Institutional Dynamics of Waste Generation and Sustainability Policy in a State University

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ABSTRACT

Waste generation in higher education institutions (HEIs) reflects their academic, administrative, and operational dynamics. This study examined waste generation trends, classification practices, and institutional responses at Bukidnon State University (BukSU) from 2022 to 2024 to inform policy and management decisions. Using a quantitative-descriptive research design, monthly waste records were examined across four categories: biodegradable, non-biodegradable, recyclable, and hazardous. Results showed a marked increase from 60,328 kg in 2022 to 113,062 kg in 2023, followed by a decline in 2024, which may indicate the initial impact of BukSU's sustainability interventions. While biodegradable waste rose sharply, improvements were noted in recyclable and hazardous waste tracking. Document analysis revealed data inconsistencies, weak enforcement mechanisms, and limited integration of waste management into institutional planning. The study highlights the need for BukSU to strengthen policy implementation, institutionalize data-driven monitoring, and integrate waste management into its broader sustainability agenda.

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INTRODUCTION

Waste generation in higher education institutions (HEIs) poses complex challenges due to the diversity of academic, administrative, and research activities that produce varying waste streams. Understanding these dynamics requires an integrated approach that examines not only material flows but also institutional behaviors and governance systems. The present study examined the waste generation patterns of a public HEI in the Philippines to develop evidence-based strategies for sustainable campus waste management.

The circular economy (CE) framework provides the foundation for reducing material throughput by emphasizing resource efficiency through reduction, reuse, and recycling (Giurea et al., 2024). Within HEIs, the CE approach encourages designing processes that extend product lifecycles, minimize resource extraction, and foster a culture of environmental responsibility (Rosario et al., 2024). Complementing this, systems thinking provides a dynamic lens that highlights interconnections and feedback loops across institutional operations. For instance, improved waste monitoring can generate data that feedback into policy adjustments, staff training, and procurement decisions, thereby reinforcing sustainable practices (Enad et al., 2025; Mukhlis et al., 2025). Meanwhile, institutional theory explains how organizational norms, structures, and values shape sustainability behaviors. It underscores that policy implementation depends not only on formal regulations but also on the alignment of institutional culture and stakeholder participation (Rodríguez-Guerreiro et al., 2024). Understanding these institutional dynamics is crucial for designing interventions that align with the organization's values and operational realities.

These three frameworks converge to provide an integrated analytical foundation for this study. The circular economy offers direction for material flow optimization, systems thinking operationalizes interdependencies and feedback mechanisms, and institutional theory situates these processes within BukSU's governance and behavioral context. Together, they enable a comprehensive examination of how structural, procedural, and cultural dimensions influence waste management outcomes in the university setting.

Globally, HEIs are evaluated for their

contribution to sustainability through initiatives aligned with the United Nations Sustainable Development Goals (SDGs), particularly SDG 12: Responsible Consumption and Production. Frameworks such as the Times Higher Education (THE) Impact Rankings and UI Green Metric World University Rankings assess performance based on waste management systems, recycling programs, and efficient resource utilization.

In the Philippine context, waste management is guided by Republic Act No. 9003, the Ecological Solid Waste Management Act of 2000, implemented by the Environmental Management Bureau (EMB) of the Department of Environment and Natural Resources (DENR). Aligned with this national directive, Bukidnon State University (BukSU) has adopted its Policy Guidelines on the Implementation of Zero Waste Management, which promotes systematic segregation, stakeholder engagement, capacity-building, and infrastructure development.

Anchored in the integration of circular economy, systems thinking, and institutional theory, this study analyzes waste generation data from 2022 to 2024 to identify temporal trends, assess existing segregation systems, and examine stakeholder perspectives. The findings aim to strengthen institutional sustainability practices and contribute to the broader discourse on responsible resource management in higher education.

METHODS

Study Design and Setting

This study employed a quantitative-descriptive design, supplemented by document analysis, to examine institutional waste management patterns at BukSU. The approach was appropriate for documenting waste generation trends and providing empirical evidence to support institutional decision-making and policy refinement rather than hypothesis testing.

