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A COMPREHENSIVE WASTE AUDIT ANALYSIS FOR ASSESSING RECYCLING OPPORTUNITIES IN THE UNIVERSITY

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Abstract

Higher Education Institutions (HEIs) have been encouraged to evaluate and utilize their substantial capacity for waste diversion, recovery, and recycling in response to Sustainable Development Goals (SDGs) set for the current decade. A significant transition is necessary for society as a whole to move toward sustainable development. Solid waste is a serious environmental problem these days. Due to the substantial population and numerous activities taking place on the campus, the university inevitably generates a significant amount of solid waste from various sources. Implementing source reduction, recycling, and composting not only enhances environmental outcomes but also imparts knowledge about sustainability to students and result in cost savings by reducing the amount of solid waste. The overall aim of the study is to determine the existing solid waste management (SWM) practices and evaluate recycling potential within female campus of the International Islamic University, Islamabad (IIUI). Solid waste samples were categorized using the American Society for Testing and Materials (ASTM) D5321-92 method for unprocessed solid waste. Over a period of twenty working days, the results found an average of 145.35 kg of waste was produced per week. The average waste composition consisted of 33.74 kg (23%) of paper and cardboard, 22.73 kg (15%) of plastics, 33.87 kg (23.3%) of food waste, and 11.7 kg (8%) of other wastes. During the study period, the waste generated comprised recyclable (55%), compostable (28%), and non-recoverable components (17%). A waste audit conducted over a span of twenty working days unveiled a significant potential for recycling (55%) within the institution. This study highlights the relevance of SDG-12 by assessing waste management practices, promoting recycling and food waste reduction, and fostering sustainability knowledge among students.

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Index Terms: Higher education, Recycling potential, Waste audit, Waste characterization, Waste generation, Waste management

1. INTRODUCTION

Solid waste is unwanted non-liquid and non-gaseous material. It can be classified into four types based on the source of generation; municipal solid waste (MSW), industrial waste, hospital waste, and agricultural waste. Each type has its own characteristics and management requirements [1]. The escalating global population has intensified the gravity of the waste problem, making it a paramount concern. According to International Trade Administration's (ITA) report published in 2022, Pakistan produced 49.6 million tons of waste annually, lacking proper infrastructure. Improper waste management practices pose environmental and health risks. Only 50-60% of MSW is collected by municipalities [2]. An increase in solid waste has resulted from the change in consumption patterns, posing a significant challenge for recycling and management, particularly in developing countries, where efficient collection and disposal methods are crucial for public and environmental health [3,4,5]. To address these issues, it is crucial to provide comprehensive education at all levels, with educational institutions and universities playing a key role in attaining sustainable development [6,7,8,9]. According to [10] and [11], Haramaya University (HU), Ethiopia was found to produced 3,509,077.15 kg/yr of waste, while Imam Abdulrahman Bin Faisal University (IAU) in Saudi Arabia generated 1350 kg/day of MSW. Western Kentucky University implemented a successful sustainability program, while the Federal Institute of Higher Education, Brazil focused on environmental awareness and training [12,13,14].

Universities as higher educational institutions (HEIs) should promote sustainability and integrate it into educational and research programs to raise public awareness. The study aim is to determine the existing practices of solid waste management (SWM) in the female campus of International Islamic University, Islamabad (IIUI). The purpose of the study is to conduct a waste audit to quantify the amount and types of waste generated in the female campus of the IIUI, and secondly to determine the potential for recycling the solid waste produced on campus. Sustainable waste management requires knowledge for waste composition and its source to enable informed decision making for optimizing services [15]. Sustainable development, a significant concept in the mid-20th century, forms the overarching framework for the United Nations (UN) [16,17,18,19]. Integrating sustainability, including waste management, is crucial for developing nation's health, environment, and economy, aligning with the UN's 2030 Agenda and sustainable development goals (SDGs)(20,21). Various high quality sustainable practices have been implemented such as establishing of organic botanical gardens [22], integration of green energy [23], effective water management strategies [24], solid waste management [25], green building initiatives [26], recycling awareness campaigns, conservation of natural resources [27], sustainable laboratories, and environmental/sustainability initiatives to monitor carbon footprints in universities [28].

