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Sustainable Proposals and Diagnosis for Solid Waste Management at the Politécnico Campus of UFPR

Diagnóstico e Propostas Sustentáveis para a Gestão de Resíduos Sólidos no Campus Politécnico da UFPR

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Abstract

Solid waste management (SWM) in higher education institutions (HEIs) poses growing challenges due to the complexity of their operations. This study evaluated SWM practices at the Polytechnic Campus of the Federal University of Paraná (UFPR) using a mixed-methods approach, combining 222 questionnaires, technical inspections, informal interviews, document analysis, and benchmarking with national and international universities. Results revealed strong user engagement in waste separation (89.6%), yet persistent issues with infrastructure, signage, irregular collection, and the lack of composting facilities. In 2018, the Catamare cooperative recovered just US$ 10,858 in recyclables, compared to an estimated potential of US$ 657,000 for UFPR, assuming a 40% recovery rate. The unrecovered fraction would also cost approximately US$ 48,288 in landfill fees. In response, a tailored Solid Waste Management Plan (SWMP) and an environmental education guide were developed and implemented through extension courses. An effective SWM system at UFPR requires adequate infrastructure, transparent governance, and sustained educational engagement. These findings position UFPR to become a national reference in university sustainability and contribute meaningfully to Sustainable Development Goals (SDGs) 11 and 12.

Keywords:
Gestão de resíduos sólidos, Sustentabilidade universitária, Educação ambiental, Percepção socioambiental, Resíduos recicláveis.

Resumo

A gestão de resíduos sólidos (GRS) em instituições de ensino superior (IES) apresenta desafios crescentes devido à complexidade de suas operações. Este estudo avaliou as práticas de GRS no Campus Politécnico da Universidade Federal do Paraná (UFPR), por meio de uma abordagem de métodos mistos, combinando 222 questionários, inspeções técnicas, entrevistas informais, análise documental e comparação com universidades nacionais e internacionais. Os resultados revelaram forte engajamento da comunidade na separação de resíduos (89,6%), mas também problemas

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persistentes com infraestrutura, sinalização, coleta irregular e ausência de compostagem. Em 2018, a cooperativa Catamare recuperou apenas US$ 10.858 em recicláveis, frente a um potencial estimado de US$ 657.000 para a UFPR, considerando uma taxa de recuperação de 40%. A fração não recuperada ainda representaria um custo de aproximadamente US$ 48.288 em taxas de aterro. Como resposta, foram elaborados e implementados um Plano de Gerenciamento de Resíduos Sólidos (PGRS) e um guia de educação ambiental, utilizados em cursos de extensão. Um sistema eficaz de GRS na UFPR exige infraestrutura adequada, governança transparente e engajamento educativo contínuo. Esses resultados posicionam a UFPR como potencial referência nacional em sustentabilidade universitária, contribuindo de forma significativa para os Objetivos de Desenvolvimento Sustentável (ODS) 11 e 12.

Palavras-chave:
Gestão de resíduos sólidos, Sustentabilidade universitária, Educação ambiental, Percepção socioambiental, Resíduos recicláveis.

I. INTRODUCTION

Solid waste management (SWM) in higher education institutions (HEIs) poses a growing challenge within the broader context of urban sustainability, particularly in middle-income countries. University campuses concentrate academic, administrative, laboratory, and food service activities that generate diverse and large volumes of waste, with significant potential for material recovery (Zhang et al., 2011; Rodríguez-Guerreiro et al., 2024). International studies show that integrated strategies, combining source separation, composting, and environmental education, can reduce landfill-bound waste by up to 60% (Di Salvatore et al., 2022; Smyth et al., 2010).

In Brazil, although the Law No. 12.305/2010 (National Solid Waste Policy; Brasil, 2010) mandates waste management plans and social inclusion of waste-picker cooperatives, many universities still operate under fragmented and inefficient systems, reflecting a broader national trend (ABREMA, 2023). This is the case of the Federal University of Paraná (UFPR), where the Polytechnic Campus, despite elevated levels of user engagement, faces operational and institutional barriers that hinder the implementation of an effective SWM model. Similar challenges occur globally, as noted by Al-Khatib et al. (2018) in HEIs of the West Bank. Among the main challenges are the lack of an official waste management plan, poorly distributed collection points, inconsistent selective collection, and limited transparency regarding waste destinations.

This scenario is particularly concerning given Article 40 of Federal Decree No. 10.936 (Brasil, 2022), which mandates that federal public institutions implement selective waste collection programs with the inclusion of waste-picker cooperatives (ABREMA, 2023). This aligns with the National Solid Waste Policy's principles of social

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inclusion, shared responsibility, and circular economy. By not fully meeting these requirements, institutions like UFPR risk noncompliance with legal and social responsibilities, especially in promoting inclusive and sustainable recycling within the federal framework.

This study aims to diagnose the SWM system at UFPR's Polytechnic Campus, identify its main weaknesses, and propose sustainable, applicable strategies grounded in institutional data, national and international benchmarks, and principles of circular economy and environmental education.

II. Materials and Methods

This study was conducted at the Polytechnic Campus of the Federal University of Paraná (UFPR), in Curitiba, Brazil, selected for its academic diversity, high population density, and significant solid waste generation. A mixed-methods approach was adopted, combining document analysis, technical field observations, informal interviews, and an online survey. Data collection took place between 2021 and 2023.

The online questionnaire remained open for 30 days, mostly during February 2021, and received 222 responses from students, faculty, and administrative staff. Quantitative data were processed using Excel and Python, while qualitative responses were categorized thematically. Field notes and photographs supplemented the dataset.

Site inspections covered both internal and external campus areas, focusing on waste generation, storage, and collection points. Meetings were held with UFPR's Environmental Management Division (DGA), and institutional documents related to waste management were reviewed. These methods enabled the identification of systemic weaknesses in infrastructure, operational procedures, user practices, and institutional governance.

The study focused on three main waste types: food packaging, academic waste (e.g., paper and pens), and cigarette butts, selected for their volume and symbolic significance. Fundamental issues included insufficient infrastructure, inadequate signage, and low institutional communication. A Solid Waste Management Plan (SWMP) was submitted with recommendations for structural upgrades, composting, educational campaigns, and monitoring tools.

To broaden the context, 63 Freedom of Information (FOI) requests were submitted between 2021 and 2022 via the Brazilian e-SIC platform (https://esic.cgu.gov.br), under the Transparency Law (Complementary Law No. 131/2009; Brasil, 2009). The sample included all federal universities (excluding five still linked to parent institutions), seven state universities in Paraná, and two private institutions. Responses were classified as

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satisfactory, partial, insufficient, or absent, based on criteria such as time coverage (2017–2019), types of waste addressed, population covered, and cost information. Waste categories followed national standards: organic (food and garden waste), recyclable (paper, metal, glass, plastic), non-recyclable (general refuse), hazardous and healthcare waste (NBR 10.004:2004, Classes A, B, and E, per ANVISA RDC No. 222/2018 and CONAMA Resolution No. 358/2005), and miscellaneous (e-waste, furniture, etc.). Due to limited institutional data on staff and graduate students, per capita estimates were based on undergraduate enrollment and regional university distribution.

Economic values related to waste recovery were estimated based on three key parameters: (i) average waste generation of 0.50 kg/person/day (UFPR, 2022), (ii) a potential recovery rate of 40% of total solid waste, based on benchmarks from UNICAMP (Fagnani; Guimarães, 2017) and the Università degli Studi di Milano-Bicocca (Di Salvatore et al., 2022), and (iii) average market values for recyclables in São Paulo in 2024: R$ 0.65/kg for paper/cardboard, R$ 4.20/kg for plastics, and R$ 2.50/kg for metals (Recicla Sampa, 2024).

Additionally, potential savings from avoided landfill disposal were calculated using a cost of R$ 81.08 per ton, as established by the contract of the CONRESOL (Intermunicipal Consortium for Urban Solid Waste Management of the Curitiba Metropolitan Region) for the period between June 2021 and June 2022 (CIM, 2022). Calculations were conducted using Excel spreadsheets and Python scripts, and results were presented as annual estimates by material type.

III. Results and Discussion

Institutional Context and Waste Typology at UFPR's Polytechnic Campus

Higher education institutions (HEIs) generate significant volumes of solid waste due to their academic, administrative, and laboratory activities (Abas et al., 2018; Fagnani; Guimarães, 2017). At the Federal University of Paraná (UFPR), this complexity is intensified by its geographic dispersion across 15 municipalities and a community of approximately 45,000 people, including undergraduates, postgraduates, medical residents, staff, and faculty (UFPR, 2022). This population exceeds 91% of Paraná's municipalities (IBGE; Brasil, 2020a), making waste management comparable to that of a medium-sized city.

In addition to household-like waste (organics, recyclables, and residuals), UFPR produces complex waste from academic and research activities, such as hazardous, healthcare, agroforestry, construction, and chemical laboratory waste. This requires integrated and adaptive waste management systems.

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This study focused on the "Centro Politécnico" Campus, chosen for its academic and operational relevance. It houses UFPR's Environmental Management Division (DGA), key undergraduate programs, research labs, and support units for environmental and health-related waste across the university. The campus reflects UFPR's broader institutional challenges and offers a representative case for evaluating solid waste management (SWM).

As reported at UNICAMP (Fagnani; Guimarães, 2017), UFPR's waste includes recyclables, organics, residuals, and hazardous waste such as chemicals, healthcare residues, and e-waste. Table 1 summarizes the main waste categories based on their composition and treatment needs.

Table 1 – Solid waste typology and user behavior in HEIs.

Waste Type	Description and Observations
Organic Waste (**OW**)	Food scraps, fruit peels, used paper towels, among others, especially in dining areas such as cafeterias and university restaurants
Recyclable Waste (**RW**)	Cardboard and paper; Plastics (e.g., PET bottles, plastic cups, food packaging); Metals such as aluminum cans and metal scraps; and Glass bottles and jars (occasionally)
Rejects (**RJ**)	Waste with no technical or economic feasibility for reuse or recycling. Includes non-recyclable plastics, diapers, greasy paper, or contaminated materials. Contaminated or improperly segregated items that hinder recovery. Hard-to-recycle plastic utensils or organic waste mixed with other materials

Note: Adapted from Mason; Oberender; Brookin (2004); Rodríguez-Guerreiro et al. (2024).

Recyclables are managed by the Catamare Waste Picker Cooperative in alignment with Brazil's National Solid Waste Policy (Brasil, 2010), though this does not reduce institutional costs or fund infrastructure improvements (Boysan et al., 2015). Residuals are collected by the city and landfilled without systematic tracking. Hazardous waste demands specialized treatment. The Polytechnic Campus, located in Curitiba's Jardim das Américas district, reflects a complex waste profile that requires tailored strategies aligned with sustainability goals (UFPR, 2022).

