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RESEARCH PAPER

Green Campus Development through Municipal Solid Waste Characterisation and Decentralised Waste Management: A Case Study of UET Peshawar, Abbottabad Campus

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ABSTRACT

This research examines how an educational institution can be transformed into a sustainable model for green campus initiatives, using a university campus as a case study. Muncipal solid waste management is emerging as a problem in developing countries because of urbanisation. Campuses can be living laboratories for implementing sustainable waste management, but currently, most campuses use centralised waste management systems. For this study, a mixed methodology was employed, which entailed a systematic review of secondary sources of information, as well as the collection of primary information at selected sites on the UET Abbottabad Campus. The secondary sources review and preliminary assessment of the existing waste management system were done in tandem to provide the conceptual basis for interventions at the sites while assessing current practices and operational gaps. Later, a comprehensive primary waste characterisation exercise was done through the segregation and weighing of waste generated in various units of the campus. Results shows that the organic waste contributed 66.8% to the total waste, but only 9.2% of the recyclable materials were processed, while the rest, 90.8%, was sent to the municipal dumping sites, which clearly reveals the disposal-centric system with a huge unrealised potential for on-site recovery and recycling. The findings establish the potential of decentralised waste management, especially when carried out in the vicinity. In an organised setting such as a university, decentralised composting can be an effective measure to treat organic waste, decrease greenhouse gas emissions, and enhance soil quality, making it a sustainable and economically viable solution for managing municipal solid waste. On-site composting and source segregation need to be implemented and institutionalised. A green campus model should be developed that can be replicated in resource-limited institutions.

KEYWORDS MSW, Decentralised MSWM, Composting, Controlled Environment, Green Campus

Introduction

Effective management of Municipal Solid Waste (MSW) is a major challenge for developing countries due to rapid urbanisation, high population growth, and socio-economic development acceleration and all this enable the generation of huge amount of waste, whereas the management of waste is mostly informal and disorganised. It is estimated that about half of the world's population lack access to waste management services, and open dumping of waste is the most commonly used waste disposal practice in most developing and lower-middle-income countries (Hyman, 2013; Mustafa, Haq, & Iftikhar, 2009; Naqvi, 2023; Pakistan Environmental Protection Agency, 2005).

Reliable data on waste generation and composition is essential for designing effective MSW management systems, as it informs recovery potential, identifies primary

waste sources, guides processing equipment design, and ensures regulatory compliance (Gidarakos, Havas, & Ntzamilis, 2006; Gursoy Haksevenler, Kavak, & Akpinar, 2022; Rodríguez-Guerreiro, Torrijos, & Soto, 2024). The type of waste also depends on seasonal, demographic, geographical, and socio-economic parameters, making it difficult yet essential to measure (Fontaine, Legros, & Frayret, 2025).

In Pakistan, the generation of MSW in large cities varies from 0.283 to 0.613 kg/capita/day, or 1.896 to 4.29 kg/household/day, depending on the population size and level of urbanisation (Ministry Of Climate Change Islamabad, 2021). The current coverage of government-provided services is only 50% of the total MSW generated, while at least 75% is needed for cleaner cities. Uncontrolled disposal, mainly through open dumping, is a major source of serious environmental and health hazards. In Pakistan, MSW is made up of plastic, rubber, metal, paper, textiles, glass, food, and other organic materials, and is collected mainly by municipalities. The efficiency of collection varies from almost 0% in rural areas to 90% in upmarket areas of large cities, while disposal is mainly open dumping or burning. Recycling is mainly done by scavengers and street vendors, and private sector participation is limited (Nisar, Ejaz, Naushad, & Ali, 2008; Pakistan Environmental Protection Agency, 2005). However, the municipalities are now exploring the possibility of privatisation and the establishment of composting plants, and proper management of contracts and operational planning is essential for success. Inefficient waste management practices are responsible for environmental degradation, pollution, clogged drains, and rising health hazards (Shafique & Clark, 2022).

Green Campus refers to an educational institution that incorporates environmental sustainability into its activities, policies, and engagement with stakeholders (Demetriou, Vatistas, Anne, Penezić, & Fokaides, 2025; Shange, Zogli, & Dlamini, 2025). Originating from the sustainable development movement, this idea translates the United Nations Sustainable Development Goals (SDGs), specifically SDG 4 (Quality Education) via sustainability-oriented education and research, SDG 7 (Affordable and Clean Energy) via the use of renewable energy and energy-efficient infrastructure, SDG 11 (Sustainable Cities and Communities) as living labs for sustainable urbanisation, SDG 12 (Responsible Consumption and Production) via waste segregation, recycling, composting, and resource efficiency, and SDG 13 (Climate Action) by lowering greenhouse gas emissions and promoting climate awareness (UNDP, 2020). Therefore, the green campus becomes a micro-model of sustainable development, where global commitments to the SDGs are implemented through concrete actions. According to Sütunc ((Sütünç, 2025) although these strategies improve the welfare of students and environmental protection, they require context-specific approaches for success. Through these strategies, the university becomes a "living laboratory," where students live in the sustainability they learn.