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Accurate data on waste amount and composition are essential for effective planning and administration of SWM in academic institutions [29]. Poor waste management and increased waste generation can pose significant threats to human welfare and environment according to a study conducted by [30,31,32]. Effective SWM systems require a comprehensive understanding of waste stream, including generation, recycling potential, and waste characterization. Although research has primarily focused on municipal waste, the healthcare industry and waste management in higher education have received less attention. This study finding will help IIUI to meet the targets of SDG 12 by assessing waste management practices and identifying opportunities for recycling and composting. This study is crucial for universities to develop SWM policies and address the increasing waste quantity in educational institutions, ensuring proper collection, transportation, segregation, recycling, and disposal to tackle health and environment [1]. The initial stage of any successful waste management strategy, as stated by [33] is waste characterization. The foremost objective of efficient Integrated Solid Waste Management (ISWM) system is to promote the reuse and recycling of materials, and ensuring proper waste management practices for the well-being of both humans and environment [34].

[35] demonstrate that the fraction of waste categorized by [36] can be recycled, reused, and used to generate energy.

Universities have an ethical obligation to manage waste sustainably for institutional sustainability, as highlighted by [37] while also setting an example for students and the community, as emphasized by [38]. Integrating sustainability into education and research programs, as advocated by [39], promotes environmental awareness. Waste audits, as discussed by [40] and [41], provide valuable data for education, program implementation, assessment, supporting environmental protection, and improvement of waste management techniques. In HEIs the generation of solid waste and the lack of proper waste management plan are significant concerns. In view of the increasing solid waste and poor management practices in the female campus of IIUI, conducting a comprehensive audit is necessary to evaluate the quantity, composition, and current waste management practices. In view of the above scenario, the present study aims to identify the prevailing practices of SWM including waste quantity and quality, and to identify the potential for recycling solid waste at IIUI.

2. MATERIALS AND METHODS

The International Islamic University Islamabad is situated in the H/10 sector of Islamabad, with coordinates approximately 33.6508° N latitude and 73.0642° E longitude. The dumping site at the female campus of IIUI was chosen for this project, where waste was collected from various sources. The study focused on key areas such as academic blocks, gardens, cafeteria, and refreshment center to characterize the waste. The academic calendar is structured into two semesters: the spring semester span from February to June and the Fall semester starts from September to January. During these semesters,

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the campus is bustling with activities, primarily occupied by staff and students, including day scholars.

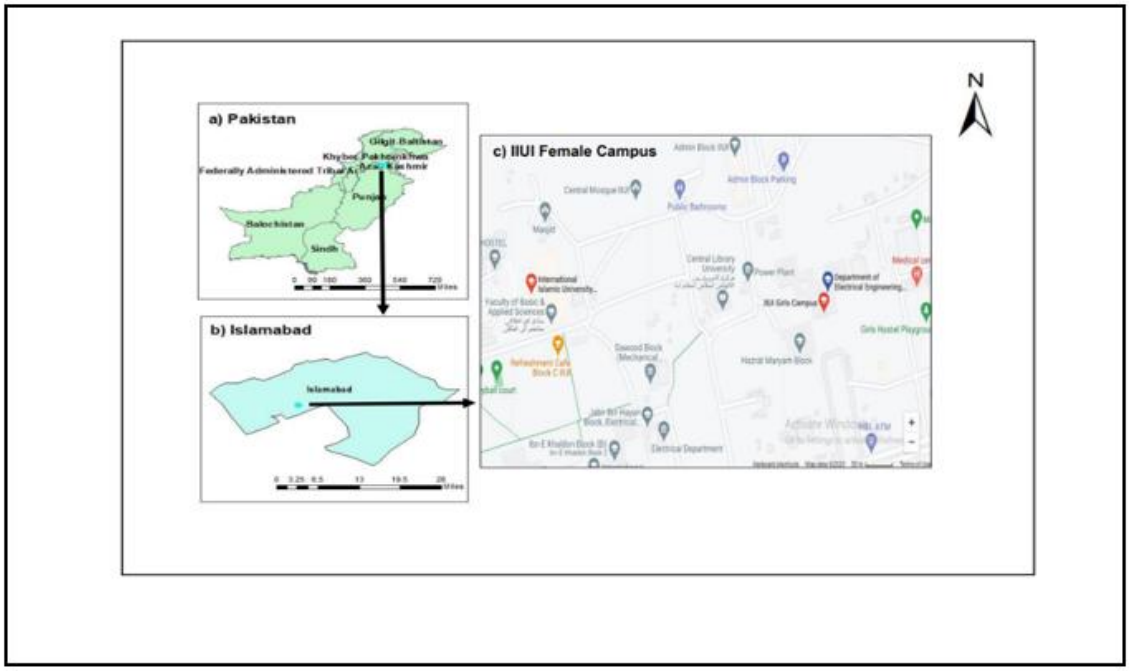

Figure 1: Study area map showing a) the provinces of Pakistan; b) area of Islamabad; c) female campus of IIUI

