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Approaching sustainability and circularity along waste management systems in universities: an overview and proposal of good practices

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In recent years, the importance of sustainability and circularity in waste management systems has become increasingly evident. As the world grapples with the environmental consequences of excessive waste generation, it has become crucial to find innovative and sustainable solutions. Universities, as centres of knowledge and research, play a vital role in achieving sustainability and circularity in waste management. The key contribution of this study is to provide: 1) a systematic review of the existing literature concerning sustainable waste management systems (SWMS) implemented in universities; 2) an analysis of the studies presented in this paper identifying applicable approaches and sustainable practices to provide novel guidelines by including waste management system in a circular and sustainable model within universities. Through research, collaboration, education, implementation of sustainable practices, and support for entrepreneurship, universities can strongly contribute to the development and implementation of sustainable waste management practices. As the world continues to face the challenges of waste generation, universities will continue to be at the forefront of finding innovative, sustainable, and circular solutions.

KEYWORDS

sustainability, circular economy, waste management, separate collection, material recovery, sustainable development

1 Introduction

In recent years, the global community has become increasingly aware of the environmental challenges we face, particularly about waste management. In the world, more than two billion tons of solid waste were annually produced. This value is expected to increase to 3.4 billion tons in 2050s mainly due to the consumer society of the last century (Dinis et al., 2022; Yao and Zhou, 2023). With new limits on waste landfilling and waste production still growing, there is a pressing need for sustainable and circular waste management systems (Ferronato et al., 2019; Rada et al., 2021; Giurea et al., 2022; Ma et al., 2023; Wilson, 2023). Universities, as centres of knowledge and innovation, have a crucial role to play in achieving these goals. They are often compared to small towns because of their size, population and activities that take place on campus. They can accelerate the

transition to a sustainable waste management system (SWMS) since they can promote waste minimization and raise awareness of sustainable waste management strategies; indeed, their staff have the necessary expertise and work with a wide range of stakeholders (Zhang et al., 2011). The universities are nowadays included also in rankings that consider sustainability through indicators that can include waste management (Baricco et al., 2018; Boiocchi et al., 2023; Gomez-Marcos et al., 2023).

Traditionally, waste management systems have followed the linear economy model, where resources are extracted, manufactured into products, and ultimately disposed of as waste. This linear approach not only contributes to waste growth but also puts a strain on natural resources and the environment (Sariatli, 2017; Lag-Brotons et al., 2020; Rada, 2023). A decrease in natural resource consumption and waste generation can be achieved through the implementation of a circular economy and production systems (Macarthur, 2012; Giurea et al., 2022; Yazdani and Lakzian, 2023). This shift in perspective has led universities around the globe to rethink their waste management practices and approach sustainability and circularity in a more proactive manner. It is time for universities to step up and take the lead in adopting sustainable waste management practices (Jakimiuk et al., 2023; Kundokrub et al., 2023). Circular economy is conceptually related to sustainability as it offers a framework for achieving sustainable development by rethinking the traditional linear approach of “take-make-dispose” (Geissdoerfer et al., 2017). Waste management is a pressing issue that affects the environment, public health, and economies worldwide (Cocarta et al., 2009; Cobo et al., 2018; Broz et al., 2023; Chen et al., 2023). Sustainability within the three dimensions (economy, ecology and society) can be achieved through circular economy that promotes the idea of a closed-loop system where resources are recycled, reused, or regenerated to minimize waste and reduce negative environmental impacts while maintaining the economic growth with the aim of preserving natural resources and human well-being (Pla-Julián and Guevara, 2019; Rada, 2023). Therefore, by focusing on sustainability, universities can ensure that their waste management systems are not only environmentally friendly, but also economically and socially responsible. Together, these two concepts work hand in hand to create a more sustainable and circular approach to waste management in universities. The Sustainable Development Goals (SDGs) set by the United Nations aim to address various global challenges and create a more sustainable and equitable world by the year 2030 (United Nations, 2015). One crucial aspect of achieving these goals is waste management (Elsheekh et al., 2021; Di Foggia and Beccarello, 2023) that encompasses waste reduction, recycling, and the responsible disposal of waste. This is an integral part of sustainable development as improper waste management can have severe environmental, social, and economic consequences (Cocarta et al., 2009; Rebehy et al., 2017; Kundariya et al., 2021; Abubakar et al., 2022). The SDGs highlight the importance of sustainable waste management, with Goal 12 specifically focusing on responsible consumption and production (United Nation, 2015).