The northern Pakistani city of Abbottabad, which is encircled by picturesque hills, has a long history of pleasant weather and is well-known for its esteemed educational establishments, such as the Army Burn Hall Public School, Ayub Medical College, and the University of Engineering and Technology (UET) Abbottabad Campus (Government of Khyber Pakhtunkhwa, n.d.; UET, n.d.). Despite its prominent educational institutions and picturesque environment, Abbottabad is also facing significant environmental challenges due to rapid urbanisation and poor management of waste disposal, which is causing huge accumulation of solid waste in streets, open areas, and residential zones. This context highlights the urgent need for sustainable waste management interventions at local levels.

This study aims to assess the composition, quantity, and recycling potential, specifically for organic waste, of MSW generated at the Abbottabad campus of UET Peshawar, as part of a pilot project to establish a green campus through systematic solid waste management aligned with national regulations and sustainable global practices. The research focuses on controlled-environment waste management within the campus, while evaluating its feasibility and potential for broader urban application.

To properly evaluate the generation of wastes in terms of quantity and composition, the campus was segmented into different units such as hostels, academic blocks, cafeteria, and open areas, and the wastes generated in these areas were collected and segregated according to their types and then weighed. Such data-based approaches are essential in determining the composition and potential for organic waste management to ensure the implementation of sustainable approaches in the management of wastes in a controlled environment.

The significance of this research can be understood in the context of the paradigm shift from the conventional and more commonly practiced disposal-oriented municipal waste management to a high-precision and decentralised SWM approach, as applicable to controlled environments. Most of the available literature has used conventional sampling techniques and data, whereas this research has used a more precise and rigorous methodology of 100% segregation and weighing of the waste at the source level in the UET Peshawar Abbottabad Campus. By identifying the need for on-site composting as a result of the analysis, as more than 66% of the waste is organic in nature, this research has filled the gap between the theoretical analysis of waste and the practical recovery of resources, thus initiating a pathway toward a 'Green Campus' model with minimal transportation costs and environmental externalities, applicable to regions such as Pakistan, which are already resource-scarce.

Literature Review

Municipal Solid Waste (MSW) and Municipal Solid Waste Management (MSWM)

Municipal Solid Waste (MSW), also known as domestic and commercial waste, comprises a mixture of waste materials collected from various urban and rural regions, including plastics, paper, metals, textiles, food waste, organic matter, and others. Being an unavoidable by-product of human activities, the generation of MSW is positively correlated with the increase in population, urbanisation, industrialisation, and economic development in different regions of the world (Gursoy Haksevenler et al., 2022; Sharma & Jain, 2021). In total, 2.01 billion tons of MSW are generated on a yearly basis in the world, out of which at least 33% is mismanaged. In the coming years, the greenhouse gas emissions from the waste could reach 2.6 billion tons of CO_2 equivalent by 2050, thus emphasising the need to adopt environmentally safe waste management approaches (Elsheekh, Kamel, Elsherif, & Shalaby, 2021).

Municipal Solid Waste Management (MSWM) is the collection, storage, transfer, processing, resource recovery, recycling, treatment, and ultimate disposal of MSW in an environmentally sound manner, following the principles that ensure public health, environmental protection, and social welfare (Khan, Mohsin, Nasar-u-Minallah, & Barkat, 2024). In developing countries, poor management of MSW results in land degradation, loss of biodiversity, air pollution, poor sanitation, and the transmission of contagious diseases. Despite the importance of ensuring environmental quality and economic sustainability in the management of MSW, many existing management systems are still based on landfills that generate greenhouse gases, including nitrous oxide, carbon dioxide and methane. Environmental fiscal reforms in the form of taxes, prices, and public expenditure can help internalise environmental costs and support the use of resources in an environmentally friendly manner (Arlinghaus & Dender, 2017; Somani, 2023; UNDP, 2020).

Sustainable MSWM contributes to the achievement of key SDGs of United Nations, including SDG 6, 11, 12, 13, and SDG 15 (T. Akmal & F. Jamil, 2021; T. Akmal & F. J. H. Jamil, 2021; Amaral, Rodrigues, Gaspar, & Gomes, 2020; Meena et al., 2023; Somani, 2023; Tangwanichagapong, Nitivattananon, Mohanty, & Visvanathan, 2017).

Pakistan faces the challenge of generating 55,000 tons of waste daily. However, the infrastructure and institutional capacity to address the challenge are lacking. As a result, various problems are experienced, including the presence of waste in the streets, drains, open plots, and sewers. The major problems facing the implementation of SWM include the lack of skilled manpower, policy and institutional issues, and the availability of technical and financial support (T. Akmal & F. Jamil, 2021).