2.1. Data Collection

The solid waste collection truck serves the female campus by collecting routine waste from campuses, cafeterias, and gardens. The waste is then disposed of in a designated area. A waste audit was conducted after getting approval from relevant authorities, and a meeting was arranged to discuss objectives and raise awareness. The audit took place for twenty working days, from Feb 27th to Mar 17th, 2023, between 10:00 am and 05:30 pm, which included the period of Ramadan. Waste was sorted into categories at the collection point using tongs, with the assistance of a small team of volunteers. Portable weighing balances were used to measure the weight of each category. Existing solid waste management staff and facilities at the university campus facilitated the collection and transfer of waste. The audit data, including the total weight of waste and its categories, were recorded on audit sheets to assess the characteristics of waste and recycling potential at the female campus, IIUI.

2.2. Waste Characterization

Waste was sorted manually into different categories and weighted at the characterization site. The composition of the unprocessed solid waste was analyzed using the ASTM (American Society for Testing and Materials) D5231-92 test method as recommended by

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[29]. Categories such as, paper, cardboard, glass, plastic, Styrofoam, aluminium, food waste, and garden waste were determined based on their significant presence. Table 1 displays the main waste categories that were identified during the waste characterization process.

Table 1: Solid Waste Categories and Main Source

Items	Classification
Styrofoam	Hot beverages cups and plates
Paper and cardboard	Packaging cardboard and paper
Plastic wrappers	Wrappers, cling sheets, plastic shopping bags
Plastic	Bottles, spoons, cups, straws
Aluminum	Beverage containers, tins, wires
Food waste	Pre-processing waste, post processing waste, excess food
Garden waste	Grass clippings, leaves
Mix waste	Dirt, textile, miscellaneous, sanitary waste
Glass waste	Glass bottles

2.3 Data Analysis

All the recorded information was screened for error and entered in excel spreadsheet for further analysis. The percentage of recyclable waste in each sub category was determined using Equation (1),

$$\% PR = \frac{WS}{WI} * 100 \qquad (1)$$

where PR = percentage recyclable, WS = weight of sub-category, and WI = weight of the initial sample [29]. The waste composition was calculated using ASTM test equation (1), and mean waste composition and standard deviation were analyzed for each waste category. MS Excel was used for graphical representations.

3. RESULTS

3.1 Current Situation of Solid Waste Management on the Campus

During the walk-through survey in the female campus, it was observed that there were 23 workers, including a supervisor and janitorial staff, involved in SWM. The existing practices of waste management were unsatisfactory. Waste was collected and dumped into a trolley located at the far end of the campus. The number of workers was insufficient for the university's population, and waste segregation was not possible due to the lack of awareness and absence of color coded bins. Moreover, workers were not provided with personal protective equipment's like masks and gloves for performing the task of waste management.

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3.2 Waste audit/characterization at female campus

From Monday 27th Feb to Friday 3rd Mar 2023, an average of 175.06 kg of waste was generated during the initial (first) week of the audit. Figure 2 shows the calculated amount of all categories during the first week of the audit.