The research covered the period January 2022 to December 2024, capturing both pre-and post-implementation phases of the university's Zero Waste Management Guidelines. BukSU, a state-funded higher education institution located in Malaybalay City, Bukidnon, Philippines, manages its institutional waste through Solid Waste Section under the General Services Unit. Data were gathered from multiple campus zones, including academic buildings, administrative offices, and common service areas, to capture variation in waste sources.

Study Variables and Data Sources

The primary variables included monthly waste volume, waste type, waste source zone, and university population. The monthly waste volume refers to the total weight (in kg) of solid waste collected each month from January 2022 to December 2024. The waste type classifications were based on standards from both the university and the city's local government.

These include the (a) biodegradable waste: organic materials that naturally decompose, such as food scraps, paper, and garden; (b) non-biodegradable waste: materials that do not easily break down in the environment, including plastics, synthetic packaging, and residual materials; (c) hazardous waste: potentially harmful materials requiring special handling, such as used chemicals, laboratory waste, or medical waste; and (d) recyclable waste: items than can be processed and reused, such as plastics, metals, paper, and certain types of glass.

The waste source zone indicates the area of waste origin within the campus, classified as academic, administrative or mixed-use zones. This classification helps identify waste intensity by function and location.

The university population data, including student and personnel headcounts, were sourced from the Human Resource Management Unit and University Registrar. These were used to normalize waste output and calculate per capita generation across the study period.

Data Collection and Validation

Monthly waste weights were obtained on official weighing logs maintained by the Solid Waste Section. These were cross-checked and verified by General Services personnel before encoding into the official waste monitoring register. In cases of discrepancy, entries were validated against waste collection receipts or reweighing reports. Documentary sources, including implementation reports, memoranda on waste segregation, and recycling inventory records, were retrieved from the Administrative Services Division through authorized access.

Data Analysis

Quantitative data were encoded and analyzed using Microsoft Excel to compute totals, means, and percentage distributions of monthly waste generation by type and source zone. Descriptive rather than inferential statistics were applied, aligning with the study's operational monitoring objectives. Population normalization enabled per capita computation, while graphical analyses illustrated trends and seasonal fluctuations.

Ethical Considerations

The study utilized only institutional administrative and operational records, without direct involvement of human participants. Hence, it was exempt from formal ethical clearance. Nevertheless, all data were handled following university confidentiality protocols and the Data Privacy Act of 2012 (Republic Act No. 10173, 2012), ensuring the responsible use and protection of institutional information.

RESULTS

Waste Generated by BuKSU (2022–2024)

From 2022 to 2024, BukSU generated a total of 277,931 kg of solid waste, reflecting notable fluctuations across the three-year period. As shown in Figure 1, waste generation nearly doubled in 2023, reaching 113,062 kg compared to 60,328 kg in 2022, which served as the baseline year with lower operational activity. This 87.40% increase corresponds with the full resumption of on-site classes, campus events, and construction projects following pandemic restrictions. In 2024, the total waste volume declined slightly to 104,541 kg, marking a 7.5% reduction from the previous year. Despite this decrease, the level remained 73% higher than in 2022, indicating that institutional operations had stabilized at a higher baseline of activity. The modest decline in 2024 may reflect the initial effects of strengthened sustainability interventions, such as reinforced waste segregation protocols and reduced single-use plastic consumption. Overall, the three-year trend shows an upward trajectory peaking in 2023, followed by early signs of improvement toward more efficient waste management.