User Profile and Sociodemographic Characteristics of the Campus Community

Data collection was conducted electronically and disseminated voluntarily through administrative channels at UFPR's Polytechnic Campus. The final sample consisted of 222 participants, including undergraduate students from programs such as Engineering, Medicine, Architecture, Nutrition, and Geography; graduate students from stricto sensu programs (e.g., Ecology, Engineering, Computer Science); and faculty and technical-administrative staff from departments such as Biology, Geography, Computer Science, and Pathology. This academic and occupational diversity ensured a representative overview of the campus population (UFPR, 2022).

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The sociodemographic profile (Figure 1) shows a young population: 55.9% of respondents were under 25 years old. Most identified as female (54.1%), single (69.4%), and childless (81.5%). This reflects the typical academic context of Brazilian public universities and suggests high receptivity to environmental education initiatives. All participants had at least some level of higher education, reinforcing the potential for comprehension and adoption of sustainable practices.

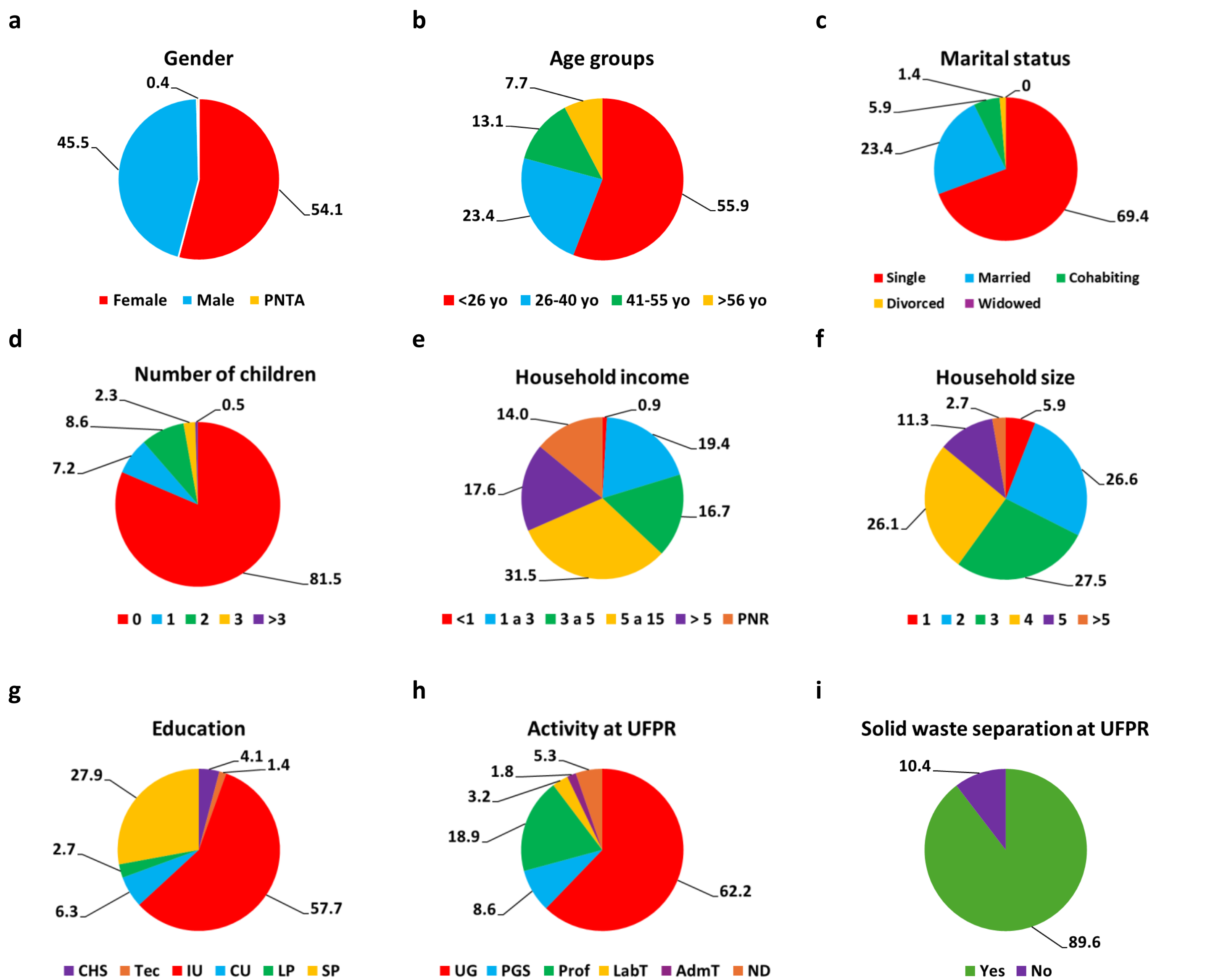

Figure 1 – Sociodemographic profile of respondents (Gender, age, marital status, number of children, income, household size, education, UFPR activity, and waste separation). PNTA = Prefer Not To Answer; CHS = Complete high school, Tec = Technical education, IU = Incomplete undergraduate degree, CU = Complete undergraduate degree, LP = Lato Sensu postgraduate degree (specialization or MBA), SP = Stricto Sensu postgraduate degree (master's, doctorate, post-doc); UG = undergraduate student, PGS = postgraduate student, Prof = professor, LabT = laboratory technician, AdmT = administrative technician, ND = not declared.

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Income data further confirms the representativeness of the sample. Additionally, 73.9% reported living with at least one other person, indicating that awareness campaigns could also influence household behaviors.

While 89.6% stated that they separate their waste, infrastructure deficiencies, such as a lack of well-located or properly labeled bins, and skepticism regarding the fate of collected recyclables limit the effectiveness of these efforts. These findings are consistent with international research (Rugatiri et al., 2021; Haksevenler et al., 2022), which suggests that women and older individuals are more likely to engage in sustainable behaviors, while young, single men are typically less engaged, highlighting the importance of targeted communication strategies.

ENGAGEMENT STRATEGIES BY AGE GROUP AND DEMOGRAPHIC PROFILE

To effectively engage the predominant group of young adult students at UFPR's Polytechnic Campus, communication and outreach strategies should emphasize speed, interactivity, and digital formats (Table 2). These approaches are aligned with the preferences of this demographic, which tends to respond positively to visually appealing, competitive, and technologically integrated tools. In parallel, faculty members and older staff serve as important behavioral role models, reinforcing sustainable practices and contributing to long-term institutional change (Table 3).

Table 2 – Engagement Strategies for Young Adults (18–25 Years).

Strategy Dimension	Description
Digital and Technological	Gamification, social media campaigns, apps, QR codes.
Time-Efficient Activities	Short workshops, fast challenges aligned with class schedules.
Social and Competitive Elements	Points systems, peer competitions, incentive-based games.
Visual and Thematic Content	Appealing graphics addressing issues like climate change or social justice.
Symbolic Incentives	Reusable gifts (e.g., bottles, bags) and digital certificates.

Note: Adapted from Haksevenler et al. (2022); Rugatiri et al. (2021).

Table 3 – Engagement Strategies for Adults Over 40.

Strategy Dimension	Description
Educational Sessions	Talks and workshops demonstrating personal contributions to sustainability.
Community-Based Actions	Volunteer groups and peer initiatives to implement change.
Skill-Based Participation	Activities using life experience (e.g., composting, reuse projects).
Practical Relevance	Emphasis on household savings, environmental improvement, long-term impact.

Note: Adapted from Sánchez-Salinas et al. (2015).

Additionally, since many community members are also parents, environmental education can be extended to their children, fostering awareness from an early age and amplifying positive impacts beyond the university (Table 4).

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Table 4 – Engagement Strategies for Children Through Outreach Programs.

Strategy Dimension	Description
Playful Environmental Learning	Theater, games, storytelling to communicate sustainability.
Family-Inclusive Events	"Green days" and joint parent-child environmental actions.
Child-Friendly Materials	Visual aids, stickers, and labeled bins for easier learning.
Sustainable Play Spaces	Playground areas made with recycled materials and eco-friendly design.

Note: Adapted from Torres-Pereda et al. (2020); Sánchez-Salinas et al. (2015).

Institutional programs must adopt inclusive, multigenerational approaches to ensure long-term engagement. Initiatives such as UAEM's University Environmental Management Program (Sánchez-Salinas et al., 2015) and the campaigns promoted by Mexico's National Institute of Public Health (Torres-Pereda et al., 2020) demonstrate that change in behavior can reach far beyond the campus when supported by structured educational strategies.

These findings confirm the importance of demographic profiling in designing effective waste management interventions. Digital, gamified approaches are more suitable for younger audiences; practical and action-oriented formats appeal more to older adults; and playful, family-integrated formats work best with children. Educational and incentive-based methods have consistently outperformed punitive approaches in changing behavior (Haksevenler et al., 2022; Rugatiri et al., 2021; Valsan et al., 2020).

INFRASTRUCTURE AND OPERATIONAL CHALLENGES IN THE MANAGEMENT OF FOOD-RELATED WASTE

Beyond educational strategies tailored to different demographic profiles, it is essential to consider the physical and operational barriers that hinder the effectiveness of waste management on campus. The following section outlines the main structural and behavioral challenges observed in handling waste generated from food-related and everyday consumption activities.

Food consumption waste is primarily classified as organic or recyclable (Figure 2), often generated from fruits brought from home and snacks wrapped in PVC film, paper bags, aluminum foil, candy wrappers, napkins, and soda cans. There is limited use of plastic straws, foam containers, and disposable cups, suggesting increased environmental awareness, consistent with the high self-reported separation rate (Figure 1).

Glass was not mentioned, which may indicate low usage or failures in user awareness and collection systems. However, given the alcohol ban on campus, its absence is due to reduced availability rather than oversight.

