3. Input the weight and volume of the segregated waste. Label the category of waste and put the results under the weight and volume.
4. In another sheet, input all the volume and weight of the result of the WACS per day. Solved the total segregated waste by weight and volume.
5. Created a pie chart to represent the percentage of the waste per category.
6. In another sheet, labeled the category in terms of the 5 main categories of waste, biodegradable, recyclables, residual with potential, residual without potential, and special waste.
7. Createdapiechartofthepercentageofthe5 main categories in terms of weight and volume
8. Calculated total weight and volume of the waste in three days of conducting WACS.

After conducting an analysis to determine the percentage of waste generated per type, the researchers identified their prioritized waste type. Subsequently, they devised a program aimed at reducing the generation of this waste type. This involved the creation of three tables illustrating various options displayed ina10-yearprojectionby employing linear regression:

1. A scenario without intervention,
2. Scenarios with intervention.

III. RESULTSANDDISCUSSION

This chapter provides different graphs and tables which present the data results that were acquired duringthedatagatheringmethod.Through the Waste Analysis and Characterization Study (WACS), survey questionnaires were provided online to the chosen respondents of Don Honorio Ventura State University. The researchers wereable to accomplish the necessary information needed in ordertoidentifyprogramsthathelpedtoachievethe different objectives in the study.Theyalsoaimedto create options for the university with and without interventions in order to fully optimize the use ofthe Materials Recovery Facility (MRF) and reduce solid waste that was being generated around the campus.

Feasibility Analysis' Results and Discussions

The feasibility analysis successfullygathered information about the respondents' participation in waste management practices. The results showed that they strongly agreed on practicing solid waste segregation (M = 4.44, SD = 0.86). However, they moderately agreed on improperly throwing waste in the campus (M =2.84, SD = 1.58) indicating that there were still individuals on campus who disposed of their trash improperly around DHVSU.Finally,theresearchers gathered information about the respondents' participation in campus clean-up events or waste reduction activities,showingthatmostofthemwere in favor of these activities (M = 4.16, SD = 0.94). The respondents' participation in wastemanagement practices showsaverbaldescriptionof "Agree" (M = 3.92, SD = 1.13).

Most of the data gathered, despite the knowledge and awareness of the people around DHVSU, still dependonthecooperationandproper management regarding the solid waste that will furtherhelptohaveasuccessfulSWM. This would also lead the university to make use of the segregated waste beneficial, by optimizing the utilization of the MRF. A well-optimized Materials Recovery Facility (MRF) at DHVSU can yield significant environmental and financial advantages.

By streamlining processes and maximizing recovery rates, the university can reduce waste disposal expenditures and potentially generate revenue from recycled materials. This translates to cost saving and promotes a more sustainablecampus operation. Furthermore, an optimized MRF serves as a valuable educational tool, raising awareness and responsible waste management practices among students, preparing them to be environmental stewards beyond their academic years.

WasteAnalysisand Characterization Study's Results and Discussions

Upon conducting a three-day WasteAnalysis and Characterization Study (WACS), the researchers wereabletoattaindataonthegenerated waste of the university and its composition. This helped the researchers create a program and intervention to optimize the Materials Recovery Facility of the university. The quantity ofgenerated waste will help identify the amount of garbage that needs to be diverted or avoided. The proponents used Google Spreadsheets to input data and solve the result acquired. Table II shows the average amount of waste produced in terms of weight and volume for the 2nd semester of the academic year 2023-2024.

TABLEII
AVERAGECOLLECTEDWASTEPERDAY

Unit	**Averagewastegenerationinaday**
Weight(kg)	389
Volume(L)	7,830

Table II presents the averagecompositionof waste categorized by weight and volume. Waste categories were determined based on researchers' segregation efforts over a three-day period.