This work aims to present an overview about possible sustainable approaches that can be implemented in universities for a circular waste management. Based on the literature review, several actions have been proposed in order to improve the quality of

the collected materials and promote the subsequent reuse of waste in a circular economy perspective. The results will be helpful for 1) the scientific community, for studying and developing new actions for sustainable waste management, and 2) the technical stakeholders (namely university managers) for implementing actions to improve.

2 Methodology and approach

2.1 Aims of the work

The scope of the paper is to provide a systematic review of existing literature on sustainable and circular waste management systems in universities. Based on these results, several best practices for a more sustainable management are proposed. The current research aim is gathering information about sustainable waste management practices in different universities. This insight could be used as a starting point for designing and structuring the waste management in universities, specifically where this system is not yet fully developed in agreement with SDGs and Circular Economy indications. In proposing best practices, complex social factors as well as environmental concerns were considered. In this work, feasibility evaluations from an economic and technological point of view were not into consideration. This first step helped identify relevant keywords to be explored in the second literature review phase.

2.2 General approach

To pursue the goal of this paper, identify and collect relevant literature was necessary. Therefore, the method applied in this paper is oriented to map the state of the art of the topic and identify trends of research in literature through the characterization of bibliometric parameters (José de Oliveira et al., 2019). The framework of the method has been adapted according to the needs of the research for a better analysis of the collected data.

Three-step method has been used to collect and analyse relevant data from the existing literature adapting a methodology already used in previous studies (Levac et al., 2010; Abubakar et al., 2022). Figure 1 summarizes the structure of the research activity. The approach involved three steps: 1) Scoping, 2) Defining research strategy and 3) Organisation and analysis of relevant papers.

For a better comprehension of the concept “sustainable waste management system” following approaches of the key components will be presented concerning sustainability and circularity along waste management systems in universities (Table 1).

2.3 Documents selection

The database used for this study was Scopus[®], considered the largest database of abstracts and citations from peer-reviewed research literature in numerous fields (Fahimnia et al., 2015). Only studies published in English were selected. The bibliographic search was carried out from 2017 to early 2023, with the strategy for finding keywords that defines the most suitable combination to fulfil the purpose of the research. The



following keywords were used for data collection: “waste management system,” “higher education institution (HEI),” “university,” “campus,” “sustainability,” “circular economy.” Six combinations of these keywords were used, as follows: 1) “waste management system” AND “higher education institutions (HEI);” 2) “waste management system” AND “university;” 3) “waste management system” AND “campus;” 4) “waste management system” AND “circular economy” AND “higher education institution (HEI);” 5) “waste management system” AND “circular economy” AND “campus;” 6) “waste management system” AND “circular economy” AND “universities” (See Table 2 Start search results). Finally, the articles were selected by reading the abstracts to identify those that developed or have implemented a waste management system with approach on sustainable development and circularity within university.

After the selection in Scopus®, 58 papers were identified, and 22 documents were selected for the subsequent bibliometric and content analysis. For instance, documents that at the same time 1) did not describe implementations or outlooks about waste management system with a focus on sustainable development and circularity, 2) did not analyse these systems from a critical perspective, and 3) did not report new approaches on sustainable waste management in universities were excluded.

3 Results

In this section, the main findings about sustainable waste practices and their associated impacts on the environment found in literature analysis have been summarized and presented. In order to present the results neatly, the selected works have been grouped into two categories: 1) published before 2020, and 2) published after 2020.

3.1 Literature published before 2020

Hannon et al. (2019) focused on the importance of academic collaboration through “living labs” research theory and practice to support the co-generation of innovation in a “university and host city-community” context. According to their study, the role of

“living labs” facilitates education and research to drive progress towards future zero waste cities (Hannon et al., 2019).

Michael and Elser, (2019) studied the employee value and opportunity costs and found that asking all employees to manage their office waste has considerable costs to the university, suggesting the implementation of good practices. They pointed out the existence of a fourth bottom line applied to sustainability-related decisions in universities: education and engagement (Michael and Elser, 2019).

Kusumawanto and Setyowati, (2019) applied the green engineering principles in waste management system to support the sustainable development, minimizing the waste generation. They also promoted the importance of a proper management of university campus waste selecting processing technology based on the main types of waste (Kusumawanto and Setyowati, 2019).