Non-recyclable items like expanded polystyrene and multilayered wrappers should be gradually replaced with compostable or biodegradable alternatives (Abas et al., 2018; Jibril et al., 2012). This is in line with the best

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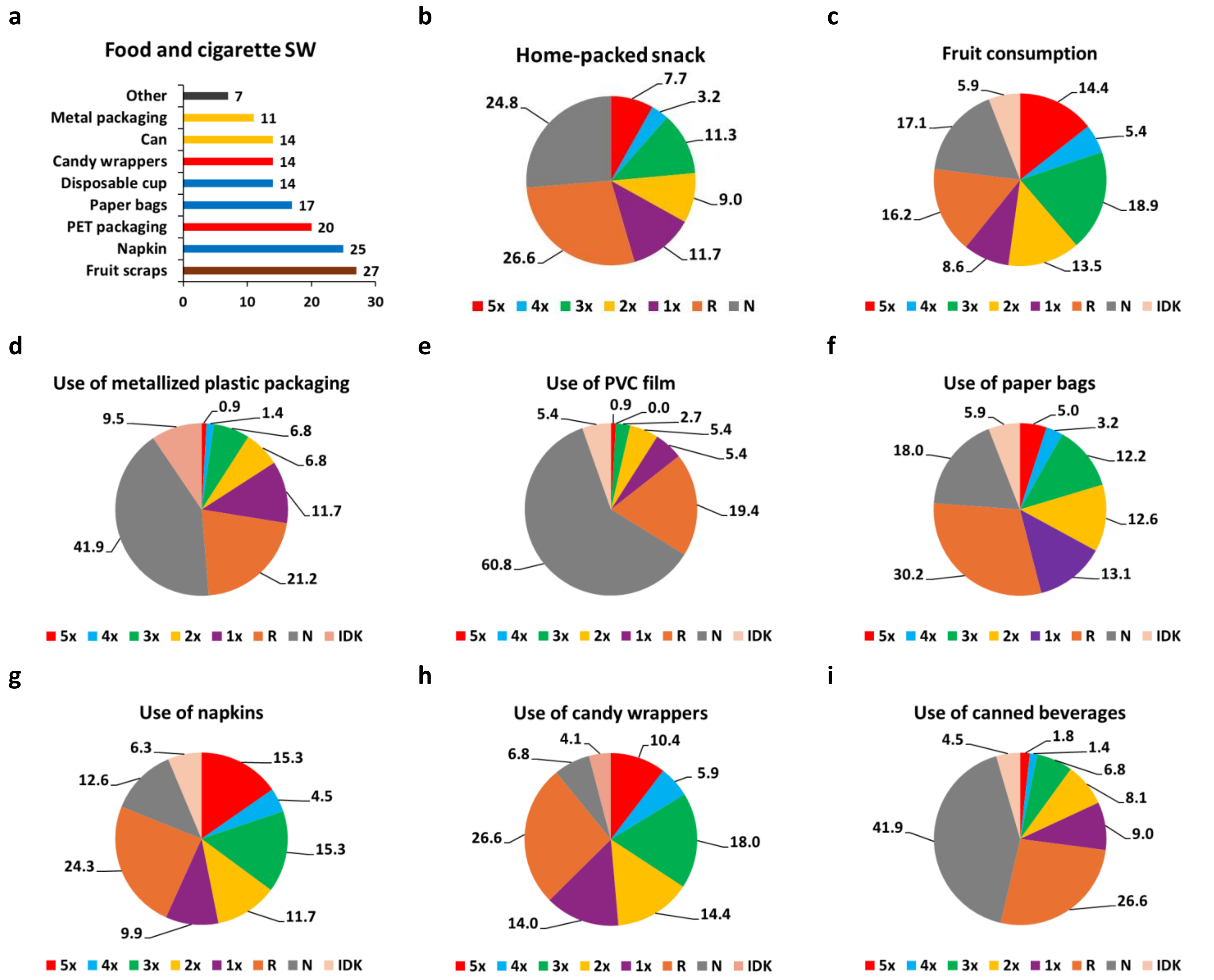
practices observed at INSP and UNBC, where combined infrastructure and outreach strategies helped reduce food-related waste (Torres-Pereda et al., 2020; Smyth et al., 2010).

The declining use of disposables highlights the success of awareness campaigns, especially among young people and women, groups shown to be more responsive to sustainability messaging (Haksevenler et al., 2022; Rugatiri et al., 2021). Still, the ongoing presence of hard-to-recycle items underscores the need for regulatory action and system-wide improvements to ensure lasting results.



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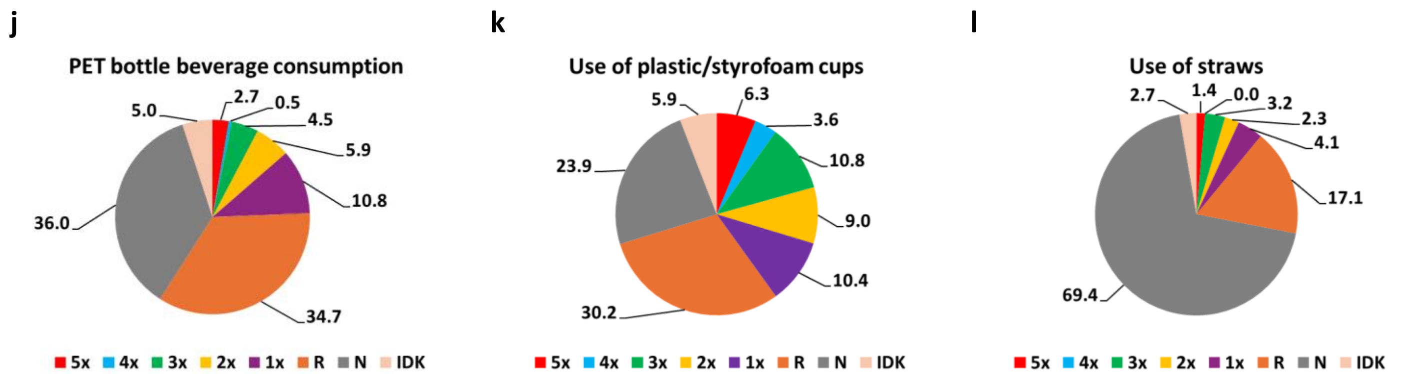

Figure 2 – Waste-related behaviors (Solid waste generated from food and smoke). Note: R = Rarely; N = Never; IDK = I do not know.

FOOD CONSUMPTION AND THE GENERATION OF COMPLEX PACKAGING WASTE

Purchasing snacks with disposable packaging remains common among users of UFPR's Polytechnic Campus (Figure 3), representing a significant source of solid waste, particularly complex plastics, and multilayered packaging, which are difficult to recycle (Jibril et al., 2012). Implementing a composting program like that of Ohio University, which processes over five tons of food waste daily into soil amendments used on campus, could help reduce waste generation while promoting healthier eating habits, demonstrating the synergy between sustainability and public health (Smyth et al., 2010).

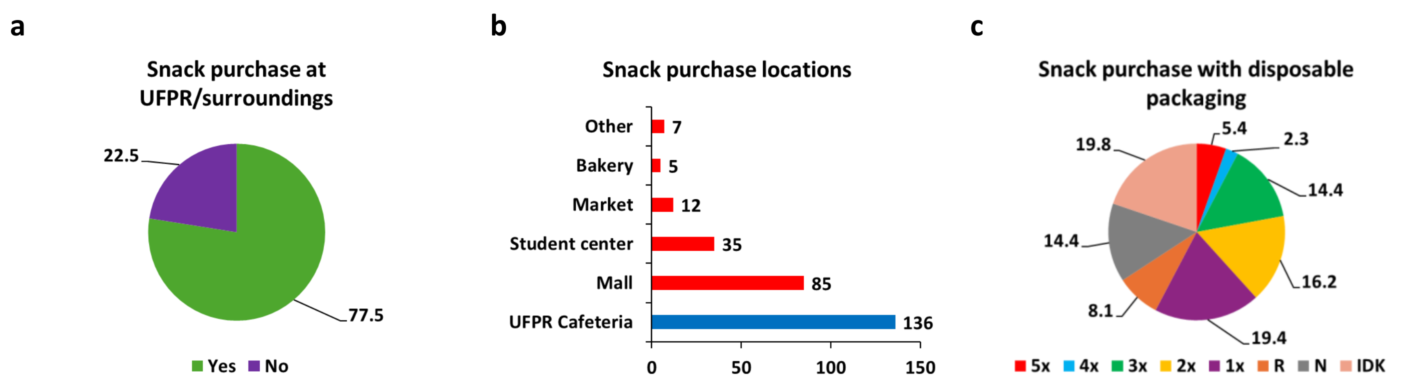

Figure 3 – Waste-related behaviors (Snack purchases with disposable packaging). Note: R = Rarely; N = Never; IDK = I do not know.

Campus cafeterias, canteens, and nearby shops are strategic intervention points. Educational talks and outreach initiatives can effectively integrate sustainability and nutrition, enhancing community impact. Partnerships with suppliers and vendors are essential to encourage compostable, reusable, or otherwise sustainable packaging. Targeted campaigns can also foster consumer habits such as using personal containers.

Figure 3 further shows that, despite progress in on-campus education and infrastructure, off-campus consumption remains a challenge. At Mexico's National Institute of Public Health (INSP), eco-conscious consumers successfully pressured vendors to replace polystyrene with sustainable alternatives, even outside

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institutional boundaries (Torres-Pereda et al., 2020). Thus, UFPR's waste management efforts must extend beyond the campus, promoting responsible consumption practices in surrounding commercial areas.

INFRASTRUCTURE GAPS AND IMPROPER DISPOSAL PRACTICES

Despite 89.6% of respondents reporting waste separation at UFPR's Polytechnic Campus (Figure 1), key weaknesses persist in infrastructure and system credibility. Bin distribution was heavily criticized (Figure 4), especially in open areas, academic buildings received 53.6% approval, while outdoor/common spaces scored just 35.1%.

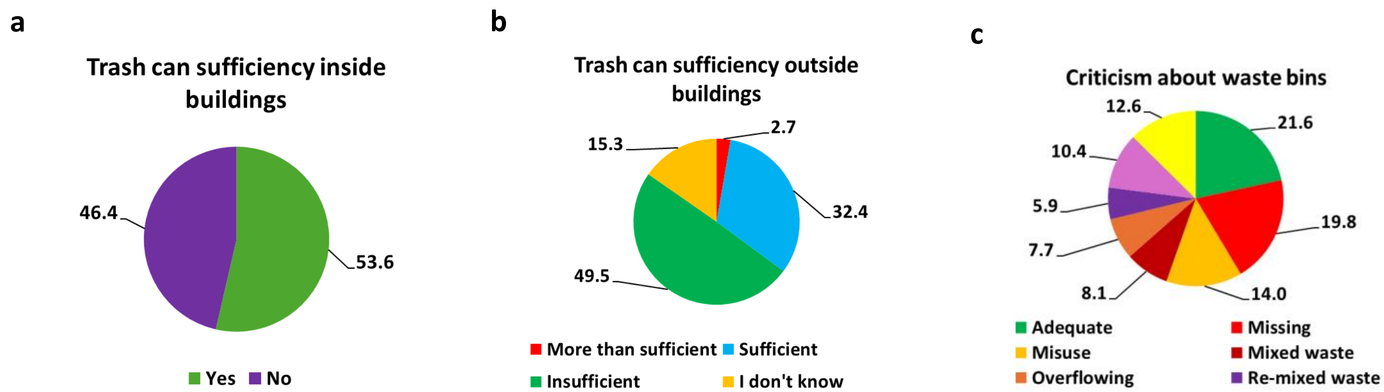

Figure 4 – Perception of bin adequacy inside and outside buildings.

Open comments (data not shown) revealed issues like overflowing bins and frequent mixing of recyclable and non-recyclable waste, often attributed to staff handling. This erodes trust and discourages participation. Respondents also noted a lack of clearly labeled bins, poor signage, and inconsistent color coding, especially in classrooms, labs, and high-traffic zones.

