

A school-based waste audit and Material Recovery Facility (MRF) collection as a basis for waste reduction

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Abstract

The study was conducted to determine the waste generated at the Materials Recovery Facility (MRF) of Central Bicol State University of Agriculture – Pasacao Campus. It also identified and classified solid waste generated in four specific areas: Recreational Zone, Academic Zone A, Study Activity Zone, and Academic Zone B. Furthermore, it proposed a functional, efficient, and context-appropriate Materials Recovery Facility (MRF) design for the school. The problem of improper waste disposal highlighted the need to establish a data-driven and effective waste management system. The descriptive research method was employed in the study, specifically using a quantitative descriptive research design. The Waste Analysis and Characterization Study (WACS) log sheet and the Solid Waste Management Office WACS guide were used as tools for data gathering. The statistical tools applied included weighted mean, percentage, and ANOVA. Findings revealed that recyclable waste was the dominant type present at the Material Recovery Facility, amounting to 51.75 kg, while special waste was the least generated, accounting for only 6 kg. Data from the four specific areas also showed that recyclable waste remained the most dominant type, with a total of 82.80 kg recorded, while residual waste with recycling potential had only 0.50 kg. In conclusion, recyclables were the most abundant waste generated at the campus. Thus, the proposed Material Recovery Facility was designed based on the waste audit findings, transforming quantitative data into a functional, evidence-based solution for the university.

Keywords: waste audit, Waste Analysis and Characterization Study (WACS), Materials Recovery Facility (MRF), campus waste management

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1. Introduction

Educational institutions generate substantial amounts of solid waste due to daily academic and administrative activities. These include paper, plastics, food waste, and other materials that often remain underutilized despite their recyclable or compostable potential (Kaza et al., 2018). Without effective management systems, these wastes contribute to environmental degradation and increased disposal costs. A major issue in school waste management is the reliance on assumptions rather than data-driven strategies. Recycling systems are often implemented without understanding actual waste composition, resulting in contamination and inefficiency (Cheng and Thompson, 2016). This gap highlights the need for systematic waste audits to inform effective waste management practices.

Material Recovery Facilities (MRFs) are essential in addressing waste management challenges by enabling sorting, recovery, and reuse of recyclable materials (Hosansky et al., 2023). In addition, waste reduction strategies focus on minimizing waste generation at the source, contributing to environmental sustainability, and reducing greenhouse gas emissions. Therefore, the study, "A School-Based Waste Audit and Material Recovery Facility (MRF) Collection as Basis for Waste Reduction," seeks to address these problems. Founded on the principle that "you cannot manage what you do not measure," it employs a systematic waste audit to move beyond assumptions and gather concrete data on the school's waste stream. This data then serves as the essential foundation for designing a targeted and efficient waste collection system modeled after a Materials Recovery Facility (MRF). The ultimate goal is to demonstrate that a data-driven and educational approach can significantly reduce landfill waste, minimize contamination, and provide an unparalleled experiential learning platform for students.

Statement of the Problem - The study was driven by the need to establish a data-driven and effective waste management system within the Central Bicol State University of Agriculture - Pasacao Campus. Despite the presence of bins, the existing system was likely based on general assumptions rather than specific localized data, which led to inefficient resource allocation, increased risks of contamination, and missed opportunities for waste reduction and composting. To address those core issues, the research was guided by the following specific questions: (1) What types and quantities of waste were commonly generated within the four locations of Central Bicol State University of Agriculture - Pasacao Campus? (2) Was there a significant difference in the composition and quantity of generated waste collected from the four identified locations? (a) Area A: Recreational Zone, (b) Area B: Academic Zone A, (c) Area C: Study Activity Zone, (d) Area D: Academic Zone B. (3) What specific recommendations could be proposed for a functional, efficient, and context-appropriate Materials Recovery Facility (MRF) design for the school?