Indirapriyadharshini et al. (2019) evaluated the feasibility of intra-institutional integration of solid waste management through small-scale onsite composting pits. They found that the program for segregation and recycling on a university campus is feasible and some alternatives for the potentially recyclables wastes are discussed (Indirapriyadharshini et al., 2019).

A zero-waste campus was proposed by Yusoff, (2018), adopting projects such as in-house composting centre, food waste segregation scheme, research composting emission and waste characterization, anaerobic digestion, used clothes collection program, wood waste separate collection, e-waste collection and drop-off recycling collection. A diagnosis of chemical and special waste produced in universities have been carried out by Pacheco et al. (2018). They also proposed methodological procedures to acquire and extract response data from a broad and diverse set of special waste generators in a university (Pacheco et al., 2018).

Shankar and Khandelwal, (2017) developed a strategic plan for sustainable waste management on a university campus through the characterization and analysis of waste samples collected from academic buildings, hostels, mess, shopping complex and residential areas for beneficial utilization. They found that potential benefits such as biogas generation from organic waste, resource optimization through 3R concept from paper, plastics, cardboard, glass, and metals can be derived by adopting a suitable waste management strategy (Shankar and Khandelwal, 2017).

TABLE 1 Key components of the present paper concerning SWMS.

Concept	Description/Explication	Approach of the present paper
Sustainability	A study introduced four indicators to assess the sustainability of HEIs: social, economic, environmental, and institutional/educational/political declarations (Aleixo et al., 2018)	Sustainability in the context of waste management systems in universities refers to practices that aim to minimize the environmental impact of waste generation and disposal, while promoting long-term social and economic viability. It involves adopting strategies that prioritize the efficient use of resources, waste reduction, and the adoption of environmentally friendly practices. Sustainability in waste management systems also includes considering social aspects such as community engagement, education, and equity. The economic and technological aspects have not been taken into account in this analysis due to the strong variation depending on a case-by-case basis
	The increased pressure from stakeholders led to the necessity of HEIs to participate in environmental, social, economic, institutional, academic, and political sustainability. Incorporating sustainability into managing and organizing enhances the quality of life for all stakeholders and helps environmental conservation, economy, and society Khodeir and Othman, (2018)	
Circular economy (CE)	One of the first definition of circular economy was proposed by the Ellen McArthur Foundation as a paradigm shift from the previous waste management vision EMAF, (2013). The circular economy is based on a circular system, alternative to the linear ones (Korhonen et al., 2018). However, this concept is under an extensive discussion among the scientific community to find the most suitable definition (Ricciardi et al., 2020). To date, more than 100 of possible definitions have been proposed and can be resumed as an economic system in which, thanks to the 3R approach (reduction, reuse, and recycling), the 'end-of-life' of materials can be overcome (Kirchherr et al., 2017)	CE in the context of waste management systems in universities refers to an approach that seeks to create a closed-loop system, where materials and resources are kept in circulation for as long as possible. It involves minimizing waste generation by focusing on reusing, recycling, and regenerating materials, thereby reducing the reliance on extracting new resources. The CE concept emphasizes the need for collaboration among stakeholders, such as universities, students, staff, and local communities, to create a sustainable and circular waste management ecosystem
Waste	Generally, waste or rubbish is known as unwanted material that results from production processes or from community and domestic activities. The material may be disposed of or accumulated, stored or treated (physically, chemically or biologically) before being disposed of or recycled. Concerning municipal solid waste, the categories into which it is classified are organic and inorganic. Waste can be divided into organic (such as food waste), paper, plastic, glass, metals, and others Hoornweg and Bhada-Tata, (2012)	Waste is any material or substance that is discarded or no longer needed. According to the specialized literature the subject is largely studied and relevant to all sectors/fields/stakeholders Thürer et al. (2017) Pongrácz and Pohjola (2004). Thus, since any product may be wasted, i.e. once a product is discarded and becomes waste, this paper focuses on the specific causes/waste of HEI that would not necessarily be applicable to other sectors/fields
	Defined by European Waste Framework Directive, waste is "any substance, material or object which the holder discards or intends or is required to discard" (European Commission).	
	Waste is an "material, often unusable, left over from any manufacturing, industrial, agricultural or other human processes" (United Nations, 2023a).	
	Waste is any substance that is discarded after its primary use or is valueless, defective, and of no use (Silva et al., 2017)	
Waste management (WM)	Waste management refers to the various schemes to manage and dispose of waste Biology Online, (2023)	Waste management refers to the collection, transportation, and disposal of waste
	The total supervision of waste production, handling, processing, storage, and transport from its point of generation to its final acceptable disposal (United Nations, 2023a).	
	Actions and activities that are needed for managing waste from the start to the final stage of disposal. Some aspects are the collection, transportation, treatment, disposal, monitoring, regulation, and the legal and regulatory framework (Silva et al., 2017)	
Waste management system (WMS)	The main purpose of the waste management system is to minimize the negative environmental impact of waste and its adverse health effects. To fulfill this objective, it is vital to manage waste production, encourage the reuse of waste, support biological recovery and recycling, create awareness of using non-recyclable waste, and guarantee that treatment and disposal of waste have no negative effects Okedu et al. (2022)	WMS is a framework or method for implementing waste management practices. Waste management as a system refers to the streamlined processes that (university) organisations use to manage and safely prevent, reduce, reuse, and dispose of the waste. WMS is based on continuous improvement stage, according to the management systems' theories and practice
	The systems approach of a WMS includes feedback loops, is process-oriented, adaptable and avoids waste disposal and to move towards a sustainable waste management system also requires the identification and implementation of leverage points to drive change Seadon, (2010)	