Environmental fiscal reforms in taxation, pricing, and expenditure have great potential in internalising environmental costs for a more sustainable use of resources, however, for efficient MSWM systems, decentralisation at local levels with active participation of local communities is required. In Abbottabad, for efficient MSWM systems, improvement in local authority systems through environmental fiscal reforms, composting plants, promotion of on-farm composting, source-level segregation of wastes, and local recycling infrastructure can be helpful in reducing landfill problems (Mustafa et al., 2009).

Adopting sustainable and decentralised MSWM approaches - where waste is managed close to its point of generation through source segregation, localised treatment, and community-level resource recovery - can further enhance system efficiency, reduce transportation and operational costs, and improve recycling and composting outcomes. Such decentralised systems offer functional and scalable approaches, especially in developing nations where centralised systems are less developed, hence facilitating long-term environmental sustainability and waste management systems.

Decentralised, On-Site Waste Management

Waste management environments are either controlled or uncontrolled, depending on the level of organisation and manpower and their role in the generation and management of waste. A controlled environment is marked by the identification of stakeholders, the presence of manpower, and the capacity to implement awareness campaigns, regulations, and monitoring of implementation. Waste generation in controlled environments is relatively manageable and predictable, and the management process can be implemented accordingly. Uncontrolled environments, which include cities and communities, have multiple sources of waste generation, making it difficult to track, educate, and regulate the process. It is important to handle such environments separately since controlled environments are ideal for effective and cheap waste management, which can be implemented in a customised way, while uncontrolled environments need generalised strategies. University campuses represent typical controlled environments that provide a unique opportunity to implement decentralised, on-site waste management strategies.

Higher Education Institutions (HEIs) generate significant amounts of biodegradable wastes due to diverse academic, residential and service activities, making campus-level waste diversion an important opportunity for improving municipal solid waste management (El-Halwagy, 2024).

Decentralised waste management is an approach of managing wastes at the place of generation using pickup, treatment, and recovery systems, rather than relying solely on large, centralised facilities. This method focuses on the sorting of wastes at the source of generation and treating them on site or nearby, especially biodegradable wastes. This reduces long-distance transport. This method is becoming popular because it is appropriate for controlled environments such as universities. This is because universities can implement context-specific strategies such as composting on site. HEIs communities consist largely of educated occupants and structured administrative systems, hence, there is strong potential for effective waste ownership and successful decentralised municipal solid waste management at the source level (Álvarez-Alonso et al., 2025; Shahid, Shafiq, & Firdaus e, 2025). The application of decentralised waste management in universities has several benefits to sustainability. These benefits include improved collection rates, better resource

recovery, cost savings, and minimising the burden on existing waste management approaches (Álvarez-Alonso et al., 2025; Torrijos, Calvo Dopico, & Soto, 2021; Vázquez, Plana, Pérez, & Soto, 2020).(Berta, Kurdi, Reider, & Banász, 2025).

The objective of developing high-quality compost at the local level through the treatment of organic waste at its source has become an important aspect of the efficient and sustainable management of urban solid waste, as well as the maintenance of healthy soils. Composting activities in local areas have many benefits, such as improving environmental conditions, creating jobs related to the circular economy, and raising people's awareness of the importance of reducing waste and recycling. A key outcome observed in decentralised composting is the reduction of collected waste that requires collection, transportation, disposal, or incineration (Álvarez-Alonso et al., 2025; Torrijos et al., 2021; Vázquez et al., 2020).

Economic assessments further indicate that decentralised composting initiatives can be implemented in a financially sustainable manner, as their operational costs are often lower than the average costs associated with municipal solid waste treatment in many regions. Consequently, decentralised waste-to-compost facilities present a cost-effective option for managing municipal solid waste while easing financial and operational pressures on municipal governments (Ashraf, Mohareb, & Vahdati, 2024; Jakimiuk et al., 2023; Kumaat, Manembu, Mambu, & Mangindaan, 2023; Shahid et al., 2025; Torrijos et al., 2021). Decentralisation is also appreciated for its ability to ensure the promotion of local interests, increase the involvement of citizens, and improve the transparency and accountability of programme implementation (Elsheekh et al., 2021).

Decentralised composting methods can be successfully applied in a university setting to produce high-quality organic fertiliser from food and landscaping waste, thus reducing the amount of waste sent off-campus. The application of source segregation and decentralised composting practices can help divert large amounts of organic waste away from landfills while producing valuable soil amendments, thus reiterating the significance of on-campus waste treatment.