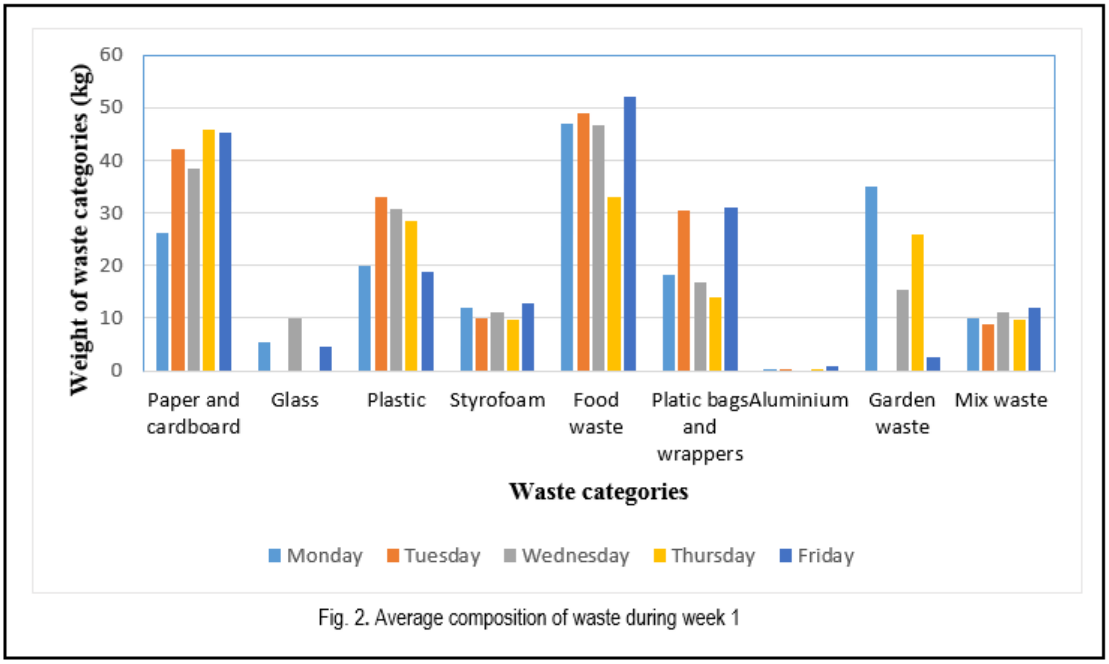

Figure 2: Average composition of waste during week 1

Figure 2 indicates the average waste composition during week 1. The student cafeteria was found to generate the highest amount of organic waste (45.60kg), while garden waste weighs approximately 15.76 kg. The university waste includes significant amount of paper and cardboard (39.57 kg), Styrofoam 11.14kg), plastic (26.23 kg), plastic bags and wrappers (22.17 kg). Approximately 190.62kg of waste was examined and evaluated from the waste stream in the second week between the dates of Monday 6th March and Friday 10th March 2023. Table 2 illustrates the composition breakdown of the audited waste.

Table 2: The Average Composition of Waste during Week 2

Week Days	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	
Date	**6th Mar**	**7th Mar**	**8th Mar**	**9th Mar**	**10th Mar**	**Average**
Waste Categories	Waste (kg)	Waste (kg)	Waste (kg)	Waste (kg)	Waste (kg)	Waste (kg)
Paper and cardboard	47.04	47.89	63.84	31.9	60.14	**50.16**
Glass		0.77	1.5	5.97	5.02	**2.65**
Plastic	45.9	7.62	22.14	9.25	17.59	**20.5**
Styrofoam	18.78	26.14	12.81	13.32	12.84	**16.78**

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Food waste	34.95	76.7	65.14	63.34	61.01	**60.23**
Plastic bags & wrappers	22.26	27.24	19.63	21.17	16.5	**21.36**
Aluminum				0.14	0.5	**0.12**
Garden waste	10.3		5.56			**3.18**
Mix waste	20.18	14.61	18.9	8.25	16.2	**15.62**
Total waste	**199.4**	**200.9**	**209.53**	**153.35**	**189.8**	**190.6**

Table 2 shows that the food waste accounted for the largest portion (60.23kg), followed by paper and cardboard (50.16kg). Styrofoam weighed 16.78kg, while plastic bags and wrappers weighed 21.36kg. Glass weighed 2.65kg, plastic weighed nearly 20.50kg, and only a small amount of garden waste (3.18kg) and aluminum (0.12kg) were observed. During the 3rd week of the audit from Monday 13th March to Friday 17th March, 2023 an average of 201.88 kg of waste was generated. The waste composition for week 3 is presented in figure 3.