(Continued on following page)

TABLE 1 (Continued) Key components of the present paper concerning SWMS.

Concept	Description/Explication	Approach of the present paper
	A waste management system can be characterized as the management of all responsibilities, practices, procedures, processes and resources for creating a system that handles waste and adheres to environmental regulations Elsaid and Aghezzaf, (2015)	
Sustainable WMS (SWMS)	<p>In the context of sustainable development, sustainable WMS means adopting practices that meet the needs of the present generation without compromising the ability of future generations to meet their own needs (United Nations, 1987). The transition to a more sustainable society requires a more structured way to manage waste and a sustainable WMS is the key of achieving many of the United Nations Sustainable Development Goals (SDGs), it involves minimizing the use of natural resources by reducing waste generation and promoting long-term environmental, social, and economic wellbeing Lemaire and Limbourg, (2019). Sustainable WM is in the long run part of the UN s Sustainable Development goals in order to reduce the negative impacts of our present-day consumption United Nations, 2023b</p> <p>The comprehensiveness of a WMS can be assessed by the number of connections between the elements of the system. A SWMS aims to minimize the negative impact of waste on the environment and human health while maximizing resource recovery by creating a WMS that minimizes environmental impact, conserves resources, and promotes a circular economy Nelles et al., 2016; Okedu et al. (2022)</p> <p>In recent years, efforts to transit from a linear to a circular economy have become an integrated aspect of waste management design Zhang et al., 2019; Luttenberger, (2020); Adami and Schiavon, (2021); Hemidat et al., 2022; Negrete-Cardoso et al., 2022 and a circular economy is a system that strives for the concept of zero (or very low) waste (Awasthi et al., 2021). Summed up, waste is approached as a resource, as it exists in nature, therefore this circularity is an essential requirement for creating future-oriented waste management services</p>	<p>A sustainable waste management system refers to a set of practices and strategies designed to reduce waste and effectively manage it (that could be part of a university sustainability plan)</p> <p>Additionally, a sustainable waste management system also considers the social and economic implications of waste management</p> <p>A sustainable waste management system is a way of managing waste that takes into account the environmental impact and long-term sustainability of waste management practices. This involves reducing waste, promoting recycling/composting, and using proper waste disposal methods while also considering the social and economic factors</p>

3.2 Literature published after 2020

[Talballa and Gichuru \(2023\)](#) reported about the initiative of Qatar University to move from a make-use-dispose linear economy to a make-use-reuse/recycle circular economy formulating The University Zero-Waste Initiative Vision Action Plan. This plan included: creating governance and monitoring structure, developing a waste measurement and prevention system, using a communication strategy to engage campus users, and promote a culture of innovation. Many practical actions, such as reduce the use of paper stimulating the spread of digital systems and the recycling of food waste as fertilizer after dehydration, were implemented ([Talballa and Gichuru, 2023](#)). [Sawalkar et al. \(2023\)](#) reported that the universities can make their resources more circular by following the strategies of reducing, reusing, and recycling (3R).

[Jaglan et al. \(2022\)](#) pointed out that source separation strategies need awareness campaigns and education in which universities can play a key role. LCA is being used to analyse the present MSW management of the university ([Jaglan et al., 2022](#)).