The effectiveness of decentralised waste management is also evident in the waste bank programs implemented in Indonesia, where the community plays a significant role in waste management, promoting decentralised waste management, source segregation, and waste recovery, especially in the absence of formal waste management infrastructure (Budiyarto, Clarke, & Ross, 2025). These cases show the potential of decentralised waste management, especially when implemented close to the source or the place where the waste is generated. For universities, where waste generation is more likely to be managed in a more structured environment, decentralised waste composting is more likely to be effective than sending the waste to the dump site. This is because universities are more likely to be able to effectively implement on-site waste reduction strategies, especially decentralised waste composting in controlled environments, to reduce the organic waste generated on campus.

The study is conducted on the campus of a university, where the objectives are to investigate the composition of all the waste generated on the campus and to identify opportunities to reduce the waste generated on the campus. The study is conducted to serve as a pilot study to show the potential effectiveness of on-site waste reduction strategies, especially decentralised waste composting in controlled environments.

Composting

Largest portion of MSW is organic. In low and middle income countries, organic waste is between 53% and 56% of all waste (de Souza & Drumond, 2022). In less developed countries such as Bangladesh and Pakistan, organic waste is greater than 65% of all waste

generated. In higher education institutions, biodegradable organic waste is between 22% and 55% of all waste generated (Ashraf et al., 2024; Torrijos et al., 2021).

Composting is considered to be a cost-effective, environmentally friendly, and sustainable biological process wherein the organic portion of municipal solid waste is decomposed by microorganisms under strictly controlled conditions, resulting in the production of stable organic-rich compost (Meena et al., 2023). Composting is considered to be one of the best practices for the sustainable disposal of organic waste (Kosuke, Liu, & Gamaralalage, 2020). Composting, which converts a significant portion of the organic fraction of MSW into stable organic matter, enhances the fertility of the soil by improving its physical and biological characteristics. Composting also results in lower greenhouse gas emissions, reduced demand for chemical fertilisers, reduced demand for peat, job creation, and reduced pressure on landfill sites (de Souza & Drumond, 2022).

Decentralised Composting

Decentralised composting systems, whether in homes, communities, or neighbourhoods, are best suited for low and middle income countries in the world. Their main advantage is that they are easy to operate and inexpensive. They are best placed near the source of the waste and where the compost will be needed, which minimises transportation requirements, operational expenses, and greenhouse gas emissions. They are usually operated using simple equipment that is inexpensive and often require manual labour, which provides employment opportunities for the less skilled in society and makes people see the results of their investment in a shorter period, in addition to increasing their participation and support for the initiative. It also ensures that the compost is of high quality due to the sorting of the waste and minimization of contaminants, and it also prolongs the life of landfills and changes people's behaviour in ways that reduce overall waste generation in the country (de Souza & Drumond, 2022; Shahid et al., 2025).

Campus-based composting programs demonstrate the effectiveness of decentralised approaches by transforming organic waste into a valuable local resource for compost production and urban agriculture. Studies indicate that compostable biowaste constitutes approximately 17% - 60% of total campus solid waste, highlighting the significant recovery potential within institutional settings (Álvarez-Alonso et al., 2025; Vázquez et al., 2020). The composting-based decentralised municipal solid waste management system (DMSWMS) has also been shown to be economically efficient, achieving carriage, sorting, and disposal efficiencies of 92%, 78%, and 81%, respectively, compared with 8.9%, 11.3%, and 2% for centralised MSW systems (CMSWMS). Its compost-based payback rate (31%) and overall net economic efficiency (57.6%) further demonstrate the cost-effectiveness of decentralised composting systems for municipal waste management (Shahid et al., 2025).

Composting converts the large fraction of organic waste that would otherwise go to dumping sites into valuable compost, supporting various SDGs comprising SDG 2, 6, 11, 12, 13, and SDG 15 (Berta et al., 2025). It also bridges the gap between waste disposal and productive urban food systems, integrating community engagement with environmental management strategies (Madrini, 2017). Decentralised composting helps in reducing the waste sent to landfills, lowers the GHG emissions, and increases the quality of the soil, making it a sustainable and economically viable option for the management of MSW in both university and urban settings (Álvarez-Alonso et al., 2025; Shahid et al., 2025).

Material and Methods

This study used a mixed-methodological approach, combining a systematic evaluation of secondary sources with site-specific primary data gathering to provide a framework for decentralised waste management. Three separate stages made up the

research design: (a) a secondary data analysis to provide a conceptual foundation for on-site treatments (b) a preliminary system assessment and (iii) thorough primary waste characterisation study.

Study Area

The University of Engineering and Technology, Peshawar established its Abbottabad campus in October 2002 on the site of the old Ayub Medical College, with the first department established in March 2004 (UET, 2025). In addition to meeting a long-standing public demand, the construction of a UET campus in Abbottabad enhances the city's reputation as a centre of learning.

The study was undertaken in the Abbottabad Campus of UET Peshawar, which is a regulated institutional setting with four academic departments, open spaces, a canteen, two hostels for boys, one for girls, and one for staff. The campus was selected as a pilot site to investigate chances for on-site trash reduction and decentralised waste management, as well as to look at solid waste generation, composition, and the quantitative contribution of various waste kinds (especially organic waste).