Notably, the total volume of segregated waste and the average waste generated by volume exhibited variations due to the unique shapes of certain waste items, such as plastic bottles, impacting their volumetric representation.Whenthe average volume of waste generation was collected, unsegregated waste was measured, where food wastes are inside containers which lessen the void between different items. During segregation, the waste has been sorted by category, sorting the food waste inside of containers leaving more space for food containers with only air inside andintroducing more space to accommodate the food waste separated. Through segregation, the volume of segregated waste shows greater value.

Conversely, the average weight generated and the total segregated weight of waste displayed minimal disparities in results, attributable to rounding calculations, resulting in slightdifferences in the overall totals.

TABLEIII
COMPOSITIONOFWASTEINTERMSOFWEIGHTANDVOLUME

Categoryofwaste	**Averageweight(kg)**	**Percentage(%)**	**Average volume(L)**	**Percentage(%)**
Foodwaste,yardwaste and otherwastebiowaste	100	25.64	261	2.91
Foodwrappersandplasticbags	23	5.90	808	9.00
Residualw/out potential	42	10.77	218	2.43
Plasticcups	38	9.74	1523	16.96
Papercups	19	4.87	963	10.72
Plasticbottles	45	11.54	1958	21.80
Plasticcontainer	10	2.56	528	5.88
Cardboard	16	4.10	186	2.07
Styro	12	3.08	839	9.34
Wetpaper	16	4.10	354	3.94

Drypaper	35	8.97	994	11.07
Spoon,forkandstraws	12	3.08	109	1.21
Cans	6	1.54	50	0.56
Ethylalcohol containers	2	0.51	93	1.04
Aluminumcontainer	1	0.26	17	0.19
Glass	4	1.03	31	0.35
Special	9	2.31	50	0.56
Total	**390**	**100**	**8982**	**100**

In Table III, the top three types of waste in terms of volumeareplasticbottles,plasticcupsand dry paper which comprises 21.8%, 16.96% and 11.07%,respectively.Thethreehighestcontributors in terms of volume are classified as recyclables, which can be recycled or sold to junk shops.

Generally, the waste composition at Don Honorio Ventura State University exhibits varying percentages depending on the measurement criteria utilized. In Figure 3, the percentages of waste composition are based on the weight of each waste category. Recyclables constitute the largest proportion at 43.1% of the total waste,followedby biodegradables at 29.9%. Residuals with potential for recycling account for 14.0% ofthewaste,while residuals without potential for recycling represent 10.8%. Special waste comprises the smallest proportion at 2.2% of the total waste.

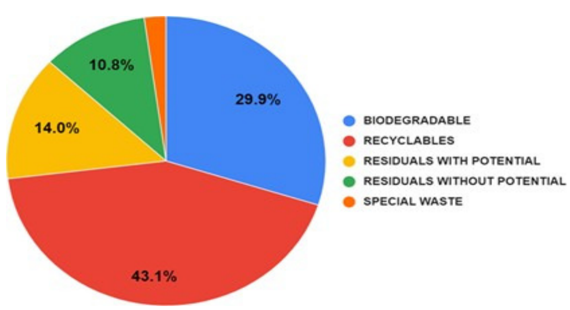

Fig.3PercentageofWasteCategoryintermsofWeight

Figure 3 depicts contrasting resultscompared to Figure 4,primarilyduetodisparitiesin theweight-to-volumeratioofdifferentwastetypes.

For instance, certain waste categories, such as food waste and yard waste, may weigh more relative to the space they occupy, while others, like plastic bottles and cups, may occupy morespacecompared to their weight.

In terms of waste volume, recyclables account for the majority at 61.1% of the total volume, followed by residual waste with potential for recycling at 29.1%.

Biodegradable waste constitutes 6.9% ofthe total volume, while residual waste withoutpotential for recycling comprises 2.4%. Special waste represents the smallest proportion at 0.6% of the total volume (Figure 4).