Participants called for continuous education, transparent communication, and logistical improvements, particularly more frequent collection, and better support for cleaning staff. Suggested actions included campus mapping to optimize bin placement, expanded composting and e-waste programs, and stronger enforcement of source separation.

Cigarette butt disposal presents additional challenges. Most respondents reported using regular waste bins or ashtrays; some mentioned "bituqueiras," while others used organic or general-purpose containers. This indicates a lack of standardized infrastructure. Improper disposal increases fire risks and may compromise composting when butts are mixed with organic waste.

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BEHAVIORAL SHIFTS AND PERSISTENT MATERIAL CHALLENGES

While infrastructure and communication improvements are essential, behavioral change remains equally important. At UFPR, post-initiative data revealed reduced use of unsustainable materials, especially among women (17.6%) and graduate students, with 33.3% reporting reduced regular use and 27.6% reduced frequent use. Among participants with lower education levels, 12.1% reported increased eco-friendly habits at home, indicating a spillover effect from campus to household routines (Torres-Pereda et al., 2020).

These trends mirror international findings. At three Vietnamese universities, Nguyen et al. (2022) found plastic bottles to be the most consumed single-use plastic (1.39 g/student/day), followed by cups (0.20 g) and bags (0.14 g). Awareness was high: 94.4% recognized the environmental harm of SUPs, 82.3% acknowledged personal responsibility, and 59.5% viewed it as a shared duty. Notably, 66.6% reported discomfort and 15.1% guilt, supporting plastic bans.

Cultural change is thus essential for campus waste reduction (Munguía et al., 2018). Replacing plastic items with compostable alternatives like paper bags and napkins aligns with best practices in food and green waste management.

For lasting impact, communication strategies must suit audience preferences. Haksevenler et al. (2022) observed that students favored internet and practical examples, while staff preferred formal notices. At UFPR, segmented messaging could improve sorting habits and rebuild trust.

However, hard-to-recycle items, such as snack wrappers and multilayered packaging, remain a challenge (Figure 2). Made of layered materials (aluminum, PET, polypropylene), they are difficult to process and sort. Despite alternatives like composite reuse or energy recovery, these materials persist, even among informed users.

At INSP, awareness campaigns reduced total residual waste by 60.1%, but multilayer packaging declined only 15.6%, even among women (Torres-Pereda et al., 2020). This highlights the need for structural changes in both product design and user behavior.

Efficient segregation remains critical in universities (De Vega et al., 2008), requiring infrastructure that meets the spatial and volumetric demands of waste generation. While many UFPR respondents reported bringing snacks from home (Figure 2), most preferred on-campus or nearby vendors (Figure 3), reinforcing the strategic need to improve waste points and signage in these areas.

Installing multi-stream bins in high-traffic zones and tailoring educational campaigns can boost participation and trust. Outreach should also extend to surrounding businesses. At INSP, consumers influenced

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vendors to abandon polystyrene due to increased use of personal containers (Torres-Pereda et al., 2020). Promoting similar actions at UFPR aligns with Brazil's National Solid Waste Policy (Brasil, 2010).

Certain materials offer high recycling value. PET bottles and aluminum cans are widely reused: PET in textiles and packaging (Joseph et al., 2024); aluminum cans with near-infinite recyclability and 95% energy savings (Al-Alimi et al., 2024). Promoting their separation supports the circular economy and reduces emissions.

Academic paper and other cellulose materials also have strong recycling potential. One ton of recycled paper saves 17 trees, 26,500 liters of water, and 4,100 kWh, cutting CO_2 emissions and supporting over 145,000 U.S. jobs (Çiçekler; Tutuş, 2024). Clean, uncontaminated separation is crucial (Gebrekidan et al., 2024), and many UFPR respondents reported reusing paper or discarding it at home to ensure recycling.

Organic waste, particularly food scraps, is often discarded in general bins. If mixed with other waste, it is landfilled (Paraná, 2006), posing sanitation and environmental risks (Gebrekidan et al., 2024). Composting systems are urgently needed to divert this material and align with global goals (United Nations, 2024).

Critical Assessment of Infrastructure, Operations, and Governance in Waste Management at UFPR's Polytechnic Campus

The Polytechnic Campus of UFPR presents multiple structural, operational, and institutional deficiencies that hinder effective solid waste management.

Infrastructure-related issues include the absence of standardized, strategically distributed bins. Many areas lack containers appropriate for the segregation of organic, recyclable, hazardous, and healthcare-related waste. Signage is often inconsistent or missing, causing confusion, and leading to frequent contamination, particularly recyclable paper being soiled by organic residues. Additionally, temporary waste storage areas are frequently unsanitary, exposed to weather, and insecure, violating national standards (ABNT NBR 11.174:1990, which establishes procedures for the storage of Class II-A (non-inert) and Class II-B (inert) solid waste, as defined by ABNT NBR 10.004:2004; NBR 12.235:1992, which provides guidelines for the storage of hazardous waste (Class I).

Operational shortcomings are equally significant. Respondents cited irregular collection schedules, unclear routing, and a complete lack of local treatment infrastructure, such as composting systems or material recovery facilities. Evidence shows that previously separated recyclables are often re-mixed and landfilled, undermining the system and discouraging community participation (Fagnani; Guimarães, 2017).

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Behavioral factors also weaken system effectiveness. Low engagement, insufficient awareness of correct disposal methods, and a prevailing perception of system failure contribute to noncompliance. The lack of ongoing environmental education, curricular integration, and user incentives further worsens this scenario. As Torres-Pereda et al. (2020) emphasize, consistent engagement strategies are key to sustaining behavioral change. Moreover, Haksevenler et al. (2022) note that communication should be adapted to user preferences, students responding better to digital content and practical demonstrations, while staff prefer formal notices.

The absence of a formal Solid Waste Management Plan (SWMP) is a serious governance gap. Without it, UFPR fails to comply with Federal Law No. 12.305/2010 and state directives such as Paraná's Zero Waste Program (Paraná, 2006), which aims to reduce landfill waste by 30% (Paraná, 2018, 2022).

In addition, the university appears not to hold a valid environmental license for the overall operations of its campuses, which is required under state environmental regulations. For university campuses, this includes the submission of a Plano de Controle Ambiental (PCA), a technical document that outlines mitigation measures for potential environmental impacts, as defined by the Environmental Institute of Paraná (IAT).

Furthermore, the absence of a registered Solid Waste Management Plan (PGRS) with the municipal environmental agency may indicate non-compliance with municipal waste management legislation, which typically requires institutions generating significant quantities of waste to develop and formally present their management plans. This lack of integration with local and state regulatory frameworks not only undermines compliance but also hinders coordination with broader waste reduction and circular economy initiatives.

Until 2022, the campus followed a simplified dual-bin model adapted from Curitiba's municipal system and replicated at the UAM-Azcapotzalco campus (Espinosa et al., 2008). This included blue-liner bins in classrooms for recyclables and black-liner bins in hallways for general waste (RJ+OW). However, this system lacks visual and dimensional standardization across buildings, as observed in the Department of Chemical Engineering (Figure 5). Despite its simplicity, the model fails to accommodate composting, as organic waste is discarded with general waste (Fagnani; Guimarães, 2017). Introducing dedicated organic waste bins, with scheduled collection to mitigate odor and pest issues, would be a significant improvement.

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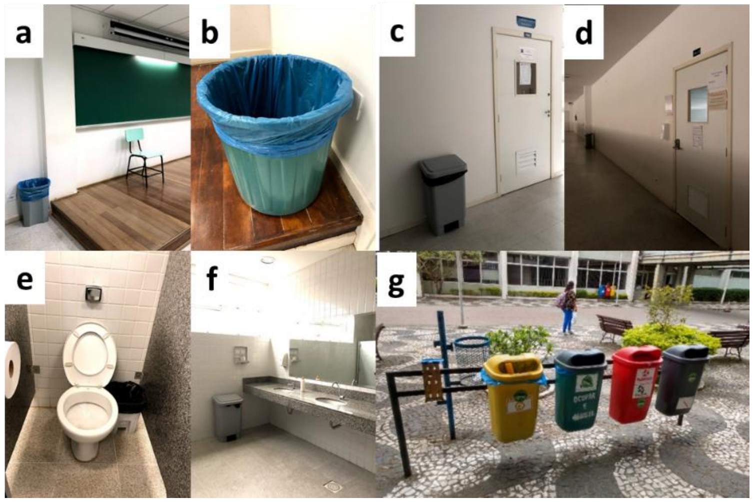

Figure 5 – Illustrative example of the location and typology of waste bins in the academic areas of UFPR's Polytechnic Campus. Photographs illustrating the typical arrangement of bins: a and b. Bins exclusively for recyclables inside classrooms; c and d. Bins for common waste (landfill and organic) in hallways; e and f. Bins located in restrooms, near toilets and sinks, used exclusively for disposing of paper towels (landfill waste); g. Set of bins for source separation according to Brazilian CONAMA Standard 275:2001 (Brasil, 2001), placed in outdoor areas. This example highlights partial source segregation and structural constraints that limit the effectiveness of selective waste collection.
Source: own elaboration, 2025.

Recyclables are collected daily by outsourced personnel and delivered to the CATAMARE waste-picker cooperative, which is responsible for sorting and selling the materials. The revenue generated goes directly to cooperative members, fulfilling the principles of social inclusion and shared responsibility established by Brazil's National Solid Waste Policy (Brasil, 2010). However, operational efficiency could be improved by adjusting collection frequency based on bin fill levels, for example, triggering collection when containers reach approximately two-thirds capacity. In contrast, daily collection of general waste remains essential to maintain sanitary standards (Barros et al., 2013; Fagnani; Guimarães, 2017).

To support a more integrated and traceable waste management system, the SWMP recommends the construction of a centralized temporary storage facility at the Polytechnic Campus. This unit would be equipped with weighing scales to monitor volumes of organic, recyclable, hazardous, healthcare, and construction waste, and would be designed to meet standards for accessibility, weather protection, and user safety.

In addition to the physical infrastructure, the system must ensure internal waste tracking throughout the campus, including the registration and monitoring of internal transport operations. Externally, the waste flow should comply with national traceability mechanisms, particularly through the issuance of the Waste Transport Manifest (MTR), as required by Portaria MMA nº 280/2020 (Brasil, 2020b), which mandates digital tracking of waste generation, transportation, and destination.

The effectiveness of SWM at UFPR depends on the integration of infrastructure upgrades, optimized logistics, proper source segregation, operator training, and active user engagement. The implementation of

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standardized waste records, audience-specific educational strategies, and structural reforms is essential for aligning campus practices with national regulations and Paraná's circular economy targets.