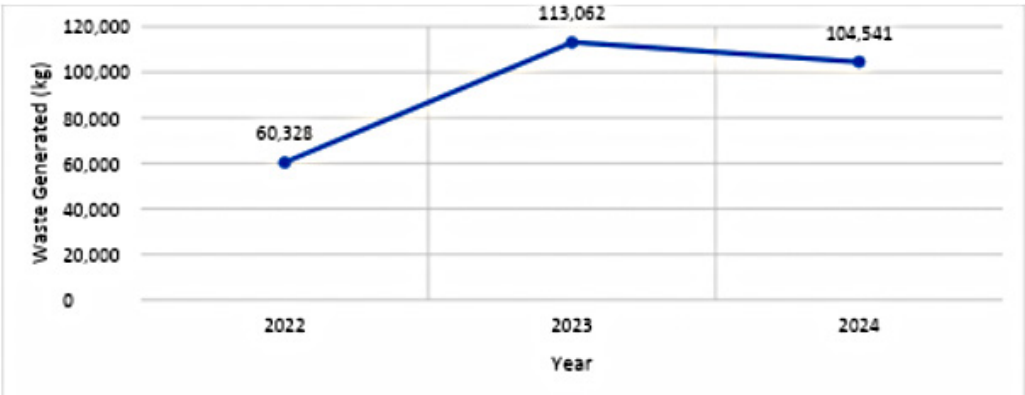
Classification of Waste (2022-2024)

Table 1 presents the annual totals of waste generated by classification from 2022 to 2024. Biodegradable waste consistently dominated the waste profile, comprising 52-69% of total output. Its volume rose sharply from 30,010 kg in 2022 to 78,163 kg in 2023, a 160% increase that coincided with the full reopening of campus facilities and canteen operations. In 2024, biodegradable waste declined to 64,886 kg, representing a 17% decrease from 2023 but still 116% higher than the 2022 baseline-suggesting initial success of enhanced composting and segregation practices under the Zero Waste Management Guidelines.

Hazardous waste data were first recorded in 2023 (57 kg) and remained nearly constant in 2024 (55 kg), reflecting consistent monitoring but minimal generation. Non-biodegradable waste peaked at 34,842 kg in 2023 before dropping to 24,854 kg in 2024, a 28.70% reduction, possibly linked to reduced plastic packaging and better waste sorting. The 2022 total of 30,318 kg for this category included recyclables, limiting direct comparison.

Importantly, recyclable waste emerged as a distinct tracked category only in 2024 (366 kg), a positive indicator of improved waste segregation and recordkeeping. This refinement in data collection demonstrates the university's

Figure 1
Three-year Monthly Waste Collection



progressing capacity for systematic waste monitoring and evidence-based sustainability management.

Table 1
Total Weight of Biodegradable, Hazardous, Non-Biodegradable, and Recyclable Waste Collected per Year

Year	Biodegradable (kg)	Hazardous (kg)	Non-Biodegradable (kg)	Recyclable (kg)
2022	30,010	–	30,318*	–
2023	78,163	57	34,842*	–
2024	64,886	55	24,854	366
Mean	57,686	56	30,005	366
Standard Deviation (SD)	19,875	1.15	4,989	--
% Change (2024 vs 2022)	+116%	--	-18%	---

**Includes recyclables*

Three-Year Monthly Waste Collection Trends (2022-2024)

Figure 2 illustrates the monthly waste collection trends from 2022 to 2024, with each year represented by distinct color lines. In 2022 (blue line), waste generation remained relatively stable and low, averaging 5,000–6,000 kg/month, with minor increases in March and August likely associated with key academic activities. This year reflects a baseline period of limited waste output. In contrast, 2023 (orange line) shows pronounced fluctuations, with sharp peaks in May (14,500+ kg) and October (13,000+ kg) and a notable dip in July. This volatility corresponds with the resumption of full on-site operations and large-scale campus events following pandemic restrictions, resulting in the highest overall waste generation across the three years.

By 2024 (gray line), the trend demonstrates greater stability and lower monthly variation. Moderate peaks remain in May and October, yet overall waste levels are reduced compared to 2023. This pattern suggests the emerging impact of strengthened segregation practices, policy enforcement, and institutional awareness campaigns under the university's sustainability initiatives.