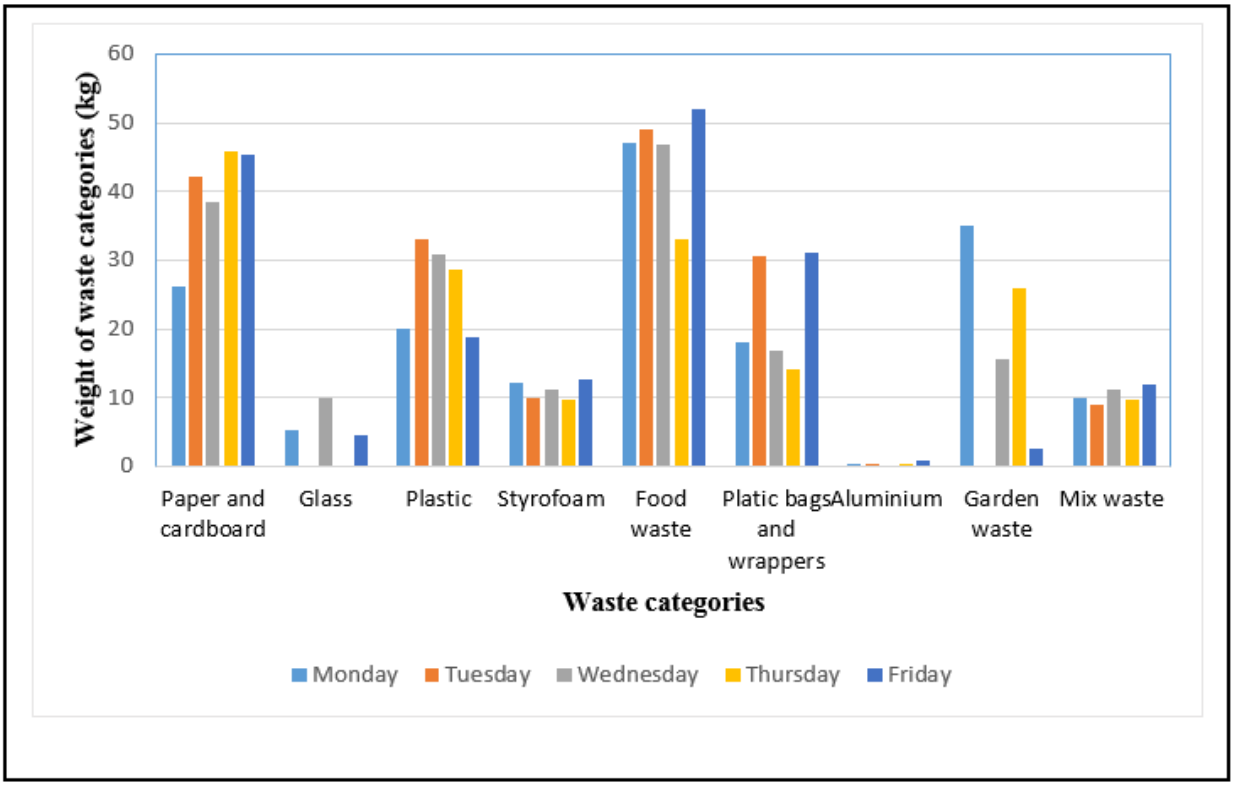

Figure 3: The average composition of waste during week 3

During the third week of the waste audit, paper and cardboard accounted for 42.61 kg, plastic bottles weighed 43.46 kg, and plastic bags and wrappers weighed 30.15 kg. Styrofoam, food waste, and glass contributed 27.22 kg, 24.52 kg, and 9.37 kg, respectively. There was a small amount of garden waste (4.42 kg) and aluminum (1.19 kg). The spring gala and entrepreneurial activities were organized (Monday and Tuesday)

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which led to variations in waste composition, with an increase in styrofoam and paper. The reduction in food waste was due to the pre-pared food at stalls and closure of cafeterias. The availability of cold beverages and fast food led to an increase in plastic waste, and sport competitions contributed to the use of glass bottles for drinks.