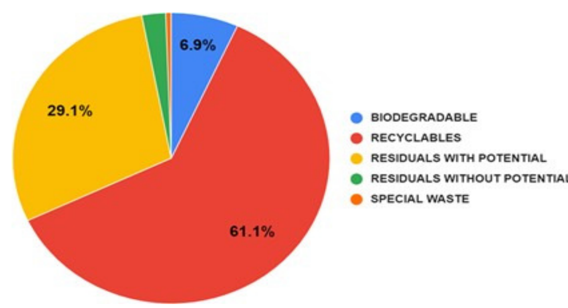

Fig.4PercentageofWasteCategoryintermsofVolume

The largest type of waste, the recyclables, show a total volume of61.1%whichisprobablefor waste diversion. The researchers based on thelargest category to reduce the waste generated bythe university.

Figure 5 shows the percentage contribution of different recyclable waste in terms of volume, 35.7% of which is plastic bottles and 27.7% is plastic cups. Dry paper shows 18.1%, as plastic containers represent9.6%.Whilecardboardexhibits 3.5% and disposable plastic straws, spoons, and forks show 2.0%.

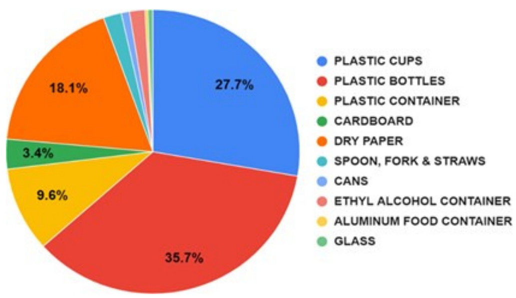

Fig.5RecyclablesPercentComposition

To fully optimize the MRF, the proponents created intervention on the generation or divert the generated waste, for the MRF to have more spaceto accommodate more waste. The intervention is based on which waste is easiest to divert or reduce and has a greater amount of volume.

They created a program called Managing Reduction for Waste orMRF-Wtoefficientlydivert the highest-generating waste type which is foundto be recyclables (61.1%) with the help of the enhancement ofthecurrentsolidwastemanagement planbyraisingtheawarenesslevelofthe stakeholdersandbyinaugurationofpolicies. MRF-W contains Honorian's Eco Campaign, Huli ka, boy!, No PM, Color-codedTrashBags,Garbage CollectionandRecyclablesDiversion.Waste diversion of recyclables will be conducted easily if categories ofwasteareproperlysegregatedfromthe source, which reduces the time it will take to segregate waste at the Materials Recovery Facility (MRF). It saves more time on diverting waste by selling recyclables in junk shops, whichreducesthe stored waste at the MRF having more space for utilizing it.

10-yearProjectionofWasteGeneration

The 10-year projection of waste generation provides estimates of the projected weight and volume of waste over a decade without intervention. This projection underscores the imperativefortheuniversitytomitigate, accommodate, or divert the waste it produces over the specified timeframe to optimize the Materials Recovery Facility (MRF) in the succeeding years.

To calculate the projected waste generation, the researchers initially computed the projected population for the next ten years using Linear Regression. This involved analyzing five years of population data from School Year (S.Y.) 2018-2019 to S.Y. 20232024 to establishatrend.Subsequently, this trend was extrapolated topredictthepopulation figures for the next ten years, serving as a basis for estimating future waste generation.

$$P\bar{x}=A+B\bar{x}$$

where:

Px = population at x

A = population factor (20,146)

B=growthfactor(3,403) x

= time in year

Then,computethePerCapitaGeneration(PCG) in L/person/day:

$$PCG=\frac{Totalvolumeperday(\frac{L}{day})}{Totalnumberofpopulation}$$

where:

TotalVolumeperday=7830L(Average waste volume generated)

Totalnumberofpopulation=33,806 (2nd semester of S.Y. 2023-2024)

$$PCG=\frac{7830L}{33,806}=0.231616L/person/day$$

ProjectedWasteGeneratedperday=Projected Population x 0.231616 L/person/day.