Figure 3 shows the monthly waste collection trends for 2022, the study's baseline year. Waste generation ranged from 4,000 to 6,000 kg/month, showing low variability. March and September had the highest collection volumes (~6,000+ kg), while June and December showed the lowest (~4,000 kg). The linear trendline ($y = 31.993x + 4819.4$) has a slight upward slope, indicating a modest increase over time. Waste volume remained relatively stable and manageable, especially when compared to the sharp spikes in 2023 and 2024. This year serves as a baseline for evaluating the impact of future interventions. The equation implies an average increase of ~32 kg of waste per month, starting from a base level of ~4,819 kg. This gradual rise provides a useful benchmark for forecasting or planning waste infrastructure if operations remained at 2022 levels.

Figure 2
Three-year Monthly Waste Collection

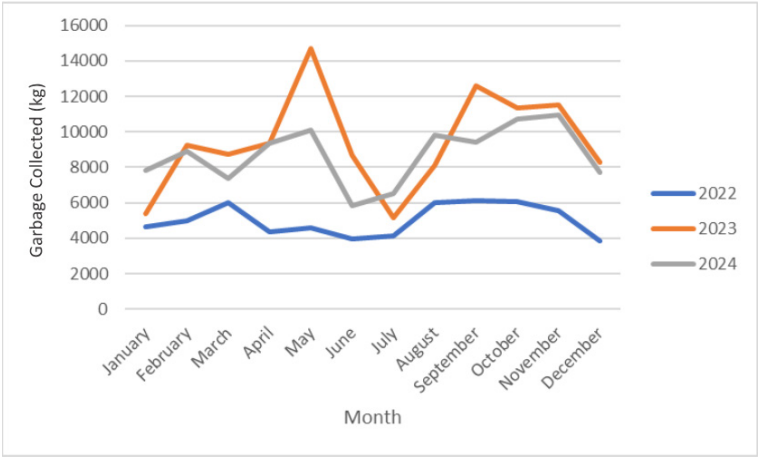
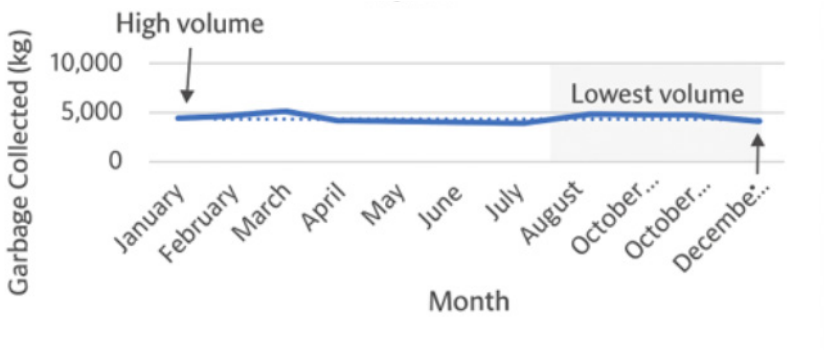


Figure 3
Monthly Waste Collection for the Year 2022



Throughout 2023 (Figure 4), the amount of garbage collected varied notably from month to month. In January, roughly 5,500 kg were gathered, followed by a noticeable rise in February, reaching about 9,000 kg. March saw a slight decline to around 8,750 kg, but the numbers picked up again in April with an estimated 9,500 kg. May recorded the peak collection for the year, approaching 15,000 kg. This was followed by a sharp drop in June to approximately 8,500 kg, and July marked the lowest collection point of the year at around 5,250 kg. August saw a moderate increase to 8,000 kg, while September experienced a significant jump to about 12,750 kg. The amount dipped slightly in October to 11,500 kg, then edged up to approximately 11,750 kg in November. Finally, December brought a decrease, with collection totals falling to around 8,250 kg.

The trendline for the garbage collected in 2023 can be represented by the equation:

$$Y = 224.37x + 7963.4 \quad (1)$$

The slope, which is 224.37, indicates that, on average, the amount of garbage collected by BukSU increased by approximately 224.37 kg per month throughout 2023.