[Owojori et al. \(2020\)](#) analysed practices on recovery and recycling solid waste (e.g.: bins, for recyclable, compostable, and trash at the academic and administrative buildings, food waste from the kitchen and cafeteria transforming in waste compositions, etc.) at university in a low-middle income country. The characterization of the waste generated and waste separation at source to measure the level of contamination of potentially recoverable materials has been

also reported on as a key aspect of a good management. The partnering with the local community for the collection of food scraps and pre-consumer food waste was also proposed ([Owojori et al., 2020](#)).

[Hadzi-Nikolova et al. \(2022\)](#) focused on the partnership with the community, promoting the role of universities in the context of increasing awareness by the local population and hospitality enterprises for separation, collection, and composting of the organic waste. [Shooshtarian et al. \(2022\)](#) reported about the research collaboration with industry experts to facilitate knowledge transfer between research institutes and the industry.

The research collaboration within community to investigate plastic waste recycling system, with the aim to find out to what extent the current performance fulfils the future scenario established by the European Commissions, was analysed by ([Foschi et al., 2021](#)).

[Ramdan et al. \(2023\)](#) evaluated the waste management practice, waste generation and characteristics of the solid waste management system in universities focusing on the general knowledge of solid waste management, awareness, and personal behaviours.

Also [Putrantomo et al. \(2021\)](#) took into consideration to overcome barriers in solid waste management in universities by implementing an "Environmental Management System". Five main potential barriers are identified: lack of commitment from the management of the stakeholders; lack of financial resources; lack of expertise on EMS; organizational; lack of engagement from student, staff, and faculty ([Putrantomo et al., 2021](#)).

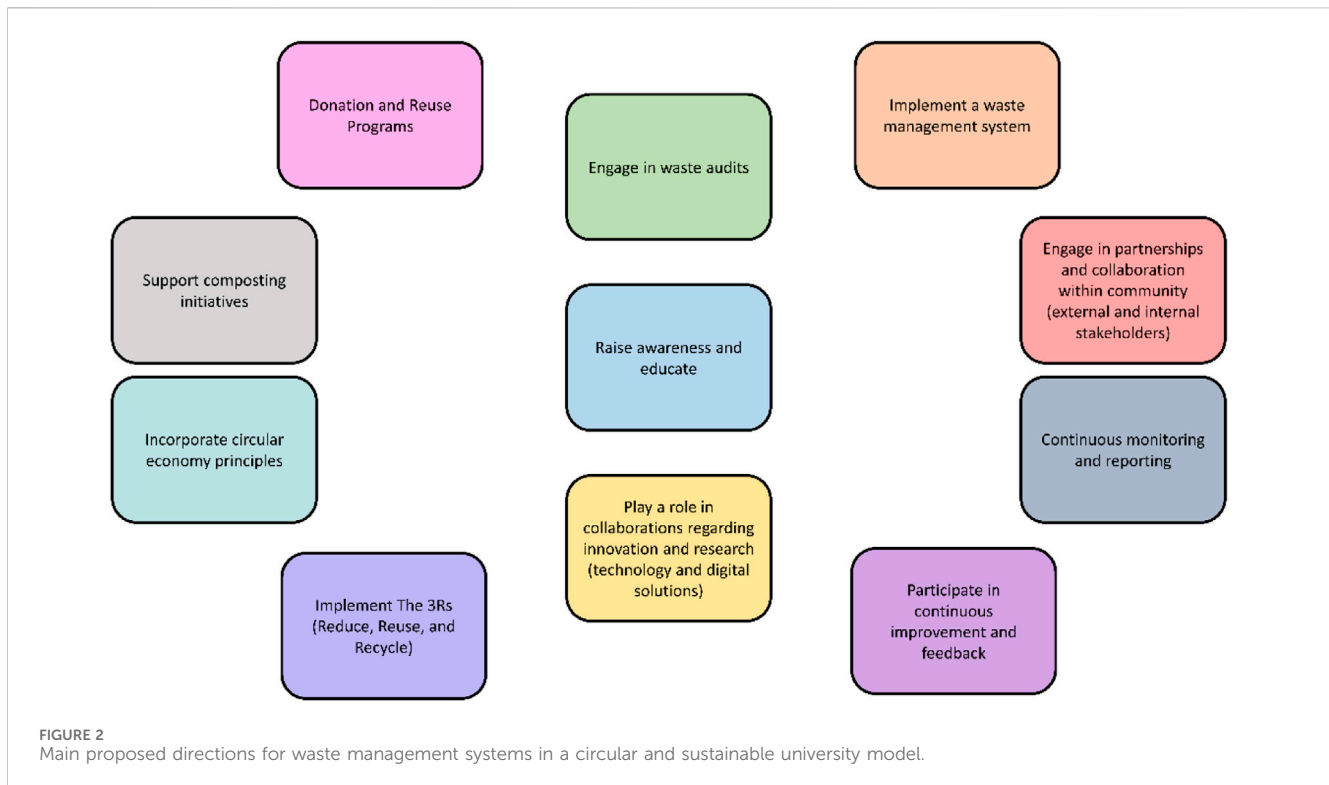
TABLE 2 Applicable approaches and sustainable practices for waste management systems in a circular and sustainable university model.