Primary Data Collection: Preliminary System Assessment

A thorough examination of the current SWM infrastructure at the UET Peshawar, Abbottabad Campus was part of the first phase, which began in 2024. Stakeholder consultations involving interviews with administrative departments and sanitation staff to identify operational bottlenecks, detailed field observations to map the flow of waste from generation points to final disposal locations, and baseline surveys to evaluate the extent of informal recovery practices and prevailing waste-handling behaviours were the methods used to gather data.

Primary Data Collection: Source-Level Segregation and Weighing

To ensure high-fidelity data, the study followed a 100% source-level segregation and weighing method instead of the conventional sampling methods used by the municipality. The campus was segmented into specified operational units such as hostels, cafeterias, academic buildings, and open spaces to collect site-specific data. After training the staff in specialised waste segregation, all the waste produced in these operational units was segregated at the source level into predefined categories such as organic (green/wet waste), cardboard, paper, plastic, plastic bags and wrappers, beverage cartons (Tetra Pak), glass, fabric, leather, Styrofoam, and others. This segregated waste was then directly weighed on selected days of 2025, creating a precise empirical baseline of waste quantities and composition without the usual margins of error in studies that use sampling methods.

Secondary Data and Conceptual Framework

In tandem with the initial field research, secondary research, - literature review- was conducted to identify the conceptual framework of the study. This involved a two-tiered logic:

Decentralised Management Theory: An examination of the literature, was conducted to determine the efficiency of decentralised systems over centralised management, especially in controlled environments.

On-Site Composting Models: The examination specifically targeted decentralised composting at the point of generation, recognising it as the best practice worldwide for managing organic waste streams in institutional settings.

The two-tiered approach enabled the study to integrate reliable, local information on waste composition with existing global best practices, thereby closing the gap between empirical research and sustainable intervention through on-site resource recovery.

Primary Data Collection

The primary data collection process involved two major steps: (a) preliminary evaluation of the current SWM practice in the campus, and (b) source-level segregation and weighing of the waste. The preliminary evaluation of the current SWM practice in the campus was carried out through surveys and interactions with administrative departments and sanitation staff. Based on the preliminary evaluation, the study chose to carry out source-level segregation and weighing of the waste for primary data collection. The data on waste generation was collected from representative units of the campus to arrive at a reliable estimate of waste generation.

Figure 1: Collected Waste at Source

Preliminary Assessment of Existing Solid Waste Management (SWM) System

An initial investigation of the SWM process was conducted at the campus in 2024. The investigation was based on information gathered through surveys of the campus, discussions with the concerned departments of the university, interactions with sanitary staff, and actual observation of the process of waste collection, transportation, and disposal. The university disposes of solid waste through a simple procedure. The cleaning process begins at 8:00 am, after which the collected waste is transported to an on-campus holding area. When the waste collected reaches a certain level, it is then taken to the city's main dumping site for disposal. However, segregation of waste at the source does not take place as part of the official process. Limited informal segregation is carried out by sanitary staff, primarily to recover recyclable materials with market value, Figure 6. The cleaning of the campus takes place from Monday to Friday but does not occur on weekends. The recyclables with marketplace value are usually separated and sold to the people who recycle the waste. However, some of the recyclable but non-reusable waste, including small plastic fragments, packaging material, broken glass, and damaged products, usually gets mixed with the organic waste and reaches the dumping site at the university before finally reaching the municipal dumping facility.

Figure 2: Source-Level Segregation of Wet/Organic Waste

Source-Level Waste Segregation and Weighing for Quantitative Analysis

This study was done differently compared to the usual routes. Instead of sampling the waste from the dumps or the final disposal points, this study traced the waste at the actual source. The waste produced at the chosen units was totally sorted and weighed exactly at the source.

Sanitation workers were trained in 2024 to segregate and weigh the waste. This was done throughout the study. The actual segregation and weighing of the waste were done in January, March, and April of 2025. For the actual data collection, the units were visited for a total of three days: two days of the week, including one Monday. The Monday data represented the accumulated waste from Friday, Saturday and Sunday, as no formal cleaning activities are carried out on campus during the weekend. Although the actual data collection was done for three days, the data collected represents a total of five days of waste generation.

Figure 3: Waste Segregation and Weighing
Upper Right: Leather; Upper Left: Plastic; Lower Right: Glass; Lower Left: Styrofoam

Division of Campus into Study Units

For systematic data collection, the campus was divided into five units:

- Units 1–4: Hostels (two boys' hostels, one girls' hostel, one staff hostel)
- Unit 5: Academic block (four departments), cafeteria, and open areas

Waste Segregation and Measurement Procedure

Throughout each study unit, wastes were segregated right at the source into specific categories: organic (green/wet), cardboard, paper, plastic, plastic bags/wrappers, beverage cartons (Tetra Pak), glass, fabric, leather, Styrofoam, and others. The weight of each of these categories was determined using a calibrated scale, which was recorded to arrive at the total amount of waste generated and the percentage of each type of waste. Initially, the collected data was recorded in note pads and later transferred to Microsoft Excel for tabulation, percentage calculation, and analysis, figures 1-5.