Table IV presents the ten-year projected population of students and employees at Don Honorio Ventura State University's Main Campus, along with the computed average waste generation foreachpopulation.Thesefiguresserveasthe projected waste generation without interventionover the specified period. This data providesinsights into the anticipated volume of waste generated by the university's population over the coming decade, highlighting the importance of proactive waste management strategies that could lessen the generated waste in the future to fully optimize the MRF.

TABLEIV
PROJECTEDWASTEGENERATIONINTERMSOFVOLUME

SCHOOL YEAR	Projected Time(years)	Projected Population	PerCapitaGeneration(L/person/day)	DailyWaste Generation basedonpopulation(L/day)
2023-2024	5	37161	0.231616	8607
2024-2025	6	40564	0.231616	9395
2025-2026	7	43967	0.231616	10183
2026-2027	8	47370	0.231616	10972
2027-2028	9	50773	0.231616	11760
2028-2029	10	54176	0.231616	12548
2029-2030	11	57579	0.231616	13336
2030-2031	12	60982	0.231616	14124
2031-2032	13	64385	0.231616	14913
2032-2033	14	67788	0.231616	15701
2033-2034	15	71191	0.231616	16489

Since more generated waste leads to less space for the MRF to accommodate, the volume of waste equates to the increaseinthenumberoftimes the MRF is collected in a year, which makes the university spend more. During the analysisofMRF, it takes six days to make it fully loaded where it makes a mountain of garbage bags on top of it exceeding the capacity of the MRF. During the collection, it was observed that the volumeofwaste is compressed as it is covered. To calculate the number collection of MRFinayear,itisrequiredto compute the compression rate and multiply it to the generated waste which shows the compressed volume per day. Then the volume that theMRFcan accommodate which is 32,000 L divides it by the compressed volume of waste tosolvethenumberof days before the MRF is collected, and then, compute the number of collections of MRF in a year. In acquiring the data needed, first, solve the total volumeofwastecollectedbeforecollectionofMRF, the solution is shown below.

The computed projectedcostofcollectionof MRF in a year is acquired by multiplying the projected number of collections in a year by21,000 which is the current cost ofeachcollection.TableV shows the tabulated resultsoftheprojectionwithout interventionscenario.ThedataonFirstSemester S.Y. 2023-2024 is estimated to havealmostdoubled in the span of 10 years. To fully optimize the utilization of MRF, cutting the waste going to it is necessary.

TABLEV
PROJECTIONWITHOUTINTERVENTIONSCENARIO

SCHOOL YEAR	WasteGenerationWithoutIntervention(L/day)	Compressed Wasteof31.9% (L/day)	Number ofdaysbeforebiniscollected	Number ofCollection inoneS.Y.	Costinayear(Php)
2023-2024	8607	5861	5.5	41	861,000
2024-2025	9395	6398	5.0	44	924,000
2025-2026	10183	6935	4.6	48	1,008,000
2026-2027	10972	7472	4.3	52	1,092,000
2027-2028	11760	8008	4.0	56	1,176,000
2028-2029	12548	8545	3.7	59	1,239,000
2029-2030	13336	9082	3.5	63	1,323,000
2030-2031	14124	9619	3.3	67	1,407,000
2031-2032	14913	10155	3.2	70	1,470,000
2032-2033	15701	10692	3.0	74	1,554,000
2033-2034	16489	11229	2.8	78	1,638,000

Development of Program

While conducting a Waste Analysis and Characterization Study (WACS) on the Materials Recovery Facility (MRF), the researchersdiscovered that most of the collected waste was unsegregated. Figure 6 shows the flow of waste in Don Honorio Ventura State University. The flowchart starts with source or also known as the wastegenerator.Thesourcegeneratesdifferent types of wastes such as biodegradable, recyclables, residual with potential, residual without potential, and special waste. The waste is thrown in their designated trash bins. On the scheduled time of the collection, thetruckpicksupthetrashbagsfromthe collection points. After collecting all the waste, the truck goes back to the MRF which serves as the starting and end point of the collection. When the makeshift MRF reaches its full capacity, the Metro Clark Waste Management Corporation (MCWMC) would be called for the disposal.