INSTITUTIONAL PRACTICES AND CHALLENGES IN HAZARDOUS AND HEALTHCARE WASTE MANAGEMENT

In Mexico, hazardous waste (HW) management is subject to strict regulation. A notable example is the Universidad Autónoma del Estado de Morelos (UAEM), where staff receive ongoing training on toxicity, legal frameworks, storage procedures, and safe transport. Waste collection is conducted by licensed companies through the University Environmental Management Program (PROGAU), with monthly shipments to certified treatment facilities. The university generates approximately 9 tons of hazardous waste annually, with mandatory reporting to government authorities (Sánchez-Salinas et al., 2015).

Adopting a comparable approach at UFPR could significantly improve safety, transparency, and compliance with Brazilian environmental legislation. Key strategies include regular staff training and formal partnerships with authorized waste management companies.

At UFPR, hazardous and healthcare waste (HCW+HW) is managed by the Environmental Management Division (DGA), following technical standards such as ANVISA RDC 222/2018 Guidelines for the Management of Healthcare Waste, ABNT NBR 11.174:1990, NBR 12.235:1992, NBR 10.157 (which establishes technical criteria for the planning and presentation of sanitary landfill projects for non-hazardous waste) and NBR 13.896:1997 (which provides technical criteria for the design, implementation, and operation of hazardous waste landfills). Laboratory-generated waste, whether from teaching or research, must be classified according to treatment requirements. Each substance is recorded using Chemical Waste Identification Forms, stored in 25–30 L containers, and held in laboratories until transferred to the Chemical Waste Center.

Transfer to the Chemical Waste Center requires prior scheduling with DGA and the submission of documentation detailing volumes and mixture components. Only properly labeled and packaged waste, in accordance with established safety protocols, is accepted. DGA also provides guidance on waste minimization strategies, including reagent reuse and redistribution of near-expiry chemicals.

Temporary storage facilities for solid waste must meet specific technical criteria to ensure environmental safety and occupational health. These include impermeable flooring to prevent soil contamination, as mandated by ABNT NBR 11174:1990, NBR 12235:1992, and RDC 222/2018. Proper signage and labeling are required by ABNT NBR 9191:1985, RDC 222/2018, and NBR 12235:1992 to ensure clear identification of waste types and associated risks. Adequate ventilation must be provided, especially for hazardous materials, as stipulated in NBR

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12235:1992 and RDC 222/2018. The chemical compatibility of stored materials and the use of containment structures for leaks are also critical requirements defined in NBR 12235:1992. Furthermore, lighting, emergency plans, and safety equipment must be readily accessible, in compliance with NBR 12235:1992 and RDC 222/2018. Time limitations for storage (e.g., 24–48 hours depending on conditions) are specified in RDC 222/2018, which also mandates restricted access to these areas to avoid accidental exposure or contamination.

The Solid Waste Management Plan (SWMP) developed for the Polytechnic Campus proposes actions to enhance waste segregation and collection, implement weighing and transport control systems, and reduce HCW+HW generation by 30% (Paraná, 2018, 2022), in alignment with the goals of Paraná's Zero Waste Program (Paraná, 2006). These measures aim to increase operational efficiency, reduce environmental impacts, and ensure compliance with legal and institutional responsibilities.

DATA GAPS AND OPERATIONAL SHORTCOMINGS IN SOLID WASTE MONITORING AND DESTINATION AT UFPR

During the analyzed period, the percentage of segregated recyclable waste varied across UFPR's campuses: at the Polytechnic Campus, it ranged from 25.4% to 31.7%; at the Botânico Campus, from 34.3% to 34.4%; and at the Agrárias Campus, it declined from 40.2% to 34.0%. No consistent or traceable explanation was identified for these variations, revealing a lack of integrated monitoring.

As of March 2022, the only complete dataset provided by the Catamare cooperative referred to the year 2018. In that year, 79,131 kg of recyclable materials were recovered, generating a total revenue of R$ 39,701.42. Cardboard accounted for the largest volume, with 42,179 kg and R$ 18,518.60 in revenue, followed by white paper (15,732 kg; R$ 7,006.34), plastic (10,884 kg; R$ 9,795.60), and metal (10,336 kg; R$ 4,380.88). At the average 2018 exchange rate of R$ 3.6558 per US dollar (Banco Central do Brasil, 2018), the total revenue equaled approximately US$ 10,858.34.

These figures illustrate the economic importance of effective waste segregation and recovery. However, persistent inconsistencies in recordkeeping raise concerns about the reliability of institutional data and point to communication gaps between generating units and the Environmental Management Division (DGA). The absence of standardized data flows undermines strategic planning and prevents accurate performance evaluation.

Despite these challenges, the partnership with the Catamare cooperative remains essential for advancing social inclusion and operationalizing the principles of Brazil's National Solid Waste Policy (Federal Law

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No. 12.305/2010), which reinforces the vital role of waste-picker cooperatives in implementing reverse logistics and integrated waste management systems.

OUTSTANDING CHALLENGES IN SOLID WASTE MANAGEMENT AT UFPR'S POLYTECHNIC CAMPUS

Data on hazardous and healthcare waste (HCW+HW) remain limited. Available records cover only the last quarter of 2018, with an average of 19,365 kg and high variability (range: 27,062 kg), suggesting sporadic peaks in generation. Although UFPR maintains active contracts for the proper treatment of this waste, the lack of continuous monitoring and volume control, despite expenditures of approximately R$ 555,000 between 2018 and 2019, underscores the need for more rigorous oversight.

Many waste types at UFPR still lack defined disposal routes, such as glass, e-waste, lab reagents, food waste, and fluorescent lamps (Table 5). This limits system efficiency, traceability, and sustainability. Restaurant food waste, for example, could be composted but is easily contaminated if poorly separated (Mason et al., 2004). Table 5 summarizes key waste streams, their sources, current destinations, and treatment gaps.

Table 5 – Waste categories, sources, and final treatment routes at UFPR (Includes gaps in current destinations).

Type	Source or Observation	Destination	Final Treatment/ Disposal
Sanitary waste (restrooms)	Restrooms; non-recyclable and untreated waste	Sanitary Landfill	Sent to landfill by PMC*
Rejects (**RJ**) and Organic Waste (**OW**)	Non-recyclable or non-recoverable materials, including food scraps.		
Paper and cardboard	Administrative and academic activities.	"*Catamare*" Waste Picker Association	Recovered and sold as secondary raw materials
Plastic	Includes PET bottles and other recyclable plastics		
Metals	Includes aluminum cans and other recyclable metals.		
Glass	Academic and administrative activities		
Green Waste	Tree pruning, gardening	Canguiri Farm	Composting
Used cooking oil	University restaurants	Contracted company	Recycled by contracted company
Wood	Non-reusable wood from maintenance activities	NPDEAS Research Lab	Burned for microalgae production
Tires	Unserviceable tires from the vehicle fleet	Automotive maintenance companies	Recycled by contracted company
Construction and demolition waste	Campus maintenance and construction	Civil Engineering companies	Managed by contracted companies
Fluorescent lamps	Stored by maintenance team; gradually replaced by LED	Not Defined	Temporarily stored
Organic waste from restaurants/canteens	Food preparation and consumption	Not Informed	Not Informed

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Inorganic reagents	Lab waste with specific characteristics	Not Informed	Not Informed
Electronic waste	Obsolete or non-functional electronic devices	Not Informed	Not Informed
Batteries and cells	Academic and administrative activities	Collected and treated by SERQUIP	Not Informed
Solvents	Teaching and research labs		
Flammable liquids	Labs, e.g., LACAUT		
Organic reagents	Teaching and research labs		
Automotive oil	UFPR vehicle fleet		
Paint waste	Maintenance and construction		
Laboratory wastewater sludge	Lab effluent treatment processes (e.g., Pilot Plants)		
Healthcare waste (**HCW**)	Hospitals, clinics, and labs at **Politécnico** and **Botânico** campuses		

Note: Direct information provided by DGA in 2022.; PMC*: Curitiba Municipal Government.

BENCHMARKING WITH BRAZILIAN FEDERAL UNIVERSITIES: INSTITUTIONAL GAPS AND OPPORTUNITIES

A national survey was conducted to evaluate the status of Solid Waste Management (SWM) across Brazil's federal universities. Of the 63 institutions contacted (excluding five still administratively linked to parent institutions), only one (1.5%) provided complete and satisfactory data on waste generation, disposal, and associated costs. Six institutions (8.8%) submitted partial data, while 28 (41.1%) provided insufficient information. Alarmingly, 33 universities (52.3%) either failed to respond or explicitly reported the absence of any control over solid waste generation or management. These findings reveal critical institutional weaknesses in SWMP implementation, despite legal obligations.

Data related to organic waste was particularly scarce. Only four universities, UnB, UFBA, UFVJM, and FURG, reported active composting initiatives during the 2017–2019 period. However, the per capita generation rates reported by these institutions varied significantly (from 0.47 kg to 7.39 kg in 2019), suggesting methodological inconsistencies and a lack of standardization.

Information on non-recyclable waste (residuals sent to landfills) was provided by only four institutions, all of which indicated upward trends in disposal. Likewise, data on recyclable waste was available from just six universities, though these showed general improvement in source separation efforts.

The management of hazardous and healthcare waste (HCW+HW) was also marked by a lack of transparency. Only UnB, UFS, UFSM, and FURG reported figures for this category. In contrast, UFPR distinguished itself by reporting higher volumes and costs, approximately R$ 555,000 per year, largely due to its Veterinary Hospital and laboratory operations.

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This national overview highlights the urgency of investing in structured SWMPs, consistent data collection, and waste minimization strategies. Strengthening these dimensions is essential for improving environmental performance and aligning Brazilian higher education institutions with national and global sustainability goals.

BENCHMARKING WITH INTERNATIONAL UNIVERSITIES: LESSONS FOR ADVANCING SUSTAINABLE WASTE MANAGEMENT AT UFPR

To assess UFPR's position and identify improvement opportunities, a global review of waste management practices in higher education institutions (HEIs) was conducted. Key differences emerged in infrastructure, user behavior, policy application, and educational strategies; dimensions that are not only critical to reducing waste and enhancing recycling, but also increasingly relevant for integrating sustainability into institutional quality assessments and decision-making processes (Oliveira et al., 2025).

At UNBC (Canada), segregation and composting diverted over 70% of waste, with per capita generation at just 0.059 kg/day (Smyth et al., 2010). UAM-Azcapotzalco (Mexico) used a two-bin system to cut landfill waste through strong community engagement (Espinosa et al., 2008). In the UK, the University of Southampton cut waste from 6,000 to under 3,900 tons in three years, reaching a 72% recycling rate and saving £125,000 via PESTLE and ISB models (Zhang et al., 2011).

UAEM (Mexico) combined composting, HW training, and separation to cut total waste by 60.1%, recovering large volumes of paper and plastic (Sánchez-Salinas et al., 2015). The University of Sakarya (Turkey) installed infrastructure with ROI in 2.3 years (Boysan et al., 2015).