Table 3: Weekly Mean and Standard Deviation of Waste

Materials	Category	Week 1 (kg)	Week 2 (kg)	Week 3 (kg)	Week 4 (kg)	Mean	Standard Deviation	Percentage
Recyclables	**Paper and cardboard**	39.57	50.16	42.61	2.64	33.74	21.21	**23.21**
	Glass	3.97	2.652	9.37	0.15	4.03	3.89	**2.77**
	Plastic	26.2	20.5	43.4	0.72	22.73	17.59	**15.63**
	Plastic bags and wrappers	22.17	21.36	30.15	1.7	18.8	12.09	**12.96**
	Aluminum	0.23	0.12	1.19	0.01	0.39	0.54	**0.26**
Compostable	**Food waste**	45.6	60.23	24.5	5.12	33.87	24.13	**23.3**
	Garden Waste	15.7	0.18	4.42	0.04	5.1	7.36	**3.51**
Non-recoverable	**Mix waste**	10.37	15.62	18.9	2.22	11.78	7.27	**8.1**
	Styrofoam	11.14	16.78	27.22	1.2	14.08	10.87	**9.69**
Total						**144.53**	**104.97**	**99.48**

Table 3 shows the mean and standard deviation of twenty working days of different categories. The month of Ramadan falls from March 23 to April 21, 2023. The average waste during Ramadan days weighs about 13.83 kg of solid waste. Table 4 indicates the calculated amount of each category observed throughout Ramadan. Table 5 shows a significant difference in waste generation between normal days and Ramadan. On normal days the waste produced on average was 145.35 kg whereas in Ramadan the waste quantity is reduced drastically to almost 13.8 kg. Figure 4 demonstrates the significant variation of waste throughout the twenty working days including the five days of Ramadan.

Table 4: The Average Composition Of Waste During Ramadan

Week Day	Monday	Tuesday	Wednesday	Friday	Thursday	Average
Date	**27th Mar**	**28th Mar**	**5th Apr**	**14th Apr**	**20th Apr**	
Waste Categories	Waste (kg)	Waste (kg)	Waste (kg)	Waste (kg)	Waste (kg)	**(kg)**
Paper and cardboard	2.5	3.2	2.3	2.7	2.5	**2.64**
Glass	0	0	0	0.02	0.75	**0.15**
Plastic	0.37	0.5	0.75	1.23	0.75	**0.72**
Styrofoam	1.7	1	0.8	0.53	2	**1.2**
Food waste	4	6	5	4.53	6.08	**5.12**
Plastic bags and wrappers	1.5	1	1.7	2.27	2.05	**1.7**
Aluminum	0	0	0.02	0	0.05	**0.01**
Garden waste	0	0	0	0.23		**0.04**

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Mix waste	1.5	1.5	2.45	3	2.67	**2.2**
Total waste	**11.57**	**13.2**	**13.02**	**14.5**	**16.85**	**13.8**

Table 5: Comparison of Ramadan Days And Normal Days

Waste Categories	Ramadan Days		Normal Days	
	Average (kg)	Percentage	Average (kg)	Percentage
Paper and Cardboard	2.64	19.08	44.11	23.44
Glass	0.15	1.12	5.33	2.83
Plastic	0.72	5.20	30.06	15.97
Styrofoam	1.20	8.67	18.38	9.76
Food waste	5.12	37.01	43.45	23.09
Plastic bags and wrappers	1.70	12.3	24.56	13.05
Aluminum	0.01	0.10	0.51	0.27
Garden waste	0.04	0.33	6.78	3.60
Mix waste	2.22	16.04	14.97	7.95
Total Waste	13.8	99.89	188.16	99.98