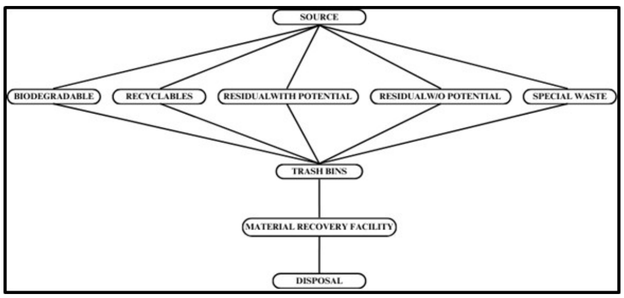

Fig.6WasteFlowWithoutApplyingInterventions

The researchers created a program called Managing Reduction For Waste or MRF-W. It is created to efficiently divert the highest-generating waste type which isfoundtoberecyclables(61.1%) with the help of the enhancement of the currentsolid waste management plan by raising the awareness level of the stakeholders and by inauguration of policies. Waste diversion of recyclables will be conducted easily if categories of waste are properly segregated from the source, which reduces the time it will take to segregate waste at the Materials Recovery Facility (MRF). It saves more time on diverting waste by selling recyclables in junk shops, which reduces the stored waste at the MRF having more space for utilizing it.

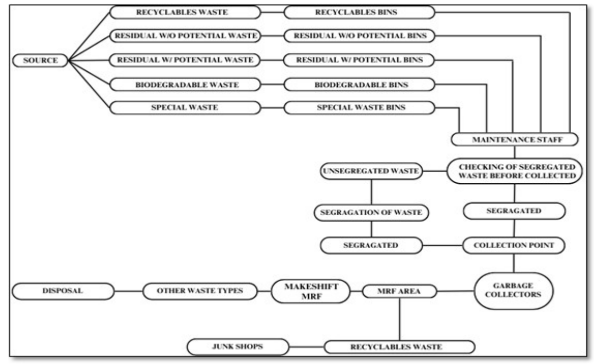

Fig7.WasteFlowwithAppliedInterventions

Figure 7 depicts a flow chart illustrating the waste flow dynamics following the implementation of an intervention and program. In contrast to the initial flow chart, wastedoesnotproceeddirectlyto disposal. Recyclables undergo diversion, whileother waste types are designated for disposal. This optimized approach maximizestheutilizationofthe makeshift Materials Recovery Facility(MRF).Asit reduces the waste entering the bin, this enables the bin's capacity to effectively manage the volume of generated waste.

TABLEVI
10-
YEARPROJECTIONOFWASTEGENERATIONWITHDIVERSION OF RECYCLABLES

YEAR	WasteGenerationwithDiversionRecyclables(L/day)	CompressedWasteof31.9% (L/day)	Numberofdaysbeforebiniscollected	NumberofCollectioninoneS.Y.	Costinayear
2023-2024	3348	2280	14.0	16	336,000
2024-2025	3655	2489	12.9	17	357,000
2025-2026	3961	2698	11.9	19	399,000
2026-2027	4268	2906	11.0	20	420,000
2027-2028	4575	3115	10.3	22	462,000
2028-2029	4881	3324	9.6	23	483,000
2029-2030	5188	3533	9.1	25	525,000
2030-2031	5494	3742	8.6	26	546,000
2031-2032	5801	3950	8.1	27	567,000
2032-2033	6108	4159	7.7	29	609,000
2033-2034	6414	4368	7.3	30	630,000