However, barriers remain. Marmara University reports 69% recycling potential but only 26% participation (Haksevenler et al., 2022). The University of Lagos generates 32 tons/day, 75% recyclable, but recycles under 1% due to systemic failures (Adeniran et al., 2017). METU and Palestinian HEIs also show low composting and partial segregation (Bahçelioğlu et al., 2020).

Technological solutions at the University of Cincinnati (USA) reduced 280 tons of CO_2 annually (Tu et al., 2015), while Universitas Pertamina (Indonesia) improved metrics via composting and segregation (Ridhosari; Rahman, 2020).

In Brazil, UNICAMP cut total waste by 22% using PDCA cycles and education, reducing paper waste from 50% to 9.4% (Fagnani; Guimarães, 2017). In contrast, UFPR saw a revenue drop from R$ 79,131 (2018) to R$ 56,942 (2019), signaling systemic inefficiencies.

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Despite 89.6% of UFPR users reporting waste separation, many distrust post-collection practices (Haksevenler et al., 2022). Challenges include the absence of a SWMP, poor segregation infrastructure, and limited data tracking. Rodríguez-Guerreiro et al. (2024) emphasize that HEIs achieving "zero waste" use integrated strategies, source separation, data systems, and education, generating 0.19 ± 0.21 kg/person/day.

Small interventions matter: hydration stations, for example, may eliminate up to 45,191 plastic bottles/year. UFPR should invest in weighing systems, selective collection, composting, targeted awareness, and a centralized waste database, aligned with PNRS (Brasil, 2010) and international best practices.

Improvement Proposal: Toward Integrated and Participatory Waste Management at UFPR

The proposed strategy addresses ten key areas of disruption in UFPR's current solid waste management (SWM) system (Table 6), encompassing infrastructure, operations, behavior, education, governance, and finance. Beyond correcting operational flaws, the plan prioritizes systemic integration, transparency, and shared responsibility across the academic community.

Table 6 – Sustainable Waste Management Action Plan – UFPR "Centro Politécnico".

Action Area	Description	Suggested Deadline	Responsible Sector
Infrastructure Expansion	Install new bins in high-traffic areas; add disposal points for batteries, cigarette butts, etc.	Short-term	Campus Administration
Collection and Operations	Increase collection frequency; pilot smart bins with fill-level sensors	Mid-term	Maintenance and Logistics Division
Education and Awareness	Conduct continuous campaigns; improve signage (visual/multilingual)	Ongoing	Environmental Education Committee
Management Transparency	Publish destination reports; promote visits to sorting facilities	Short-term	Sustainability Office
Incentives for Sustainable Practices	Launch rewards program; encourage reusable item use	Mid-term	Student Affairs and Campus Services
Composting Systems	Implement composting units; reuse compost in campus green areas	Long-term	Agronomy and Environment Department
Participatory Engagement	Promote workshops and "green ambassador" student initiatives	Ongoing	Extension Programs and Student Groups
Monitoring and Feedback	Conduct periodic audits; adjust based on community input	Mid-term	Sustainability Committee

Note: Short-term = 0–6 months; Mid-term = 6–12 months; Long-term = 12–24 months.

Core measures include optimizing the distribution and labeling of bins, enhancing environmental education efforts, implementing data transparency mechanisms, and promoting participatory initiatives, such as student-led projects and environmental ambassador programs.

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To support implementation, short courses in "Solid Waste Management" have been developed and taught by students in UFPR's GATMA extension group (part of PPGMAUI), using materials tailored to institutional challenges (GATMA, 2021). These courses align with Brazil's National Solid Waste Policy (Brasil, 2010) and cover waste segregation, storage, transport, treatment, disposal, and technologies such as composting, biodigestion, incineration, and pyrolysis, alongside reverse logistics and occupational safety. The university itself serves as a case study, fostering practical learning and critical reflection.

International benchmarks reinforce those low-cost actions, such as improved signage, stakeholder engagement, and composting, can yield remarkable results. At UNICAMP, improperly discarded recyclables dropped from 60% to 15.3% (Fagnani; Guimarães, 2017); at Milano-Bicocca, residual waste fell from 73% to 30% (Di Salvatore et al., 2022); and at IST, separation reached 58%. UNBC demonstrated a 70% diversion potential (Smyth et al., 2010), while INSP (Mexico) reduced waste by 60.1% through education-based interventions (Torres-Pereda et al., 2020).

Despite 89.6% of respondents at UFPR's Polytechnic Campus reporting that they separate their waste, inefficiencies, such as poor bin distribution and lack of labeling, along with the perception that waste is later mixed, undermining user confidence and discourage participation.

An integrated SWM approach, anchored in environmental education, infrastructure modernization, and community engagement, can transform UFPR into a reference in campus sustainability and circular economy alignment.

INSTITUTIONAL SWMP AT UFPR: LEGAL COMPLIANCE, OPERATIONAL STRUCTURE, AND BEST PRACTICES

The document "Proposta de Plano de Gerenciamento de Resíduos Sólidos (PGRS)" developed for the Polytechnic Campus of the Federal University of Paraná (UFPR) presents a comprehensive solid waste management (SWM) model, aligned with Brazil's National Solid Waste Policy (Federal Law No. 12.305/2010). The plan was elaborated by the authors in collaboration with three UFPR students and aims to standardize disposal, collection, treatment, and destination of campus-generated waste (Mathias et al., 2022).

GUIDELINES AND OBJECTIVES

Formally, the campus lacked SWMP until September 2021. The proposal responds to legal requirements through an evidence-based framework grounded in technical inspections, analysis of historical data (DGA/SUINFRA), stakeholder consultation, and benchmarking with national and international universities. It

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identifies critical weaknesses, absence of waste inventories, non-standardized containers, and inadequate storage, and proposes dual-stream segregation for administrative/academic sectors and specific classifications for laboratories and construction waste.

The plan incorporates key legal instruments, including ABNT NBR 10.004 (classification; 2004), NBR 12.235:1992 (which establishes technical requirements for the storage of hazardous waste; 1992) and NBR 11.174:1990 (guidelines for the storage of non-hazardous waste; 1990), CONAMA Resolution 275:2001 (color coding; Brasil, 2001), and ANVISA Resolution RDC nº 222/2018 (guidelines for healthcare waste). It categorizes waste into general (RSCD), recyclable, hazardous (HW), healthcare (HCW), reverse logistics (RSLRO), construction and demolition (CDW), and green waste. Recommendations include installing weighing systems, defining compliant storage areas, standardizing containers, and expanding training in alignment with the PNRS (Brasil, 2010) principles of sustainability and institutional accountability.

Operational Framework: Short, Medium, and Long-Term Actions

The SWMP structures actions around the waste lifecycle: generation minimization; safe classification and handling; segregation and labeling; on- and off-site collection and transport; temporary storage; and destination. With over 46,000 people and high waste generation, Politécnico exceeds municipal collection thresholds and must comply with Decree No. 983/2004 and the State Solid Waste Plan (Paraná, 2018), which mandates a 30% reduction in municipal-type waste.

A dual-stream system is proposed for general campus areas (recyclables and general waste), while detailed classification is recommended for labs and construction sectors. Segregation follows CONAMA 275:2001 (Brasil, 2001), and all containers/liners must comply with NBR 9191:1985 (which establishes requirements for the identification and labeling of containers used in the storage and transportation of hazardous materials, 1985). Waste is collected internally by electric vehicles and stored by type; recyclables are sent to Catamare, and HW+HCW to SERQUIP.

Monitoring and System Integration

While functional, the current system lacks full traceability, standardization, and dedicated infrastructure. The SWMP recommends installing proper storage facilities, acquiring weighing systems, and maintaining updated operational procedures. It also calls for strengthened institutional coordination, including formalized

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contracts, identification of responsible staff, and the use of traceability tools such as the FIRQ (Chemical Waste Identification Form).

More than a legal obligation, the SWMP aims to embed sustainability in UFPR's institutional culture, fostering practices that are environmentally sound and socially inclusive. It is designed to be scalable and replicable across other campuses. Effective implementation requires collaboration among administrators, faculty, staff, students, and external partners, alongside periodic reviews to incorporate legal updates and shifts in waste generation patterns.

WASTE RECOVERY AS A TOOL FOR SOCIAL INCLUSION AND ECONOMIC REDISTRIBUTION

Assuming a 44% recovery (Fagnani; Guimarães, 2017; Di Salvatore et al., 2022) of residual waste at UFPR and an average generation of 0.50 kg/person/day among 44,131 individuals (UFPR, 2022), the recyclable potential reaches over 3,500 tons annually. Most of this would be paper/cardboard (23%), plastic (16%), and metals (6%), following the profile reported by Rodríguez-Guerreiro et al. (2024). At current market prices, R$ 0.65/kg for paper, R$ 4.20/kg for plastics, and R$ 2.50/kg for metals (Recicla Sampa, 2024), the total estimated revenue exceeds R$ 3.829 million per year (US$657 mil; Banco Central do Brasil, 2025; or 2,522 Brazilian minimum wages, based on the national rate of R$ 1,518.00 in effect as of May 2025).

In addition to the R$ 3.8 million revenue potential from recyclable sales, diverting these materials from landfilling would also avoid an estimated R$ 287,000 per year in disposal fees, considering the rate of R$ 81.08 per ton paid by the regional consortium (CIM, 2022).

IV. CONCLUSION

Solid waste management (SWM) at UFPR's Polytechnic Campus faces persistent structural, operational, and informational challenges, despite strong community engagement, with 89.6% of respondents reporting active waste separation. Key obstacles include uneven bin distribution, poor signage, irregular selective collection, absence of composting infrastructure, and a lack of transparency about waste destinations. These issues are further compounded by the absence of a formal Solid Waste Management Plan (SWMP) and systematic monitoring tools, which hinder legal compliance and strategic planning.

To address these gaps, this study developed and delivered a campus-specific SWMP, organized into ten strategic categories. Designed with scalability in mind, the plan can be adapted to other UFPR campuses while respecting local specificities. A complementary environmental education guide was also produced and

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implemented in short courses by GATMA (Academic Group on Environmental Technologies), aligning training content with Brazil's National Solid Waste Policy.

The analysis also highlights a missed financial and social opportunity. In 2018, the Catamare cooperative recovered only US$ 10,858.34 from recyclables on three campuses, a fraction of the estimated US$ 657,000 annual potential across UFPR based on 40% recovery of total solid waste. Furthermore, failing to recover this material results in disposal costs nearing US$ 48,288 annually, borne by either UFPR or municipal services.

Implementing the proposed structural reforms, operational adjustments, and educational initiatives can reposition UFPR as a national leader in university sustainability. These actions directly contribute to the fulfillment of Sustainable Development Goals (SDGs) 11 and 12, reinforcing the university's commitment to circular economy principles and inclusive environmental governance (Oliveira et al., 2025).