Figure 5 shows that the waste collection totals fluctuated over the course of the year, beginning with roughly 7,800 kg collected in January. February saw an increase to about 8,800 kg, but this was followed by a decline in March, when the total dropped to around 7,400 kg. The figures climbed again in April, reaching approximately 9,300 kg, and continued to rise in May to about 10,000 kg. However, June recorded a sharp decrease, with only 5,800 kg collected.

Figure 4
Monthly Waste Collection for the Year 2023

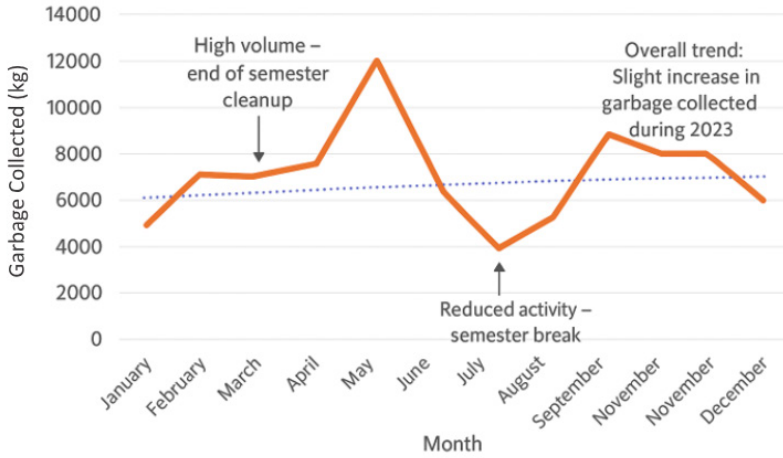
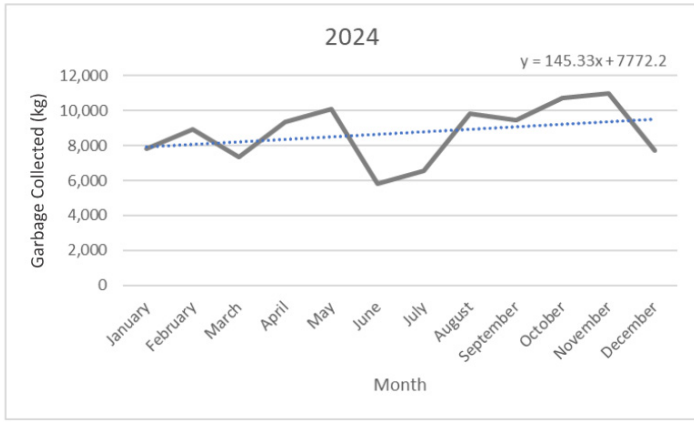


Figure 5
Monthly Waste Collection for the Year 2024



In July, the amount increased slightly to 6,600 kg, before jumping up significantly in August to around 9,800 kg. September brought a modest decline to roughly 9,400 kg, but the total climbed again in October to approximately 10,600 kg. November marked the highest collection of the year, reaching 11,000 kg, before dropping noticeably in December back to about 7,800 kg.

The trendline for the garbage collected in 2023 can be represented by the equation:

$$Y = 145.33x + 7772.2 \quad (2)$$

The slope, which is 145.33, indicates that, on average, the amount of garbage collected by BukSU increased by approximately 145.33 kg per month throughout 2024.

DISCUSSION

Total Waste Generated in Three Years

The three-year waste trends at BukSU reflect how operational resumption and population recovery after the pandemic directly influenced environmental impact. Waste generation rose sharply with the full return face-to-face classes in 2023, driven by increased mobility, food service activity, and administrative functions. Similar post- lockdown surges have been documented in other higher education institutions, where the rapid return

of campus populations often exceeded existing waste handling capacities (Mahyari et al., 2022; Rodriguez-Guerreiro et al., 2024). Evidence from non-Philippine contexts supports this pattern: for example, the study conducted at the Federal University of Technology Akure in Nigeria documented substantial daily waste generation and highlighted how waste composition, collection inefficiencies, and limited infrastructure can challenge sustainability efforts, especially when campus populations increase (Ojuri et al., 2024). Collectively, these findings reinforce that institutional waste levels are closely linked to campus activity intensity and underscore the need for responsive, data-driven waste management systems in post-pandemic university settings.