Significance of the Study - The study's results benefited several stakeholders: The Central Bicol State University of Agriculture – Pasacao Campus benefited from the findings as they served as a critical source of information on the status of solid waste management, supporting the Environmental Management Office in crafting and implementing effective policies and programs. Students also benefited as the study served as a guide for sustainable practices and provided an experiential learning platform, empowering them to become active agents of environmental change. Environmental conservationist organizations were able to use the data and proposed model to advocate for and implement evidence-based waste management practices in other institutions. Likewise, school utility personnel gained a better understanding of the major waste streams on campus, leading to more efficient collection, segregation, and handling practices. For the researchers, the data served as baseline information for conducting similar studies, while future researchers may use the study as a reference for waste audit, MRF development, and sustainable campus operations. Overall, the study contributed to the existing body of knowledge on waste audit and helped various stakeholders understand the importance of conducting waste audits within the Central Bicol State University of Agriculture – Pasacao Campus.

Limitations of the Study - The study was limited to the Central Bicol State University of Agriculture (CBSUA) Pasacao Campus and specifically focused on four identified areas: the Recreational Zone, Academic Zone A, Study Activity Zone, and the Academic Zone B landmark. The research covered only the types, volume, and sources of solid waste generated in these areas during the period of September 15 to November 9, 2025. The waste audit and Materials Recovery Facility collection did not include liquid waste or waste generated outside the mentioned areas. Likewise, the study did not evaluate waste produced by nearby communities or commercial establishments outside the campus. The findings were used strictly as a basis for developing school-based waste reduction strategies and did not fully represent broader environmental conditions beyond the campus.

Theoretical Framework - The theoretical framework integrated three complementary theories to form a holistic model for understanding and promoting environmental stewardship. At its foundation lay the Value-Belief-Norm (VBN) Theory, which explained the individual's internal motivation for action. It posited that personal values (such as caring for the natural world) shaped beliefs about environmental threats and one's responsibility to address them, ultimately activating a personal moral obligation or norm to act. This internal normative foundation was necessary but not sufficient for sustained change. To translate this motivation into capability and learned behavior, the framework incorporated Social Cognitive Theory (SCT). SCT emphasized that individuals learned and built self-efficacy, the belief in their own ability to make a difference through observation, social modeling, and experience. In the context of environmentalism, this meant that seeing others engage in sustainable practices and receiving supportive feedback strengthened one's confidence to act on personal norms. Additionally, the VBN component can be operationalized in the study through the assessment of students' and stakeholders' environmental values, awareness of consequences, and sense of responsibility toward waste management practices. This allows the framework to connect abstract moral drivers with measurable attitudes and behavioral intentions within the school setting.

However, individual motivation and capability were embedded within a social context. This was where the Community of Practice (CoP) concept completed the framework. It provided the social structure in which sustained learning and action occurred. Within a CoP, members united by a shared concern for sustainability engaged in joint activities, developed a shared repertoire of practices, and collectively negotiated what it meant to be an environmental steward. This community reinforced the norms from VBN theory and served as the primary social arena for the observational learning and modeling central to SCT. Ultimately, the framework illustrated a dynamic cycle: personal norms motivated engagement in social learning, which built efficacy and skills within a supportive community, and this communal participation in turn strengthened and validated the individual's initial values and beliefs, leading to deeper, more resilient pro-environmental behavior.

Furthermore, the integration of these theories supports the implementation of school-based interventions such as peer-led waste management initiatives, collaborative learning activities, and participatory decision-making in the design and operation of the Material Recovery Facility (MRF). The framework also acknowledges the role of institutional support, policies, and environmental education programs in reinforcing both individual and collective behaviors. By aligning internal motivations, learned competencies, and social engagement, the theoretical framework ensures a comprehensive approach to fostering long-term behavioral change and sustainable waste management practices within the school community.

2. Methodology

Research Design - The study employed a quantitative descriptive research design. This design was appropriate for measuring and describing the types, composition, and volume of waste generated within the selected areas of the campus. It allowed for the systematic collection of numerical data to characterize the waste stream and identify patterns, which subsequently served as the empirical basis for proposing waste reduction strategies and MRF design improvements.

Research Method - The study utilized the descriptive method of research. Data were collected through a direct

Waste Analysis and Characterization Study (WACS), using a standardized log sheet. This method enabled the researchers to quantify and classify the waste into specific categories. The data gathered provided measurable and objective data on the university's waste generation, forming a solid foundation for evidence-based recommendations.