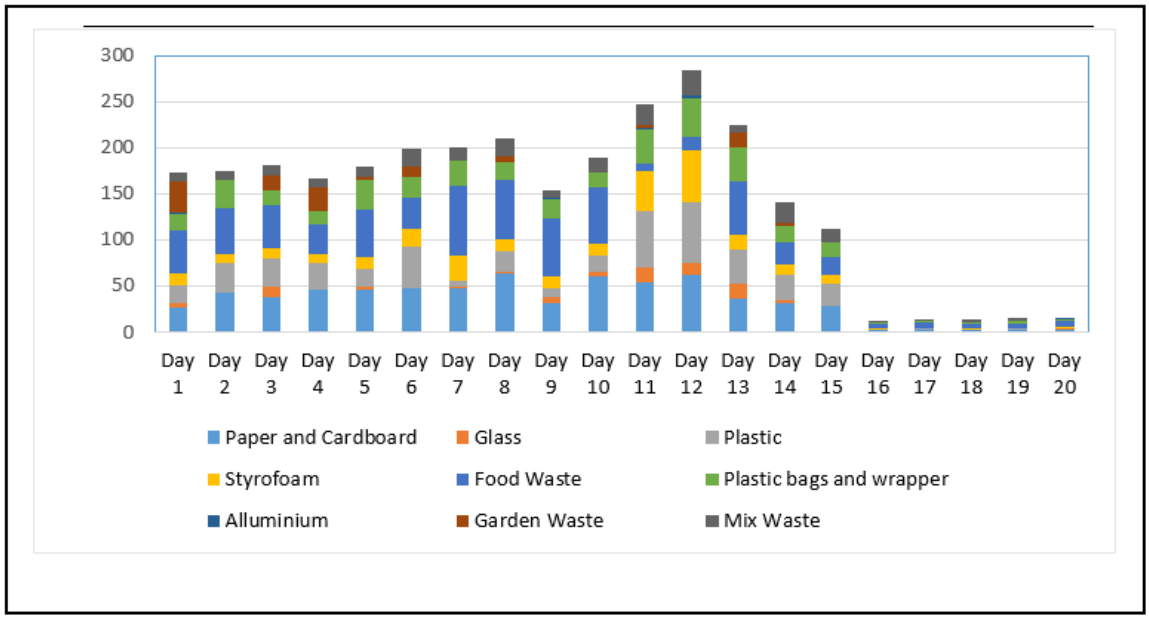

Figure 4: Significant variation of twenty working days

3.3 Recycling potential

A waste audit was conducted to determine the recycling potential of solid waste at the university campus. The waste was categorized as recyclable, compostable, and non-recoverable. The results showed that 55% of the waste was recyclable, 28% was compostable, and 17% was non-recoverable. Figure 5 illustrates the composition of waste.

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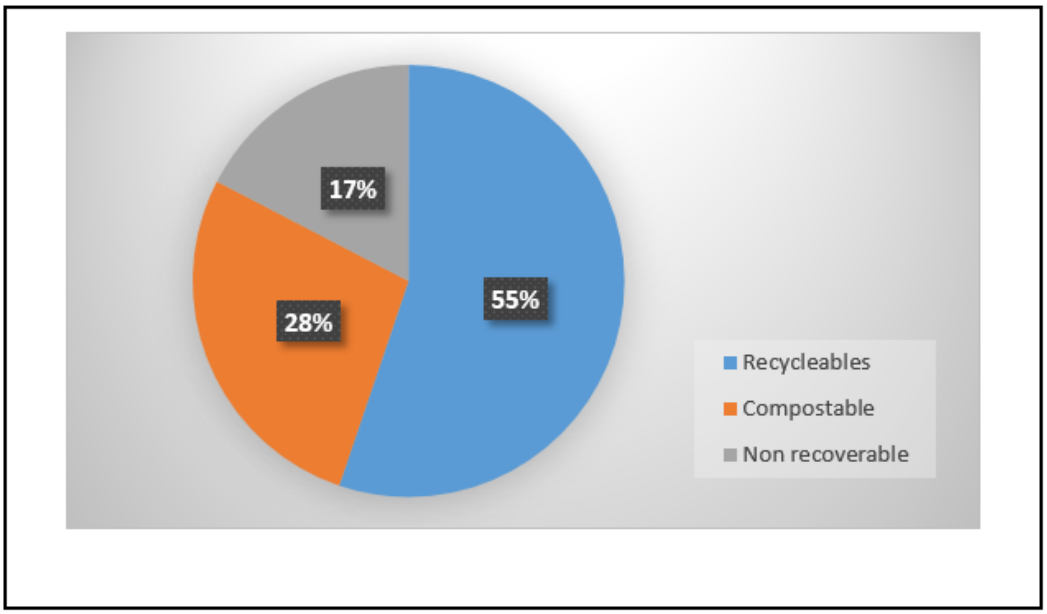

Figure 5: Waste Composition

4. DISCUSSION

This study assessed waste management practices and recycling potential on the university campus by conducting a waste audit and categorizing the types of waste generated. In this regard seven major categories were found, namely styrofoam, plastic, food waste, garden waste, paper, cardboard. Similar observations were made by [29]. Performing a waste characterization study is an essential initial phase in effective waste management planning and enhancing the overall sustainability of a higher education institution [42]. The study aimed to assess campus waste quantity and composition, identify recycling and composting potential, and improve sustainability. Findings showed around 70% waste diversion potential, aligning with the study's objective.