Approaching sustainability and circularity along waste management systems in universities	
Directions	Explanation and good practices
Engage in waste audits	<ul style="list-style-type: none"> • Conducting regular waste audits to assess/understand waste generation patterns, identify areas for improvement, and track progress. This can help in identifying sources of waste, implementing targeted reduction strategies, evaluating the effectiveness of waste management initiatives
Implement a waste management system	<ul style="list-style-type: none"> • Establish a comprehensive waste management system that includes proper waste segregation, recycling facilities, and composting infrastructure. This system should cover all areas of the university campus, including classrooms, laboratories, offices, libraries, kitchen and cafeteria and student residences
Engage in partnerships and collaboration within community (external and internal stakeholders)	<ul style="list-style-type: none"> • Collaborating with local waste management agencies, recycling facilities, and community organizations to ensure proper disposal and recycling of different waste streams. This can include establishing partnerships for waste collection and recycling services or participating in local waste management initiatives • Engage students, faculty, and staff through partnerships with local waste management agencies, environmental organizations, and sustainable businesses. Collaborate on waste reduction initiatives, research projects, and awareness campaigns • Engage the university community through an active encourage participation and engagement from the entire university community. This can be done through student-led initiatives, forming sustainability committees, and involving staff and faculty members in decision-making processes related to waste management
Play a role in collaborations regarding innovation and research (technology and digital solutions)	<ul style="list-style-type: none"> • Encouraging innovation and research in waste management practices and technologies. Supporting academic and student-led initiatives to find sustainable solutions for waste reduction, recycling, and resource recovery can contribute to continuous improvement in waste management practices • Encourage interdisciplinary collaborations between students, researchers, and staff to develop and assess sustainable waste management solutions • Conduct research on innovative waste management technologies and initiatives that can be implemented on campus • Adopt digital platforms and technologies to monitor waste generation, track recycling rates, and streamline communication between departments, facilities management, and the waste management team. This can help identify areas of improvement and measure the effectiveness of waste management practices • Establish partnerships with industry experts and waste management organizations to stay updated on best practices and emerging trends
Raise awareness and educate	<ul style="list-style-type: none"> • Conduct regular educational campaigns and workshops to raise awareness among the campus community regarding the importance of waste management and sustainable practices. Involve students in waste management decision-making processes and provide opportunities for innovation and engagement • Conduct regular awareness campaigns and educational programs among the campus community regarding the importance of waste management and sustainable practices • Promoting waste management literacy and environmental awareness among students, faculty, and staff. Offering educational programs, workshops, and training sessions can help individuals understand the importance of waste management and their role in the process. Provide training and guidelines on proper waste management practices, such as reducing plastic waste, reusing materials, and responsibly disposing of hazardous waste • Encourage interdisciplinary collaborations between students, researchers, and staff to develop and assess sustainable waste management solutions
Support composting initiatives	<ul style="list-style-type: none"> • Set up composting facilities on campus for organic waste generated from dining halls, food courts, and gardens • Encourage the use of compostable food containers, utensils, and packaging • Educate the university community on the proper segregation of organic waste and its benefits for soil health and the benefits of composting for soil health and reducing greenhouse gas emissions • Establish on-site composting facilities to divert organic waste from landfills

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TABLE 2 (Continued) Applicable approaches and sustainable practices for waste management systems in a circular and sustainable university model.