Analytical Approach

The data collected was then studied to find out the total sum of waste generated by the campus units, the quantity of waste generated for different types of waste, the percentage of different types of waste, and the percentage of different types of recyclables, organic, and residual waste (Figures 7-8). This source-specific methodological approach allowed for the accurate identification of waste contributions from various units of the campus and formed a sound basis for the development of waste reduction strategies.

Significance of the Methodological Approach

By virtue of the controlled environment made possible by institutions, this study proves that full source segregation and measurement can be effectively carried out. The staffing system, learning environment, and regulatory environment made possible by campus regulations make universities the ideal place for the early adoption and adaptation of a decentralised approach to waste management.

Figure 4: Waste Segregation and Weighing
Right and Upper Left: Paper; Lower Left: Tetra Packs

Results and Discussion

The composition of different kinds of solid waste produced on campus is presented in Table 1. Green/wet waste has the highest percentage composition, accounting for 66.8% of the total waste, which reveals that biodegradable waste has the highest proportion. Of the other kinds of waste, plastic bags/wrappers (9.3%) and the "others" (10.8%) category have significant proportions. Cardboard (3.3%), plastic (2.8%), and paper (2.6%) have moderate proportions, while Tetra Pack (1.5%), glass (1.2%), and Styrofoam (1.2%) have smaller proportions. Fabric (0.2%) and leather (0.2%) have only minor proportions in the total waste (Figure 7). The total waste is dominated by green/wet waste, with smaller proportions of packaging and miscellaneous materials.

Figure 5: Segregation and Weighing of Wrappers and Plastic Bags

Figure 6: Waste Segregation for Informal Recycling Activities

Table 2 and Figure 8 show the percentage composition of campus solid waste based on its current final destination from campus: waste sent to the city dumping site and waste currently being recovered at campus. A huge majority of the waste, 90.8%, is sent to the city dumping site. This comprises green/wet waste (66.8%) as the major component, together with plastic bags and wrappers (9.3%), glass (1.2%), Styrofoam (1.2%), Tetra Pack (1.5%), and other mixed materials (10.8%), which make up 24.0% in addition to the green/wet fraction. On the other hand, only 9.2% of the total waste is currently being recovered at campus by informal means. This is made up of cardboard (3.3%), plastic (2.8%), paper (2.6%), fabric (0.2%), and leather (0.2%). This is done by the sanitation workers, who manually sort out the reusable materials of economic value and then sell them to local

recyclers or junk dealers. Overall, the results indicate that the campus waste management system is still largely disposal-oriented, with only a small portion of materials being recovered under the existing informal recovery practices.

Table 1
Campus Solid Waste: Composition and Proportional Breakdown

Type of Waste	Green/Wet	Cardboard	Plastic	Plastic Bag & wrapper	Fabric	Glass	Paper	Leather	Tetra Pack	Styrofoam	Others
%age of waste	66.8	3.3	2.8	9.3	0.2	1.2	2.6	0.2	1.5	1.2	10.8

Altogether, the results point to the conclusion that there is significant potential for upgrading the management of campus waste in terms of keeping the big chunk of organic material on the campus and treating it here. That is, since 66.8% of the total waste stream is biodegradable, if we divert this from the city landfill and run our own campus-based composting systems, we could greatly reduce the amount of waste that needs to be sent off campus and also obtain useful compost for our landscaping and other green initiatives around the campus.

Table 2
Distribution of Campus Solid Waste Transported to the City Dumping Site and Currently Recovered Materials (%)

Type of Waste	Type and Percentage of Campus SW Transported to City Dumping Site						Type and percentage of Campus SW Currently Recycled				
		Others									
	Green/Wet	Plastic Bags & wrappers	Glass	Styrofoam	Tetra Pack	Others	Cardboard	Plastic	Paper	Fabric	Leather
%age of waste	66.8	9.3	1.2	1.2	1.5	10.8	3.3	2.8	2.6	0.2	0.2
	66.8			24.0					9.2		
Total				90.8					9.2		