The moderate decline in 2024 indicates the early influence of internal sustainability initiatives, such as stricter enforcement of segregation guidelines and campus-wide campaigns on reducing single-use plastics. These findings support Klaniecki et al. (2018) and Henao-Rodríguez et al. (2024), who emphasized that consistent policy-driven behavioral interventions are key to achieving sustained waste reduction in higher education institutions. To institutionalize this progress, BukSU should adopt a Five-Year Integrated Waste Management Roadmap (2025-2030) anchored on International Organization for Standardization (ISO) 14001 principles, clearly defining targets for reduction, infrastructure improvement, and behavioral engagement.

Classification of Waste

Shifts in waste composition reveal both changing activity patterns and evolving institutional practices. The spike in biodegradable waste during 2023 coincides with increased food service operations, aligning with Duran-Sandoval et al. (2024), who identified post-pandemic food waste as a dominant contributor in universities. The subsequent decline in 2024 suggests growing adherence to the Zero Waste Management Guidelines and localized composting initiatives.

The documentation of hazardous waste starting 2023, albeit minimal, signifies a strengthening of classification and reporting mechanisms, a trend consistent with Siril et al. (2021) and Hassanvand et al. (2011), who noted that improved monitoring systems often lead to more accurate but low-volume hazardous waste data. Similarly, the separation of recyclable waste as an independent category in 2024 reflects improved data disaggregation, an important advancement noted by Konstantinidou et al. (2024) in effective campus waste systems.

These institutional improvements align with the Malaybalay City Solid Waste Management Ordinance (City Government of Malaybalay, 2018) and barangay-level materials recovery initiatives. Strengthened coordination with the City Environment and Natural Resources Office (CENRO) and local materials recovery facilities (MRFs) will ensure compliance with Republic Act No. 9003, particularly in the diversion of biodegradable and recyclable waste streams.

Three-Year Monthly Waste Collections

The monthly waste data from 2022 to 2024 illustrates how BukSU's waste generation closely follow the rhythm of its academic and operational calendar. Overall, three patterns emerge: a low and stable baseline during restricted operations in 2022, a pronounced surge with full reopening in 2023, and a more balanced distribution in 2024 reflecting initial policy gains.

In 2022, waste generation remained consistently moderate (around 4,000 to 6,000 kg per month), with slight peaks in March and September corresponding to midterm and enrollment periods. This stability reflects limited on-site activity under pandemic-adjusted operations- a pattern also noted in other higher education institutions where hybrid or reduced campus operations led to significantly lower waste outputs (Lopes Silva et al., 2024; Ojuri et al., 2024).

By 2023, the resumption of full in-person classes, major academic events, and facility renovations led to visible fluctuations. Waste volumes spiked sharply in May and October, coinciding with graduation, enrollment, and

university-wide activities, before dropping during the July break. These fluctuations mirror post-lockdown pattern identified in other institutions, where rapid increases in campus activity temporarily strained existing waste-handling systems (Mahyari et al. (2022); Rodriguez-Guerreiro et al., 2024). The steep rise in 2023 also exposed operational gaps, particularly in waste segregation adherence and available storage capacity.

In 2024, monthly variations became less volatile, and waste generation showed a gentler upward slope. While peaks still appeared in May and October, they were substantially lower than in 2023. This smoother pattern suggests that institutional measures, such as reinforced segregation, stricter enforcement of the "No Single-Use Plastic" policy, and enhanced coordination with the Malaybalay City Environment and Natural Resources Office (CENRO), began yielding positive outcomes. The stabilization also aligns with Henao-Rodríguez et al. (2024), who found that continuous institutional monitoring and awareness campaigns foster gradual behavioral adaptation in campus settings.