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V. References

ABAS, M. A.; NAJIHAR, A.; MALEK, N. H. A.; HASSIN, N. H. A. A review of sustainable campus concept in the context of solid waste management. Journal of Education & Social Policy, v. 5, n. 4, p. 71–76, 2018. Disponível em:https://doi.org/10.30845/jesp.v5n4p9. Acesso em: 16 maio 2025.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS (ABNT). NBR 9191: Rótulos preventivos para produtos químicos perigosos. Rio de Janeiro: ABNT, 1985.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS (ABNT). NBR 11174: Gestão de resíduos sólidos — Princípios, procedimentos e diretrizes. Rio de Janeiro: ABNT, 1990.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS (ABNT). NBR 12235: Armazenamento de resíduos sólidos perigosos — Terminologia. Rio de Janeiro: ABNT, 1992.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS (ABNT). NBR 13896: Aterros de resíduos perigosos — Critérios para projeto, implantação e operação. Rio de Janeiro: ABNT, 1997.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS (ABNT). NBR 10004: Resíduos sólidos – Classificação. Rio de Janeiro: ABNT, 2004.

ASSOCIAÇÃO BRASILEIRA DE RESÍDUOS E MEIO AMBIENTE (ABREMA). Panorama dos Resíduos Sólidos no Brasil 2023. Disponível em:https://www.abrema.org.br/wp-content/uploads/dlm_uploads/2024/03/Panorama_2023_P1.pdf. Acesso em: 16 maio 2025.

ADENIRAN, A. E.; NUBI, A. T.; ADELOPO, A. O. Solid waste generation and characterization in the University of Lagos for a sustainable waste management. Waste Management, v. 67, p. 3-10, 2017. Disponível

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V.64, n.1, p. 154 – 186, 12/2025
http://dx.doi.org/10.5380/raega.v64i1.102183

em:http://dx.doi.org/10.1016/j.wasman.2017.05.002. Acesso em: 16 maio 2025.

AL-ALIMI, S.; YUSUF, N. K.; GHALEB, A. M.; LAJIS, M. A.; SHAMSUDIN, S.; ZHOU, W.; ALTHARAN, Y. M.; ABDULWAHAB, H. S.; SAIF, Y.; DIDANE, D. H.; T, I. S.; ADAM, A. Recycling aluminium for sustainable development: a review of different processing technologies in green manufacturing. Results in Engineering, [s.l.], v. 23, p. 102566, 2024. Disponível em:https://doi.org/10.1016/j.rineng.2024.102566. Acesso em: 16 maio 2025.

AL-KHATIB, I. A.; KONTOGIANNI, S.; AL-SARI, M. I.; AL RAJABI, H. Current trends in solid waste management in higher education institutions: The case of West Bank region, Palestine. Environmental Engineering and Management Journal, v. 17, n. 8, p. 1887–1896, 2018. Disponível em:https://doi.org/10.30638/eemj.2018.188. Acesso em: 16 maio 2025.

BAHÇELIOĞLU, E.; BUĞDAYCI, E. S.; DOĞAN, N. B.; ŞİMŞEK, N.; KAYA, S. Ö.; ALP, E. Integrated solid waste management strategy of a large campus: A comprehensive study on METU campus, Turkey. Journal of Cleaner Production, v. 265, p. 121715, 2020. Disponível em:https://doi.org/10.1016/j.jclepro.2020.121715. Acesso em: 16 maio 2025.

BANCO CENTRAL DO BRASIL. Cotações e boletins. Brasília, DF: Banco Central, [2025]. Disponível em:https://www.bcb.gov.br/estabilidadefinanceira/historicocotacoes. Acesso em: 16 maio 2025.

BARROS, R. M.; TIAGO FILHO, G. L.; MOURA, J. S.; PIERONI, M. F.; VIEIRA, F. C.; LAGE, L. R.; MOHR, G. S.; BASTOS, A. S. Evaluation of solid waste management in Brazilian higher education institutions. Resources, Conservation and Recycling, v. 80, p. 97–106, 2013. Available at: http://dx.doi.org/10.1016/j.resconrec.2013.09.005. Accessed on: May 16, 2025.

BOYSAN, S.; BALOĞLU, A.; KURTULUŞ, H. Project on solid waste recycling plant in Sakarya University Campus. Procedia - Social and Behavioral Sciences, v. 195, p. 2222–2230, 2015. Disponível em:https://doi.org/10.1016/j.sbspro.2015.06.316. Acesso em: 16 maio 2025.

BRASIL. Conselho Nacional do Meio Ambiente (CONAMA). Resolução nº 275, de 25 de abril de 2001. Estabelece o código de cores para os diferentes tipos de resíduos, a ser adotado na identificação de coletores e transportadores, bem como nas campanhas informativas para a coleta seletiva. Diário Oficial da União: seção 1, Brasília, DF, n. 117-E, p. 80, 19 jun. 2001. Acesso em: 16 maio 2025.

BRASIL. Conselho Nacional do Meio Ambiente (CONAMA). Resolução nº 358, de 29 de abril de 2005. Dispõe sobre o tratamento e a disposição final dos resíduos dos serviços de saúde e dá outras providências. Diário Oficial da União: seção 1, Brasília, DF, n. 84, p. 63–65, 4 maio 2005.

BRASIL. Lei Complementar nº 131, de 27 de maio de 2009. Acrescenta dispositivos à Lei Complementar nº 101, de 4 de maio de 2000, que estabelece normas de finanças públicas voltadas para a responsabilidade na gestão fiscal, para determinar a divulgação em tempo real das informações sobre a execução orçamentária e financeira da União, dos Estados, do Distrito Federal e dos Municípios. Diário Oficial da União: seção 1, Brasília, DF, ano 146, n. 100, p. 1, 28 maio 2009.

BRASIL. Lei N.º 12.305, de 02 de agosto de 2010. Institui a Política Nacional de Resíduos Sólidos. Diário Oficial da República Federativa do Brasil, Poder Executivo. Brasília, DF. 2010. Disponível em:https://www.planalto.gov.br/ccivil_03/_ato2007-2010/2010/lei/l12305.htm.

BRASIL. Agência Nacional de Vigilância Sanitária (ANVISA). Resolução da Diretoria Colegiada – RDC nº 222, de 28 de março de 2018. Dispõe sobre as Boas Práticas de Gerenciamento dos Resíduos de Serviços de Saúde e dá outras providências. Diário Oficial da União: seção 1, Brasília, DF, n. 61, p. 76, 29 mar. 2018.

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V.64, n.1, p. 154 – 186, 12/2025
http://dx.doi.org/10.5380/raega.v64i1.102183

BRASIL. INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (IBGE). Tabelas de estimativas para 1º de julho de 2020, atualizadas e enviadas ao TCU após a publicação no DOU. Julho de 2020a. Disponível em:https://www.ibge.gov.br/estatisticas/sociais/populacao/9103-estimativas-de-populacao.html?edicao=28674. Acesso em: 16 maio 2025.

BRASIL. Ministério do Meio Ambiente (MMA). Portaria nº 280, de 29 de junho de 2020. Estabelece critérios e procedimentos para elaboração, implementação, monitoramento e avaliação do Relatório de Desempenho do Sistema de Logística Reversa. Diário Oficial da União: seção 1, Brasília, DF, n. 123, p. 82, 30 jun. 2020.

BRASIL. Decreto nº 10.936, de 12 de janeiro de 2022. Regulamenta a Lei nº 12.305, de 2 de agosto de 2010, que institui a Política Nacional de Resíduos Sólidos, e a Lei nº 14.026, de 15 de julho de 2020, que atualiza o marco legal do saneamento básico, e dá outras providências. Diário Oficial da União: seção 1, Brasília, DF, n. 8, p. 1, 13 jan. 2022.

BRASIL. Plano de Dados Abertos - PDA UFPR - Consulta Pública. 2024. Disponível em:https://www.gov.br/participamaisbrasil/pda#:~:text=A%20Universidade%20Federal%20do%20Paran%C3%A1,de%204%20de%20dezembro%20de. Acesso em: 16 maio 2025.

CONSÓRCIO INTERMUNICIPAL DA REGIÃO METROPOLITANA DE CURITIBA (CIM). Sistema integrado e descentralizado de tratamento de resíduos sólidos urbanos e disposição final de rejeitos: estudo de viabilidade técnico-econômica. Curitiba: CIM/CONRESOL, 2022. Disponível em:https://www.conresol.pr.gov.br. Acesso em: 16 maio 2025.

ÇİÇEKLER, M.; TUTUŞ, A. Chapter4 – Assessing the Advantages and Disadvantages of Paper Recycling for Sustainable Resource Management: A Systematic Review. In: TUTUŞ, A.; ÇİÇEKLER, M. (Eds.). Contemporary Perspectives in Forest Industry Engineering: A Comprehensive Review. Klaipeda: SRA Academic Publishing, 2024. p. 65-96. Disponível em:https://www.researchgate.net/publication/385230238_Assessing_the_Advantages_and_Disadvantages_of_Paper_Recycling_for_Sustainable_Resource_Management_A_Systematic_Review. Acesso em: 16 maio 2025.

DE VEGA, C. A.; BENÍTEZ, S. O.; RAMÍREZ BARRETO, M. E. Solid waste characterization and recycling potential for a university campus. Waste Management, v. 28, supl. 1, p. S21–S26, 2008. Disponível em:https://doi.org/10.1016/j.wasman.2008.03.022. Acesso em: 16 maio 2025.

DI SALVATORE, S.; MAGATTI, G.; ACCIARRI, M.; ROSSETTI, M.; COSTA, L. P. da; RIBEIRO, I. Solid waste management approach at the university through living labs and communication strategies: case studies in Italy and Portugal. Sustainability, v. 14, n. 9, p. 5240, 2022. Disponível em:https://doi.org/10.3390/su14095240. Acesso em: 16 maio 2025.

ESPINOSA, R. M.; TURPIN, S.; POLANCO, G.; DE LA TORRE, A.; DELFÍN, I.; RAYGOZA, I. Integral urban solid waste management program in a Mexican university. Waste Management, v. 28, n. S1, p. S27–S32, 2008. Disponível em:https://doi.org/10.1016/j.wasman.2008.03.023. Acesso em: 16 maio 2025.

FAGNANI, E.; GUIMARÃES, J. R. Waste management plan for higher education institutions in developing countries: The Continuous Improvement Cycle model. Journal of Cleaner Production, v. 147, p. 108–118, 2017. Disponível em:https://doi.org/10.1016/j.jclepro.2017.01.080. Acesso em: 16 maio 2025.

GESTÃO, AVALIAÇÃO E TECNOLOGIA EM MEIO AMBIENTE (GATMA). Minicurso de Gestão de Resíduos Sólidos – GATMA/UFPR (2021). Curitiba: Universidade Federal do Paraná, 2021. Disponível em:https://doi.org/10.5281/zenodo.15769739. Acesso em: 29 junho 2025.