TABLEVII
10-YEAR PROJECTION OF WASTE GENERATION WITHDIVERSIONOFRECYCLABLESANDWITHOUTINTERVENTION

YEAR	WasteGeneration WithoutIntervention(L/day)	WasteGenerationwith DiversionRecyclables(L/day)
2023-2024	8607	3348
2024-2025	9395	3655
2025-2026	10183	3961
2026-2027	10972	4268
2027-2028	11760	4575
2028-2029	12548	4881
2029-2030	13336	5188
2030-2031	14124	5494
2031-2032	14913	5801
2032-2033	15701	6108
2033-2034	16489	6414

TABLEVIII
COSTANALYSISBETWEENWITHANDWITHOUTINTERVENTION ON WASTE GENERATION

YEAR	WithoutIntervention		WithIntervention	
	Numberof CollectiononeS.Y.	Cost in ayear(Php)	Numberof CollectiononeS.Y.	Cost in ayear(Php)
2023-2024	41	861,000	16	336,000
2024-2025	44	924,000	17	357,000
2025-2026	48	1,008,000	19	399,000
2026-2027	52	1,092,000	20	420,000
2027-2028	56	1,176,000	22	462,000
2028-2029	59	1,239,000	23	483,000
2029-2030	63	1,323,000	25	525,000
2030-2031	67	1,407,000	26	546,000
2031-2032	70	1,470,000	27	567,000
2032-2033	74	1,554,000	29	609,000
2033-2034	78	1,638,000	30	630,000

IV. CONCLUSION

Don Honorio Ventura State University (DHVSU) is one of the superior universities in Pampanga in catering future professionals. The exceptional quality of education offered by this universityattractsnumerousprospectivestudents seeking admission. This led to the growth of population in the university with a corresponding increase in waste generation. The large university population results in a significant volume of waste, estimated at 8,607 liters per day. Waste collection occurs every six days through Metro Clark Waste Management Corporation (MCWMC), totaling 41 collections per academic year and incurring an annual expenditure of PhP 861,000 for waste disposal.

Through this study, it has become evident that awareness, behavior, and attitude contributes hugely to the success of the attainment of environmental sustainability.Therespondentsofthe study showed a great level of awareness about the Republic Act 9003, waste management actions undertaken by the university, and agreed that the university proactively supports initiatives aimed at reducing and managing solid waste.

Despite their awareness, the findings regarding the respondents' admission of improper waste disposal highlight the necessity for a strong initiative to reinforce the program and ensure compliance among stakeholders. This goal will be attained by the incorporation of relevant provisions from the Republic Act and university regulations that endorse and authorize the program. This will enhance the current Solid Waste Management Plan (SWMP) of the university by thecooperationofthe internal stakeholders, to optimize the utilization of its Materials Recovery Facility(MRF).Thisfinding highlights the importance of continuous participation and efforts to achieve the goals of the program.

The study underscores that recyclables comprise the majority ofthewastegeneratedwithin the university. This emphasizes the necessity for a waste reduction program, as this waste type significantly contributes to the MRF exceeding its capacity and resulting in overflow.

One key revelation from this study is that a significantreductioninwastethatgoesdirectlyto the MRF will be achieved through successful implementation of the program. From an estimated daily volume of8,607liters,wastecouldpotentially be reduced to as little as 3,348 liters per day which means from a total of 41 collections annually with an annual expenditure of PhP 861,000, it could be reduced to 16 collections with an annualexpenditure of PhP 336,000.

Furthermore, the success of the intervention measures demonstrated in the analysis underscores the importance of evidence-based decision-making and proactive management practices. Byleveraging insights from this research, DHVSU can develop tailored strategies and action plans to address its specific waste management needs effectively. Moreover, ongoing monitoring and evaluation will be essential to track progress, identify areas for further improvement, and ensure the sustainability of waste management efforts over time.

In conclusion, the findings presented in this study provide a compelling rationale for the implementation of a comprehensive solid waste management programatDonHonorioVenturaState University. By embracing thisholisticapproachand committing to continuous improvement, DHVSU can not only mitigatethechallengesassociatedwith waste management but also emerge as a leader in sustainable practices within the academic community and beyond.

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