Sampling Area - The population of the study comprised all the waste generated within the Bicol State University of Agriculture - Pasacao Campus. To ensure a representative sample of the campus's diverse waste stream, a stratified random sampling technique was employed. The population was divided into four strata (stations) based on their distinct functions and user activity: Station 1: Recreational Zone, Station 2: Academic Zone A, Station 3: Study Activity Zone, Station 4: Academic Zone B. Waste was collected from each of these stations throughout the study period to ensure data comprehensively reflected the waste profile of different campus zones.

Data Gathering Procedure - A permit to conduct the study was secured from the Campus Administration. The university's utility personnel and the head of the Environmental Management Office were coordinated to ensure smooth implementation. For eight weeks, from September 22 to November 10, 2025, waste was collected every Monday from the pre-identified bins in each of the four stations. The collected waste from each station was transported to a designated sorting area. The waste was manually sorted into the pre-defined categories (biodegradable, recyclable, residual, special waste). Each category was weighed using a weighing scale, and the data was recorded in a WACS log sheet. The weight (in kilograms) of each waste category per station was meticulously recorded weekly. After the collection period, all data were compiled, tabulated, and subjected to statistical analysis to identify trends, compositions, and significant differences.

Statistical Treatment of Data - To facilitate the analysis and interpretation of gathered data, the study used mean, percentage technique, and ANOVA. All calculations were performed using an electronic calculator, a mobile phone, and online applications, specifically in Excel.

- Mean: A quantity that has a value intermediate between those of the extreme members of some set. This was used to determine the average of the waste generated at Central Bicol State University of Agriculture - Pasacao Campus.
- Percentage: A relative value indicating hundredths parts of any quantity. This was used to determine the percentage composition of different waste types (biodegradable, recyclable, residual, hazardous waste, etc.).
- ANOVA (Analysis of Variance): This statistical procedure was used to compare the means of the four groups. It helped identify if a significant difference existed in the composition and quantity of waste generated from four specific locations.

Ethical Consideration - The researchers adhered to strict ethical and safety protocols throughout the study. The handling of waste materials was conducted with care, and personal protective equipment (PPE) such as gloves and masks was used at all times during sorting. The data gathered was used solely for the purpose of this academic research. Furthermore, the study was conducted in compliance with university policies and relevant environmental laws, particularly RA 9003 (Ecological Solid Waste Management Act of 2000).

3. Results and Discussions

3.1 Waste Identification and Quantification

The study conducted a hands-on Waste Analysis and Characterization Study (WACS), involving the systematic collection, sorting, and weighing of solid waste at the Material Recovery Facility (MRF). Data were gathered on September 18, 2025, and from September 22 to November 10, 2025, across four campus locations: Recreational Zone, Academic Zone A, Academic Zone B, and the Study Activity Zone of Central Bicol State

University of Agriculture – Pasacao Campus. Table 1 presents the WACS results from the MRF as of September 18, 2025.

Table 1
Material Recovery Facility (MRF) baseline data collected.

Waste Classification	Weight (kg)	Percentage (%)	Rank
Recyclable	51.75 kg	63.303 %	1st
Residual Waste for Disposal	24 kg	29.358 %	2nd
Special Waste	6 kg	7.339 %	3rd
Total	81.75 kg	100.000 %	

Note. Values represent the baseline weight and percentage composition of waste collected at the MRF on September 18, 2025, with rankings indicating each waste type’s relative contribution.

The data show that recyclable waste was the largest component, totaling 51.75 kg (63.303%) and ranking first. This included paper (SWL: 10.75 kg, OCC: 6 kg, mixed paper: 3.5 kg), plastics (HDPE rigid: 1 kg, PVC: 5 g, LDPE rigid: 1.45 kg, PP rigid: 1.25 kg, polystyrene: 11.75 kg, others: 2.75 kg), and plastic bags (HDPE: 1 kg, MLL: 1.75 kg). Additional recyclables included clear glass (6.25 kg) and tin (4.25 kg). The total waste collected at the MRF was 81.75 kg. Residual waste ranked second at 24 kg (29.358%), consisting mainly of heavily soiled paper (23.50 kg) and worn-out leather (0.5 kg). Special waste was the least generated at 6 kg (7.339%), including air fresheners (4.25 kg) and cosmetic waste (1.75 kg). The high proportion of recyclables, particularly plastics like polystyrene, reflects common waste patterns in educational institutions, where single-use packaging is prevalent. Meanwhile, the significant residual waste highlights issues with contamination, which limits recyclability. The presence of special waste also indicates a need for proper disposal awareness. Overall, the results suggest strong potential for waste reduction through improved segregation, reduced polystyrene use, and enhanced recycling practices on campus.