Taken together, the three-year data demonstrate how academic activity intensity directly drives waste fluctuations, while consistent policy implementation gradually moderates them. BukSU's evolving monthly patterns highlight the value of using waste monitoring as a proxy indicator of institutional sustainability performance. Future monitoring should formalize a monthly verification protocol, where weighing logs are cross-checked by the General Services Unit and encoded into a database, to ensure reliable trend tracking aligned with the Malaybalay City Solid Waste Management Ordinance and RA 9003.

Institutional Implications

The observed waste trends offer concrete insights for refining BukSU's sustainability framework. The increase from 2022 to 2023, followed by a modest decline in 2024, highlights the importance of integrating environmental management into core operations and governance systems. Early interventions, such as the reactivation of the Zero Waste Management Guidelines and the restriction of single-use plastics, are yielding measurable improvements but require institutionalization to ensure long-term impact.

Policy Integration and Governance

Variations across years point to the need for a stronger policy coherence and shared accountability. Establishing a University Solid Waste Management Committee would enhance coordination among the General Services Unit, Administrative Services Division, Environmental Health and Safety Services, and academic departments. Alignment with the Malaybalay City Solid Waste Management Ordinance and Republic Act No. 9003 will also enhance compliance and strengthen partnerships with local authorities. Framing this under the lens of institutional theory, BukSU's transition toward sustainability depends on the consistency and legitimacy of governance structures that formalize environmental stewardship within its operations.

Infrastructure and Resource Management

The dominance of biodegradable waste and the emerging record of recyclables point to opportunities for campus-level circular economy initiatives. Establishing on-site composting and material recovery facilities, supported by digital waste monitoring tools, can reduce landfill dependency while improving the accuracy of reporting. Such systemic improvements respond to the waste trends revealed in the study and are aligned with systems thinking, recognizing that sustainable waste reduction relies on integrated infrastructure, behavioral incentives, and data-informed management.

Capacity Building and Behavioral Change

The reduction of waste generation in 2024 reflects the initial behavioral response to sustainability campaigns and enhanced segregation enforcement. To maintain this progress, BukSU can institutionalize environmental orientation programs for students and personnel, integrate waste reduction

modules into course-based activities, and promote incentive-driven waste minimization through departmental scorecards or recognition systems. These initiatives strengthen the university's contribution to SDG 12 (Responsible Consumption and Production) by embedding sustainability into daily campus culture.

Strategic Planning and Monitoring

To ensure continuity and measurable progress, BukSU should develop a Five-Year Integrated Waste Management Roadmap (2025-2030) anchored on the principles of ISO 14001 Environmental Management Systems. The roadmap should set quantifiable waste reduction targets, outline monitoring indicators, and identify budgetary and policy support mechanisms. Such forward-looking planning transforms the institution's waste management approach from compliance-driven to evidence-based resource stewardship, aligning operational efficiency with environmental responsibility.

CONCLUSION

BukSU's waste management performance from 2022 to 2024 reflects both the challenges of post-pandemic recovery and emerging progress in institutional sustainability. The surge in waste generation during 2023 exposed gaps in segregation and monitoring systems, while the modest reduction in 2024 suggests early gains from improved awareness and policy interventions.

To sustain this progress, the university should institutionalize a Five-Year Waste Management Strategy (2025-2030) anchored on data-driven planning, compliance with the Malaybalay City Solid Waste Ordinance, and integration of waste management into academic and operational systems. This roadmap should establish clear reduction targets, strengthen segregation infrastructure, and formalize monitoring mechanisms.

Equally vital is the active participation of students and campus stakeholders in promoting responsible consumption and circular practices. By combining institutional planning with community engagement, BukSU can advance toward a culture of environmental accountability and position itself as a leading model for sustainable university governance in the region.

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