Approaching sustainability and circularity along waste management systems in universities	
Directions	Explanation and good practices
	<ul style="list-style-type: none"> • Encourage the use of compostable materials, such as biodegradable food containers and utensils • Set up composting systems to divert food and organic waste from landfills. Encourage the use of compostable packaging and support student-led initiatives such as community gardens or composting clubs
Donation and Reuse Programs	<ul style="list-style-type: none"> • Establish donation and reuse programs on campus to give new life to unwanted items • Encourage students and staff to donate clothes, furniture, textbooks, and other items that can be reused by others
Implement The 3Rs (Reduce, Reuse, and Recycle)	<ul style="list-style-type: none"> • Reduce: <ul style="list-style-type: none"> o Encourage the use of electronic communication and digital platforms to minimize paper waste o Promote sustainable procurement policies, including purchasing goods with minimal packaging and selecting products made from recycled materials o Encourage students and staff to bring reusable water bottles, coffee cups, and food containers to minimize single-use plastic waste o Organize awareness campaigns and educational programs to encourage responsible consumption and waste reduction • Reuse: <ul style="list-style-type: none"> o Set up designated areas for donating and collecting reusable items like textbooks, electronics, furniture, and clothing o Promote the use of reusable shopping bags instead of single-use plastic bags o Establish a system for distributing second-hand goods or materials within the university community o Encourage staff and students to repair and repurpose items rather than replacing them • Recycle: <ul style="list-style-type: none"> o Establish accessible and clearly marked recycling stations throughout the university campus o Implement a comprehensive recycling program that covers various materials like paper, plastic, glass, and metal o Educate the campus community about proper recycling practices through workshops or informative signage o Collaborate with local recycling facilities or waste management companies to ensure proper collection and processing of recyclables o Consider implementing composting programs for organic waste, such as food scraps and yard waste, to reduce landfill disposal
Participate in continuous improvement and feedback	<ul style="list-style-type: none"> • Encourage feedback from the university community to continuously improve waste management practices. This can include regular surveys, suggestion boxes, or feedback sessions to gather input and ideas for further enhancing sustainability efforts
Incorporate circular economy principles	<ul style="list-style-type: none"> • Promote the concept of a circular economy within the university. This involves designing products and systems that minimize waste generation and maximize material reuse or recycling. Universities can support research and innovation in areas such as sustainable packaging, product lifecycle analysis, and circular design • Implementing circular economy principles by prioritizing waste-to-resource approaches. This can involve setting up schemes for reusing or repurposing materials, encouraging second-hand markets, supporting repair and refurbishment initiatives, and developing partnerships with local businesses or organizations for material exchange or upcycling
Continuous monitoring and reporting	<ul style="list-style-type: none"> • Implementing monitoring systems and reporting mechanisms to track waste management performance and evaluate the effectiveness of sustainability initiatives. <ul style="list-style-type: none"> o Regularly reporting on waste management metrics and targets can promote accountability and transparency (e.g. regularly monitor waste generation, recycling rates, and composting processes on campus) o Evaluate the effectiveness of waste management initiatives through data analysis and feedback from the university community o Continuously improve the waste management system based on identified gaps and opportunities)



Vasconcelos et al. (2021) focused on the perception of sustainability by university students and studied how the university decision-makers could improve the sustainable practices to increase the students' engagement. The interaction between formal and informal waste management actors in this context are well described by (Chikowore and Kerr, 2023).

Ramasawmy and Nagowah, (2023) found that a "Smart Waste Management" system, meaning waste monitoring system suggesting the integration of internet of things and machine learning for real-time monitoring of the bins and the waste predictions, could facilitate the university to take proactive measures.

User friendly application model for chemical waste inventory and management at the engineering laboratories were promoted and developed by Jammoul et al. (2023). This highlighted the importance of using technological tools in waste management.

Nguyen et al. (2021) carried out a waste audit to evaluate the total emission and characteristics of the solid waste generated by a university campus. Simultaneously, the 3R program was applied for assessing the status of a waste management practice system. This same system at source proved to raise the awareness of students toward environmental protection (Nguyen et al., 2021).

4 Discussion and proposal of good practices

This section presents a guide for consolidating research directions from the reviewed literature and provides elaborations of recommendations with examples specific to developing a more sustainable and circular waste management system within

universities. Achieving this goal requires a combination of different approaches and best practices.

By integrating these approaches and best practices, universities can create a more sustainable and circular waste management system, contributing to environmental conservation and promoting a responsible waste management culture among students, staff, and community. To develop and achieve sustainable and circular waste management systems within universities and to create innovative guidelines, the approaches reported in Figure 2 and detailed in Table 2 could be adopted and promoted.