Table 2 presents the Waste Analysis and Characterization Study (WACS) data collected from four campus locations: Recreational Zone, Academic Zone A, Academic Zone B, and the Study Activity Zone. Data were gathered every Monday from September 22 to November 10, 2025.

Table 2
Overall waste collected in Recreational Zone, Academic Zone A, Academic Zone B, and the Study Activity Zone.

WASTE CLASSIFICATION	WEIGHT (KG)	PERCENTAGE (%)	RANK
Recyclable	82.80 kg	51.72 %	1st
Residual Waste for Disposal	62.87 kg	39.26 %	2nd
Biodegradable	13.95 kg	8.71 %	3rd
Residual with Potential for Recycling	0.50 kg	0.31 %	4th
Total	160.12 kg	100 %	

LOCATION	WASTE CLASSIFICATION	WEIGHT (kg)	PERCENTAGE (%)	RANK
Recreational Zone	Residual Waste for Disposal	9.55kg	56.133%	1st
	Recyclable	6.2kg	38.390%	2nd
	Biodegradable	0.4kg	2.477%	3rd
	Total	16.15kg	100%	
Academic Zone A	Recyclable	35.6kg	52.146%	1st
	Residual Waste for Disposal	23.07kg	33.792%	2nd
	Biodegradable	9.1kg	13.329%	3rd
	Residual with Potential for Recycling	0.5kg	0.732%	4th
Academic Zone B	Total	68.27kg	100%	
	Recyclable	12.8kg	56.763%	1st
	Residual Waste for Disposal	7.7kg	34.146%	2nd
	Biodegradable	2.05kg	9.091%	3rd
Total	22.55kg	100%		

Study Activity Zone	Recyclable	28.2kg	53.057%	1st
	Residual Waste for Disposal	22.55kg	42.427%	2nd
	Biodegradable	2.4kg	4.516%	3rd
	Total	53.15kg	100%	

Note. Values represent the total weight and percentage distribution of waste collected across the Recreational Zone, Academic Zone A, Academic Zone B, and Study Activity Zone from September 22 to November 10, 2025.

The data show that recyclables ranked first, contributing 82.80 kg (51.72%) of total campus waste. The highest amounts came from Academic Zone A (35.6 kg), followed by the Study Activity Zone (28.2 kg), Academic Zone B (12.8 kg), and the Recreational Zone (6.2 kg). This indicates that areas with higher academic and administrative activity generate more recyclable materials, such as paper, plastics, and metals. Residual waste ranked second at 62.87 kg (39.26%), with Academic Zone A (23.065 kg) and the Study Activity Zone (22.55 kg) as the main contributors. This suggests the need for improved waste segregation and the reduction of single-use materials. Biodegradable waste ranked third, totaling 13.95 kg (8.71%), mostly from Academic Zone A (9.1 kg). Its relatively low share may indicate limited food-related waste or under-collection of biodegradable materials. The least generated was residual waste with potential for recycling, at 0.50 kg (0.31%), recorded only in Academic Zone A. This minimal amount suggests generally effective sorting, though awareness can still be improved to prevent recyclables from being misclassified as residual waste.

The dominance of recyclable waste aligns with previous studies indicating that academic institutions generate large amounts of paper, plastics, and metals from routine activities. Residual waste ranked second, indicating the continued presence of mixed and non-recoverable materials and suggesting gaps in proper segregation practices. Special waste was observed only at the MRF and not in the four campus locations, implying that hazardous materials are either minimally generated or properly centralized in designated storage areas, consistent with national waste management guidelines. Biodegradable waste accounted for 13.95 kg (8.71%), a relatively small share, which may reflect limited food-related activities or gaps in organic waste collection. Residual waste with potential for recycling was the least recorded (0.50 kg or 0.31%), indicating generally effective sorting but also highlighting the need to prevent misclassification of recyclables.