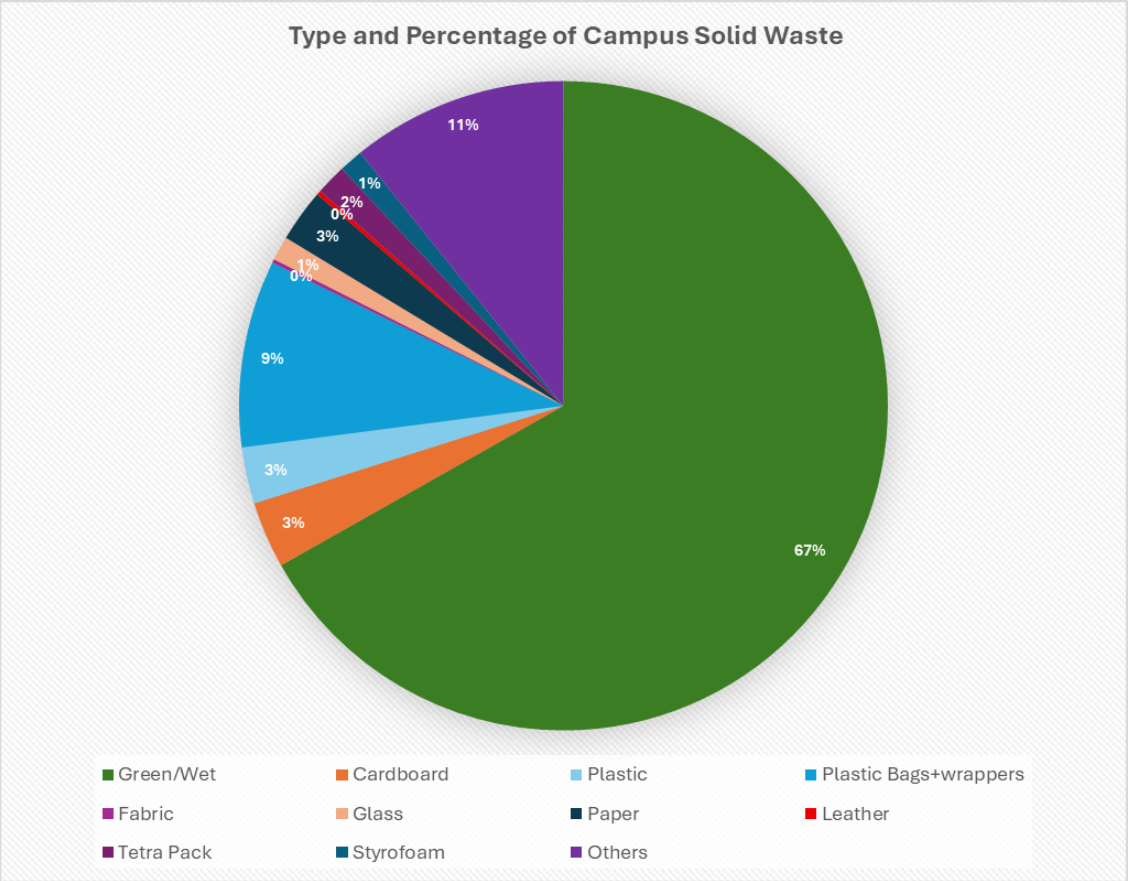
There is also a significant potential to improve the management of the non-organic portion of the waste that is sent to the dump, such as plastic bags and wrappers, glass, Styrofoam, Tetra Pak, and other mixed materials. Expanding the coverage of the non-organic materials that are already separated today could also improve the overall recycling rate and help the campus move towards a more decentralised approach to waste management.

Conclusion

The findings of this research prove the potential of the university setting to act as a living laboratory for the transition from disposal-centric waste management practices to more localised resource recovery practices. In fact, the waste composition data gathered in the UET Peshawar Abbottabad Campus indicates a substantial potential for the on-campus treatment of organic waste, considering the high percentage of biodegradable green and wet waste, which constitutes 66.8% of the total waste composition. Presently, the waste management practices in place at the UET Peshawar Abbottabad Campus is mostly disposal-focused, with more than 90% of the waste being disposed of at municipal dumps, with only a small percentage being recovered through unofficial channels. This research, however, confirms that the current waste management system, which is dependent on municipal

disposal, presents both environmental concerns and possible financial drawbacks. The adoption of on-campus composting systems, as well as more formalised source separation systems, will afford the chance to complete the nutrient cycle, using the largest component of the waste stream to provide nutrients for gardening activities on campus. In fact, the adoption of waste management systems on the UET Peshawar Abbottabad Campus will not only lower the financial burden of waste disposal but also instil a sense of environmentalism among the campus community. Finally, this research work offers the recipe for making the Green Campus, offering insights into the relevance of data-driven and place-specific approaches to waste management, not only in the local but also in the global setting.

Figure 7: Type and Percentage of Campus Solid Waste



Recommendations

To transition from the old, throw-away mentality to the new, smarter, more resource-friendly approach, academic and professional groups should transition away from large, centralised "collect-and-dump" contracts towards smaller, on-site waste treatment solutions. The idea is to provide smaller, on-site composting equipment capable of treating the main organic waste component (66.8%) to reduce municipal tipping fees, thereby reducing carbon emissions related to waste transport.