In the context of universities, these concepts mean implementing waste management systems that prioritize the reduction of waste generation through practices like waste prevention, recycling, composting, and the use of renewable materials. It also involves promoting awareness and education about waste management among students, staff, and the wider university community. Sustainability and the CE can further encourage universities to collaborate with local communities, businesses, and waste management authorities to develop innovative solutions and technologies for more sustainable waste management practices. By adopting these principles, universities can strive towards a more sustainable and circular approach to waste management that aligns with broader sustainability goals.

The following are suggestions for future research on this subject to extend the findings. Relevant aspects from the literature are included below to provide a comprehensive overview of the topic:

- **Green Purchasing:** Green purchasing refers to the practice of making sustainable and environmentally conscious purchasing decisions. It involves considering the

sustainability and circularity aspects of products and services, especially with regards to waste management systems in universities. There are many ways on how green purchasing can be integrated into waste management systems in universities, focusing on sustainability and circularity e.g. sustainable procurement policy, supplier selection, product assessment, green cleaning supplies, paperless practices (Fachrudin, et al., 2019; Naz et al., 2020). Encourage the procurement of sustainable and environmentally friendly products. Prioritize suppliers who focus on reducing packaging waste, offer environmentally friendly alternatives, and promote recycling and take-back programs (Khan et al., 2022).

- Upgrade waste management infrastructure: Waste management infrastructure in universities typically includes a combination of strategies and facilities to reduce, reuse, recycle, and dispose of various types of waste generated on campus e.g. recycling programs waste sorting facilities, hazardous waste disposal, composting systems (Zhang et al., 2011). Investing in efficient and effective waste infrastructure is crucial for the success of a sustainable waste management system (Esmailian et al., 2018). This can include installing compactors, balers, and other waste management equipment to properly handle and manage waste on campus.

5 Conclusion

In conclusion, integrating practical and innovative sustainability and circularity findings into waste management systems in universities can have several benefits. These include reducing the environmental impact of waste generated by the campus, showcasing the institution's commitment to environmental stewardship, and serving as role models for students and the broader community. Additionally, integrating innovative waste management practices can lead to cost savings and improved resource efficiency. Correspondingly adopting efficient waste segregation, (e.g., implementing a comprehensive recycling program with separate bins for different types of waste, including paper, plastics, and e-waste, can ensure that valuable resources are recovered and reused) and recycling practices (e.g., initiatives to reduce single-use plastics on campus by providing alternatives such as reusable water bottles and offering water refill stations), universities can reduce the amount of waste sent to landfills and promote the reuse of valuable resources. Can also be implemented sustainable procurement policies that prioritize environmentally friendly and sustainable products and technology-driven solutions such as smart waste bins and waste-to-energy systems can further optimize waste management processes. Additionally, universities can encourage research and development activities that focus on developing new methods for waste reduction and conversion. By continuously adopting various management practices to approach sustainability and circularity in waste management systems, universities can contribute significantly to creating more sustainable and circular waste management systems.

Universities have a vital role to play in achieving sustainability and circularity along waste management systems. Through

education, research, collaboration, and advocacy, universities can drive significant change and contribute to a more sustainable future. These results are valid in universities where there are research and dissemination activities and/or educational programs that deal with aspects of environmental protection but are potentially also applicable in those educational structures that do not present research activities or whose teaching activity does not specifically deal with topics related to environmental protection. In this sense, the implementation of actions aimed at minimizing the production of waste and increasing the percentage of waste destined for recycling is potentially feasible in all educational contexts. By harnessing their intellectual resources and fostering partnerships, universities can be at the forefront of the transition towards a more sustainable and circular approach to waste management. Overall, universities should strive to integrate sustainability and circularity principles into waste management systems through a combination of infrastructure, awareness, education, collaboration, and innovation. By implementing these approaches and best practices, universities can develop a more sustainable and circular waste management system, reducing their environmental impact and preparing students for a future driven by sustainable practices. However, it should be noted that before any implementation a feasibility study should be carried out from an economic and technological point of view to evaluate the best solutions on a case-by-case basis.

Data availability statement

The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

Author contributions

RG: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Resources, Validation, Visualization, Writing–original draft. MCM: Data curation, Investigation, Validation, Visualization, Writing–review and editing. VT: Validation, Visualization, Writing–review and editing. ER: Conceptualization, Investigation, Methodology, Supervision, Validation, Visualization, Writing–review and editing.

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