Differences in waste distribution are evident. Ador et al. (2025) found biodegradable waste to be dominant (42.01%), while this study identified recyclables as the largest share (51.72%). This variation is likely due to differences in sampling areas and timing. Ador et al. focused on common areas during event-heavy months, capturing spikes in biodegradable waste. In contrast, this study covered multiple zones over a longer period, reflecting more consistent recyclable outputs. These findings are complementary rather than contradictory. Ador et al. captured event-driven organic waste increases, while the present study highlights the steady generation of recyclables. Together, they indicate a dual waste management need: handling occasional biodegradable surges and continuously recovering recyclable materials. This supports targeted strategies, such as establishing an Income-Generating Project (IGP) for recyclables while maintaining systems for managing organic waste during peak periods.

3.2 Comparative Analysis of Waste Generation Across Designated Locations

The comparative analysis across campus locations shows that waste generation varies by function and activity. ANOVA results (Table 3) further confirm that waste types differ significantly ($p = 0.000755645 < 0.05$), while differences in total waste across locations are only marginally significant ($p = 0.051986354 > 0.05$). This suggests that waste composition varies more strongly by type than by location, guiding the need for category-specific management strategies.

The ANOVA results in Table 3 show that waste classification significantly affects waste generation, with a p-value of 0.000755645 (< 0.05). This indicates that some waste types are consistently produced in larger amounts than others, largely due to common daily activities such as food consumption and packaging use. In contrast,

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differences in total waste across the four campus locations are not statistically significant ($p = 0.051986354 > 0.05$). This suggests that overall waste generation is relatively similar among the areas, likely due to comparable population sizes, functions, and waste management practices.

Table 3
Analysis of Variance (ANOVA)

	Source of Variation	SS	df	MS	F	P-value	F crit	Interpretation
Waste Classification	Rows	1468.835	4	367.208	10.26330058	0.00075564	3.2591667	Significant
	Columns	369.0309	3	123.0102946	3.438077224	0.05198635	3.4902948	Non-significant
	Error	429.3457	12	35.778805				
	Total	2267.211	19					

Note. Values present the results of the Analysis of Variance (ANOVA) used to determine significant differences in waste generation by classification and campus area at a 0.05 level of significance.

Overall, the findings indicate that variation in waste is driven more by type than by location. Therefore, waste management strategies should focus on reducing high-volume waste categories rather than prioritizing specific areas, enabling more effective and targeted waste reduction efforts. Both table 1 and 2 consistently show that recyclables are the predominant waste type across the MRF and all campus zones. This pattern is supported by a comparable study by Ador et al. (2025), which reported similar statistical results ($F = 13.50, p < 0.05$), confirming that waste type is a significant factor in campus waste generation.

3.3 Evidence-Based Recommendations for a Functional Material Recovery Facility (MRF) Design

The proposed Materials Recovery Facility (MRF) Ground Floor Plan (Figure 1) translates waste audit findings into a functional, evidence-based design for CBSUA–Pasacao Campus. It applies the principle that effective waste management should be based on localized data rather than general assumptions. The design is directly informed by the campus waste profile, where recyclables dominate (63.30% in the MRF; 51.72% across campus), followed by residual (29.36%) and special waste (7.34%). High volumes of paper and plastic bottles guided the proportional allocation of space.



Figure 1. proposed Material Recovery Facility (MRF)

The layout follows a zoning-based system for efficient waste flow. It begins with a Receiving Area for initial waste intake, followed by a centrally located Sorting Area to minimize handling and improve workflow. Surrounding this are designated storage zones sized according to waste type. The Recyclable Area occupies the largest space, reflecting its high volume. It is strategically placed near the facility entrance to allow easy access for collection and transport, reducing handling time and improving operational efficiency. The design improves safety and efficiency through a dedicated entrance and exit system for collectors in the Recyclable Area. A one-way traffic flow allows vehicles to enter, load materials, and exit without reversing, reducing congestion and accident risks while ensuring smoother operations. This system also prevents interference with other facility activities. Adjacent to this is the Residual Waste Area, sized for the 29.36% waste share, and a Biodegradable Area to support future composting of the 13.95 kg organic waste identified on campus. A secure Special Waste Room is included for hazardous materials such as air fresheners and cosmetic waste.