The waste audit identified waste streams and opportunities to enhance waste reduction and recycling for sustainable waste management. Similar procedure was adopted by [43]. This study finding underscores the relevance of SDG-12 in IIUI, as it assesses SWM practices and advocate for source reduction, recycling, and composting. It aligns with SDG 12 targets 12.5 (waste reduction) and 12.3 (food waste reduction), promoting sustainable development and enhancing student knowledge. By utilizing waste potential, the study addresses solid waste as an environmental concern while striving for sustainable solutions. The study found that universities have a significant opportunity to recycle waste and efficiently manage organic and inorganic waste, with an average of 145.35kg produced per week over twenty working days. The research conducted at a Jordanian university by [11] also resembles this study. The sampling was done on week days and was analyzed using the ASTM standard methods. Similar sampling procedures were

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adopted by [29,33,44]. Food waste and paper dominate, indicating a significant opportunity for composting and recycling. The similar observations were made by [45]. The study deduced that 55% of university's waste stream can be recycled and 28% can be composted. Similar type of observations were conveyed by [29] which shows 67.1% waste can be recycled. However, [46] shows 80% recycling potential in their research. The study revealed that paper and Styrofoam plates/cups constituted 22.27% and 9.48% of the university's waste stream respectively, with plastic accounting for 27%. [1] also observed and reported identical tendencies.

The findings revealed that food waste accounted for approximately 33.87% of the total organic waste generated on campus. Additionally, garden waste, including wood cuttings, leaves, and grass, constituted about 3.51% of the total organic waste. Similar observations were deduced by [33]. The research findings formulate that majority of organic waste was from the cafeteria and garden waste of the campus and other types of waste were mostly from the administrative blocks of the campus, [37] also observed and reported identical tendencies. The study deduced that adopting recycling and composting activities in the university can enhance landfill diversion and improve solid waste management efficiency. Similar research observations were conveyed by [32]. Paper and cardboard constituted the largest percentage (approximately 23.21%) of the total waste generated, primarily due to their extensive use in the university's academic blocks by students and teachers. Similar observations were depicted by [4]. The study concluded that the lack of proper allocation of color-coded bins near the cafeterias hindered waste minimization through recycling activities. The study of [41] rendered likely observations of the installation of color-coded bins. The findings formulate that color-coded bins will be helpful in the efficient sorting of waste in the university. While the results of [47] also transpired that implementing a four-bin system is an effective approach to enhance waste diversion rates.

CONCLUSIONS

In conclusion, sustainable management of solid waste generated by educational institutes poses a growing challenge in developing countries, and the ISWM approach offers a comprehensive solution. This research demonstrates that IIUI has significant potential to meet SDG 12 for waste diversion, recovery, and recycling. The campus generates an average of 145.35kg of waste per week over twenty working days, with paper, cardboard, plastics, and food waste being the primary constituents. The waste audit revealed that approximately 55% of the generated waste is recyclable, indicating a strong potential for recycling within the institution. These findings emphasize the importance of implementing proper waste collection, segregation, recycling, and composting systems to establish a self-sustained ISWM system at the university. The amount of solid waste can be reduced by implementing source reduction, recycling, and composting methods. The institution can enhance environmental outcomes, promote sustainability education among students, and achieve cost savings. This study provides valuable insights for higher education

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institutions striving to fulfill sustainable development goals and adopt more environmentally responsible practices.

RECOMMENDATIONS

To enhance solid waste management on campus, it is crucial for the university to address certain issues. This includes installing color-coded bins for efficient waste sorting, promoting the composting of organic waste for fertilizer and biogas production, and reducing the use of water bottles by installing water coolers. Additionally, transitioning to e-learning can help reduce paper waste. These measures will contribute to better waste handling practices and overall sustainability at the university.

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AUTHOR'S CONTRIBUTION

All authors were equally involved in the conception, design, and elaboration of this research as well as in the writing of this paper. All authors have thoroughly reviewed and given their approval to the final manuscript. Dr. Sarah Amir supervised the overall work and has extracted and shaped the basic idea, methodology, results, discussion and conclusion of the research paper.

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CONFLICT OF INTEREST

The authors affirm that there is no conflict of interest regarding this research.

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