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V.64, n.1, p. 154 – 186, 12/2025
http://dx.doi.org/10.5380/raega.v64i1.102183

GEBREKIDAN, T. K.; WELDEMARIAM, N. G.; HIDRU, H. D.; GEBREMICHAEL, G. G.; WELDEMARIAM, A. K. Impact of improper municipal solid waste management on fostering One Health approach in Ethiopia – challenges and opportunities: a systematic review. Science in One Health, v. 3, p. 100081, 2024. Disponível em:https://doi.org/10.1016/j.soh.2024.100081. Acesso em: 16 maio 2025.

HAKSEVENLER, G. B. H.; KAVAK, F. F.; AKPINAR, A. Separate waste collection in higher education institutions with its technical and social aspects: A case study for a university campus. Journal of Cleaner Production, v. 367, p. 133022, 2022. Disponível em:https://doi.org/10.1016/j.jclepro.2022.133022. Acesso em: 16 maio 2025.

JIBRIL, J. D.; SIPAN, I. B.; SAPRI, M.; SHIKA, S. A.; ISAE, M.; ABDULLAH, S. 3R's critical success factor in solid waste management system for higher educational institutions. Procedia - Social and Behavioral Sciences, v. 65, p. 626–631, 2012. Disponível em:https://doi.org/10.1016/j.sbspro.2012.11.175. Acesso em: 16 maio 2025.

JOSEPH, T. M.; AZAT, S.; AHMADI, Z.; JAZANI, O. M.; ESMAEILI, A.; KIANFAR, E.; HAPONIUK, J.; THOMAS, S. Polyethylene terephthalate (PET) recycling: A review. Case Studies in Chemical and Environmental Engineering, v. 9, p. 100673, 2024. Disponível em:https://doi.org/10.1016/j.cscee.2024.100673. Acesso em: 16 maio 2025.

MASON, I. G.; OBERENDER, A.; BROOKING, A. K. Source separation and potential re-use of resource residuals at a university campus. Resources, Conservation and Recycling, v. 40, n. 2, p. 155–172, 2004. Disponível em:https://doi.org/10.1016/S0921-3449(03)00068-5. Acesso em: 16 maio 2025.

MATHIAS, A. L.; COSTA, A.; MOSER, M. E.; LINS, S. S.; RODRIGUES, T. C. Proposta de Plano de Gerenciamento de Resíduos Sólidos CP – Universidade Federal do Paraná. Curitiba: UFPR, 2022. Disponível em:https://doi.org/10.5281/zenodo.15771981. Acesso em: 30 maio 2025.

MUNGUÍA, N. E.; DÍAZ, Á. M.; VELAZQUEZ, L. E.; PEREZ, R.; ESQUER, J.; ZEPEDA, D. S. Valorization of solid waste recovery in an institution of higher education. Green and Sustainable Chemistry, v. 8, p. 180–189, 2018. Disponível em:https://doi.org/10.4236/gsc.2018.82013. Acesso em: 16 maio 2025.

NGUYEN, X. C.; DAO, D. C.; NGUYEN, T. T.; TRAN, Q. B.; NGUYEN, T. T. H.; TUAN, T. A.; NGUYEN, K. L. P.; NGUYEN, V.-T.; NADDA, A. K.; THANH-NHO, N.; CHUNG, W. J.; CHANG, S. W. Generation patterns and consumer behavior of single-use plastic towards plastic-free university campuses. Chemosphere, v. 291, p. 133059, 2022. Disponível em:https://doi.org/10.1016/j.chemosphere.2021.133059. Acesso em: 16 maio 2025

OLIVEIRA, L. C. de; OLIVEIRA, U. R. de; APRIGLIANO, V. Integrating sustainability into quality assessment for higher education institutions. Journal of Cleaner Production, v. 486, p. 144466, 2025. Disponível em:https://doi.org/10.1016/j.jclepro.2024.144466. Acesso em: 16 maio 2025.

PARANÁ. SECRETARIA DE ESTADO DE MEIO AMBIENTE. Desperdício Zero: Programa da Secretaria de Estado de Meio Ambiente e Recursos Hídricos do Paraná (SEMA). Curitiba, PR. 2006. Disponível em:http://planetareciclavel.com.br/desperdicio_zero/kit_res_15_laranja.pdf . Acesso em: 16 maio 2025.

PARANÁ. SECRETARIA DE ESTADO DE MEIO AMBIENTE. Plano Estadual de Resíduos Sólidos do Paraná (PERS). Consórcio EnvEx-Engebio, Relatório de Síntese. Curitiba, PR. 2018. Disponível em:https://www.sedest.pr.gov.br/sites/default/arquivos_restritos/files/documento/2023-09/PERS%20-%20Sintese%20Final%20V3.pdf . Acesso em: 16 maio 2025.

PARANÁ. Instituto Água e Terra. Governador sanciona lei que institui o Plano Estadual de Resíduos Sólidos do Paraná. Curitiba: IAT, 2022. Disponível em:https://www.iat.pr.gov.br/Noticia/Governador-sanciona-lei-que-institui-o-Plano-Estadual-de-Residuos-Solidos-do-Parana. Acesso em: 16 maio 2025.

RECICLA SAMPA. Estação Preço de Fábrica reajusta valores dos recicláveis. 2024. Disponível

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V.64, n.1, p. 154 – 186, 12/2025
http://dx.doi.org/10.5380/raega.v64i1.102183

em:https://www.reciclasampa.com.br/artigo/estacao-preco-de-fabrica-reajusta-valores-dos-reciclaveis?utm_source=chatgpt.com. Acesso em: 16 maio 2025.

RIDHOSARI, B.; RAHMAN, A. Carbon footprint assessment at Universitas Pertamina from waste sector. IOP Conference Series: Earth and Environmental Science, v. 420, p. 012143, 2020. Disponível em:https://doi.org/10.1016/j.jclepro.2019.119172. Acesso em: 16 maio 2025.

RODRÍGUEZ-GUERREIRO, M. J.; TORRIJOS, V.; SOTO, M. A review of waste management in higher education institutions: The road to zero waste and sustainability. Environments, v. 11, n. 293, p. 1–24, 2024. Disponível em:https://doi.org/10.3390/environments11120293. Acesso em: 16 maio 2025.

RUGATIRI, J.; ABIDIN, Z.; ISMAIL, A. Assessing solid waste management strategy in higher education institutions of Indonesia: A case study of IPB University. IOP Conference Series: Earth and Environmental Science, v. 771, p. 012023, 2021. Disponível em:https://doi.org/10.1088/1755-1315/771/1/012023. Acesso em: 16 maio 2025.

SÁNCHEZ-SALINAS, E.; ORTIZ-HERNÁNDEZ, M. L.; RODRÍGUEZ, A.; CASTREJÓN-GODÍNEZ, M. L. Waste management in institutions of higher education as a tool for environmental education. Proceedings Sardinia 2015, Fifteenth International Waste Management and Landfill Symposium, S. Margherita di Pula, Cagliari, Italy, 5–9 October 2015. Disponível em:https://www.researchgate.net/publication/292326746. Acesso em: 16 maio 2025.

SMYTH, D. P.; FREDEEN, A. L.; BOOTH, A. L. Reducing solid waste in higher education: The first step towards 'greening' a university campus. Resources, Conservation and Recycling, v. 54, n. 11, p. 1007–1016, 2010. Disponível em:https://doi.org/10.1016/j.resconrec.2010.02.008. Acesso em: 16 maio 2025.

TORRES-PEREDA, P.; PARRA-TAPIA, E.; RODRÍGUEZ, M. A.; FÉLIX-ARELLANO, E.; RIOJAS-RODRÍGUEZ, H. Impact of an intervention for reducing waste through educational strategy: A Mexican case study, what works, and why? Waste Management, v. 114, p. 183–195, 1 Aug. 2020. Disponível em:https://doi.org/10.1016/j.wasman.2020.06.027. Acesso em: 16 maio 2025.

TU, Q.; ZHU, C.; McAVOY, D. C. Converting campus waste into renewable energy – A case study for the University of Cincinnati. Waste Management, v. 39, p. 258–265, May 2015. Disponível em:https://doi.org/10.1016/j.wasman.2015.01.016. Acesso em: 16 maio 2025.

UNIVERSIDADE FEDERAL DO PARANÁ (UFPR). Normas para Coleta, Tratamento e Armazenagem de Resíduos Químicos da UFPR. Divisão de Gestão Ambiental. 2021. Disponível em:https://docs.ufpr.br/~dga.pcu/NORMAS%20atualizada.pdf . Acesso em: 16 maio 2025.

UNIVERSIDADE FEDERAL DO PARANÁ (UFPR). Relatório de Autoavaliação CPA 2022. Curitiba, PR. 2022. Disponível em:https://cpa.ufpr.br/wp-content/uploads/2023/03/relatorio_2022_ufpr.pdf. Acesso em: 16 maio 2025.

UNITED NATIONS. The Sustainable Development Goals Report 2024: Progress towards the Sustainable Development Goals – Advanced Unedited Version. New York: United Nations, 2024. Disponível em:https://unstats.un.org/sdgs/files/report/2024/SG-SDG-Progress-Report-2024-advanced-unedited-version.pdf. Acesso em: 16 maio 2025.

VALSAN, V.; SREEKUMAR, G.; CHEKKICHALIL, V.; KUMAR, A. S. Effects of service-learning education among engineering undergraduates: A scientific perspective on sustainable waste management. Procedia Computer Science, v. 172, p. 770–777, 2020. Disponível em:https:// https://www.sciencedirect.com/science/article/pii/S1877050920314393. doi.org/1 10.1016/j.procs.2020.05.110. Acesso em: 16 maio 2025.

RA'EGA
O ESPAÇO GEOGRÁFICO EM ANÁLISE
https://revistas.ufpr.br/raega
ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V.64, n.1, p. 154 – 186, 12/2025
http://dx.doi.org/10.5380/raega.v64i1.102183

ZHANG, N.; WILLIAMS, I. D.; KEMP, S.; SMITH, N. F. Greening academia: Developing sustainable waste management at higher education institutions. Waste Management, v. 31, n. 7, p. 1606–1616, 2011. Disponível em:https://doi.org/10.1016/j.wasman.2011.03.006. Acesso em: 16 maio 2025.

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V.64, n.1, p. 154 – 186, 12/2025
http://dx.doi.org/10.5380/raega.v64i1.102183

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O ESPAÇO GEOGRÁFICO EM ANÁLISE
https://revistas.ufpr.br/raega
ISSN eletrônico 2177-2738
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http://dx.doi.org/10.5380/raega.v64i1.102183

RA'EGA
O ESPAÇO GEOGRÁFICO EM ANÁLISE
https://revistas.ufpr.br/raega

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V.64, n.1, p. 154 – 186, 12/2025
http://dx.doi.org/10.5380/raega.v64i1.102183