Additional features include a handwashing area, controlled access points, and a main gate to regulate movement and maintain hygiene and safety. The MRF elevation design highlights structural and functional elements, including proper ventilation, natural lighting, and a durable 150 mm concrete slab foundation. The roof and overall structure are designed to suit local climate conditions while ensuring safe and efficient operations. The proposed design directly translates the quantitative findings from Tables 1 and 2 into a functional, evidence-based MRF layout. The large volume of recyclable waste (51.75 kg) is reflected in a prominent Recyclable Area with dedicated entrance and exit gates for efficient collection and transport. The 6 kg of special waste is addressed through a secure Hazardous Area Facility located near the laboratory, while the 13.95 kg of biodegradable waste supports the inclusion of a composting drum in the garden for fertilizer use. Each design element is grounded in actual data and aligned with campus operations, safety needs, and spatial context. Zone-specific results further justify the design, with high recyclable outputs from Academic Zone A, Study Activity Zone, and Academic Zone B supporting expanded storage and collector access. The ANOVA results ($F = 13.50$, $p < 0.05$) confirm significant differences among waste types, reinforcing the need for category-specific facilities rather than a single undifferentiated structure.

The design also reflects key theoretical frameworks by linking environmental awareness to practical action through accessible and safe infrastructure. It supports compliance with Republic Act 9003 by promoting proper waste segregation, safe handling of hazardous materials, and resource recovery through composting. Operationally, the layout strengthens the proposed Income-Generating Project (IGP) by enabling efficient handling and transport of recyclables, reducing delays, and improving market readiness. Finally, the design contributes to broader sustainability goals, including responsible consumption, climate action, and safe working conditions. It serves as a practical, replicable model for integrating waste management, safety, and sustainability in educational institutions.

4. Conclusion

Recyclables make up the largest share of waste (63.30% at the MRF; 51.72% at sampled locations), mainly paper and plastics, with polystyrene as a major component. Residual waste is the second-largest stream (29.36% at the MRF; 39.26% at sampled locations). Biodegradable and special wastes are smaller but still significant. The Academic Zone A and the Study Activity Zone generate the most recyclable and residual waste. Statistical analysis (ANOVA) showed that waste types differ significantly in quantity. However, total waste amounts across the four campus locations were not significantly different, though a slight variation was observed.

The Material Recovery Facility (MRF) design recommendations were based directly on waste audit data, translating findings into practical architectural and infrastructure solutions. The audit identified recyclables as the dominant waste type (51.75 kg or 63.30%), followed by residual waste (24 kg or 29.36%) and special waste (6 kg or 7.34%). Detailed inventory data, such as 128.5 kg of unshredded paper, 98.35 kg of plastic bottles, 35.5 kg of shredded paper, and 33.45 kg of single-use plastics and non-recyclables, guided the sizing and layout of storage areas in the proposed facility.

The findings of the study highlight the practical value of adopting a data-driven approach to effectively address significant waste generation. By establishing that recyclables constitute the majority of the campus waste stream (up to 63.30%), the findings provide a critical empirical foundation for the Environmental Management Office to craft targeted policies and for utility personnel to optimize collection efficiency. For students, the study fosters environmental awareness and responsibility, and develops practical skills through active participation in sustainable practices. At the institutional level, the findings serve as a baseline for policy development, enabling schools to design efficient, context-specific Materials Recovery Facilities (MRFs), reduce waste disposal costs, and explore income-generating opportunities from recyclables. This systematic approach not only ensures compliance with RA 9003 but also fosters a sustainable "Community of Practice" in which evidence-based infrastructure and peer-led initiatives collectively empower stakeholders as active agents of environmental change. Overall, the study reinforces the role of schools as active agents in promoting sustainability and environmental stewardship.

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