To ensure the effectiveness of the waste treatment, it is recommended to require source segregation, i.e., the implementation of color-coded waste segregation bins, especially in places where high volumes of waste are generated, such as hostels or cafeterias, to maintain the purity of the chemical composition required to obtain high-quality compost.

The local, closed-loop approach also promotes local economic circularity, where the campus can utilise the organic waste to obtain high-quality organic fertilisers instead of commercial ones, for campus horticulture and green belts. Finally, it is recommended that other controlled environments, including hospitals, residential societies, and other settings, adopt the 100% source-weighing methodology established in this study.

Abandoning national average waste data in favour of site-specific, actionable waste data is critical to scaling up effective waste management strategies throughout the region.

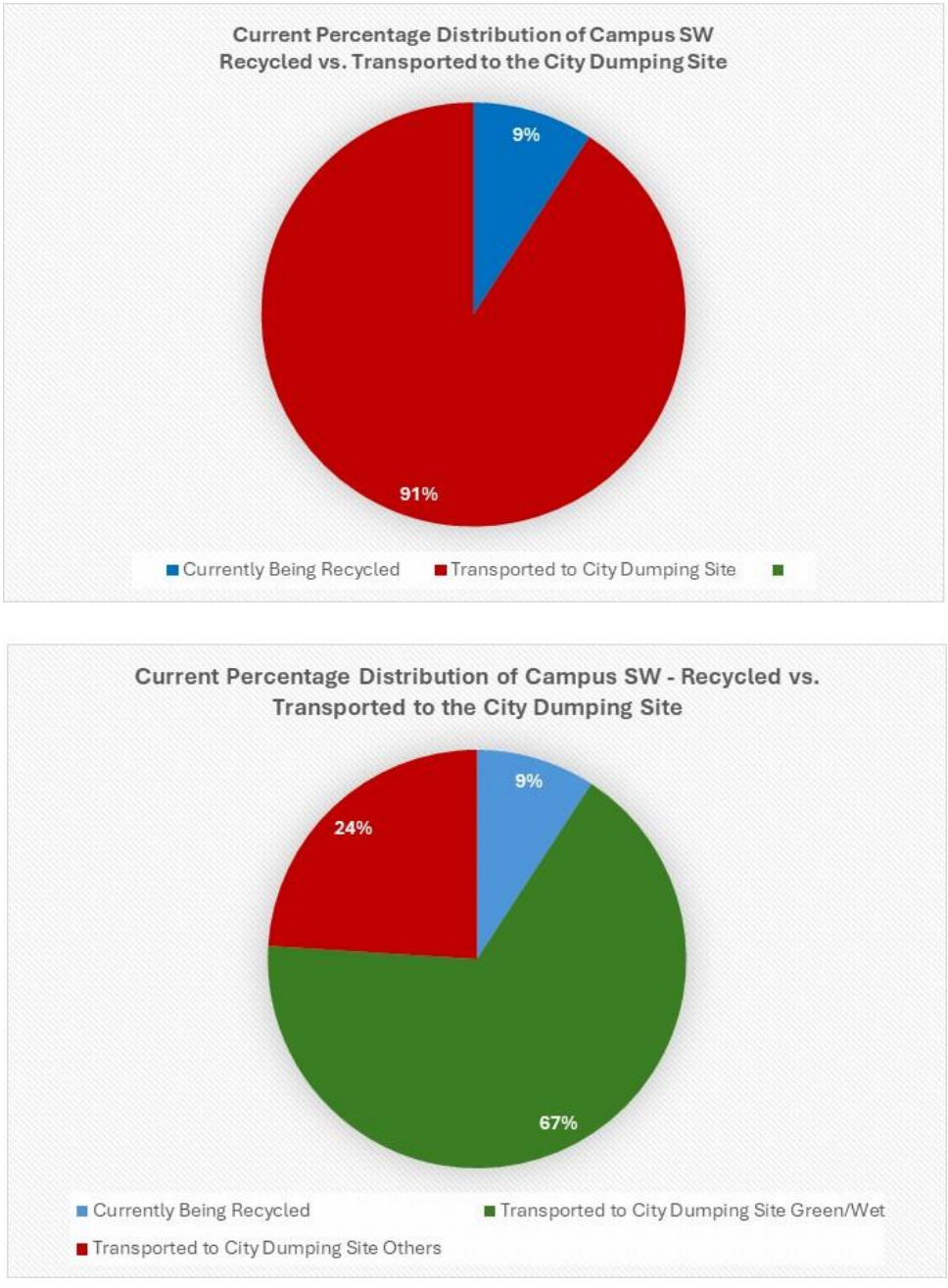


Figure 8. Percentage Distribution of Campus SW by current management pathway - Recovered Materials vs. Waste Transported to the Municipal Dumping Site
(Upper: Overall; Lower: Organic and Other Waste Fractions)

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