SOLID WASTE COMPOSITION, GENERATION RATE, AND MANAGEMENT PRACTICES AT THE UNIVERSITY OF KABRIDEHAR, ETHIOPIA: IMPLICATIONS ON SUSTAINABLE MANAGEMENT OF SOLID WASTE IN HIGHER EDUCATION INSTITUTIONS

M.SC. THESIS

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HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA

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A THESIS SUBMITTED TO THE
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ADVISOR'S APPROVAL SHEET

This is to certify that this thesis entitled ***"Solid Waste Composition, Generation Rate, and Management Practices at the University of Kabridehar, Ethiopia: Implications on Sustainable Management of Solid Waste in Higher Education Institutions"*** is submitted in partial fulfillment of the requirements for Master of Science degree with specialization in ***Ecotoxicology And Environmental Health***, the Graduate Program of the Department of Biology, and has been carried out by ***Muhumed Mohamed Ibrahim*** with **ID. Nº**. ***GPECEHR/0009/15***, under my supervision. Therefore, I recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

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We, the undersigned, members of the Board of Examiners of the final open defense by ***Muhumed Mohamed Ibrahim*** have read and evaluated his/her thesis entitled ***"Solid Waste Composition, Generation Rate, and Management Practices at the University of Kabridehar, Ethiopia: Implications on Sustainable Management of Solid Waste in Higher Education Institutions"***, and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree of Masters of Science.

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DECLARATION

I hereby declare that this MSc thesis is my original work and has not been presented for a degree in any other university, and all sources of material used for this thesis have been duly acknowledged.

Name: **Muhumed Mohamed Ibrahim**

Signature: -----------------------

This MSc thesis has been submitted for examination with my approval as Thesis advisor.

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ABBREVIATIONS AND ACRONYMS

ISWM ----------------------Integrated Solid Waste Management

KAP ------------------------Knowledge, Attitude and Practices

MoE ------------------------Ministry of Education

MSW------------------------Municipal Solid Waste

MSWM ---------------------Municipal Solid Waste Management

PET --------------------------Polyethylene Terephthalate

PPE---------------------------Personal Protective Equipment

SDGs-------------------------Sustainable Development Goals

SSWM-----------------------Sustainable Solid Waste Management

SWM-------------------------Solid Waste Management

UNEP------------------------United Nations Environmental Program

UoK -------------------------University of Kabridahar

4Rs---------------------------Reuse, Recycling, Recovery, and Reduce

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ABSTRACT

Attributable to the population and various activities entailed, Tertiary Educational Institutions (Universities) are one of the large producers of solid wastes, which, if not properly managed, could pose risk to health and the environment. Consequently, information on the solid waste generation and composition is a critical first step towards developing successful and effective planning of solid waste management service and strategies across university campus. This study aimed to assess the solid waste composition, generation rate, and management practices at the University of Kabridahar (UoK). Total population sampling method was employed to include all 28 buildings of the university. All of the waste containers placed at all the buildings consisting of 24 dustbins and 15 dumpsters were the measurement sites. Onsite Segregation and Weighing were used to assess the quantity and characteristics of the solid waste generated at UoK. Conversely, Key Informant Interview and Direct Observation were employed to generate qualitative data. Stratified Random Sampling technique was also used to select 373 respondents for the evaluation of the knowledge, attitude, and practice (KAP) of the university's population towards solid waste management (SWM) using a close-ended, self-administered questionnaire. The data was analyzed in SPSS using frequency, chi-square, and crosstab analysis to describe the data and examine associations between the KAP statements and demographic features. The results revealed that the UoK generated an average of 2172.5 kg/day. The per capita waste was 0.40 kg/day. The major waste sources were cafeteria (48.1%), dormitories (25.1%), academic and research (14.9%), and administrative (8.9%) buildings. The waste is composed of organics (54.5%), polyethylene terephthalate (PET) bottles (18.8%), paper and cardboards (16.3%), plastics (5.9%), metal (2%), textiles (1.6%), glass (0.5%), medical (0.3%), and miscellaneous (0.1%). From the generated waste, 45.1% were recyclable, 54.5% compostable and 0.4% non-recoverable. Despite the implementation of essential SWM practices, there were still instances of improper SWM practices. The survey results revealed that the majority of respondents demonstrated good knowledge (73.5%) and attitude (62.9%) towards SWM, but their practice was only fair (44.8%). The Chi-square test showed statistically significant association between respondents' demographic features and their KAP ($P < 0.05$). In conclusion, the UoK generated a substantial amount of solid waste that requires further improved management. Suitable solid waste site selection and waste handling training for SWM workers were recommended.

Keywords: Solid Waste, Solid Waste Composition, Solid Waste Generation, University of Kabridahar.

1. INTRODUCTION

1.1.Background of the Study

The amount of solid waste generated globally is continuously mounting due to the upsurge in population, increased urbanization, and economic growth. According to Chen *et al*. (2020) and World Bank (2022), the amount of solid waste generated globally was 1.99 billion tons in 2015 and 2.24 billion tons in 2020. A recent study by Kaza *et al.* (*2*018) estimated that the annual generation of global solid waste will be about 2.59 billion tons by 2030 and 3.40 billion tons by 2050. On the other hand, the United Nations proposed 17 Sustainable Development Goals (SDGs) by 2030. Some of these goals include making cities and human residencies safe and sustainable (Goal 11) and ensuring sustainable consumption and recycling patterns (Goal 12) (UN, 2015). However, the increasing generation of solid waste can hinder these goals.

Improper management of solid waste adversely impacts on both environmental and human health. The environmental impacts include air and water contamination, soil degradation, and contributions to climate change and methane release (Salim *et al*., 2023; Amde Eshete *et al*., 2024). The health effects include diseases such as infectious, respiratory, diarrheal, and protozoan illnesses (Amde Eshete *et al*., 2024).

Developed Nations employ effective collection, disposal, and treatment methods to properly manage waste, while Developing Nations practice waste collection at only urban regions and discarding and burning in unauthorized dumps (Kaza *et al*., 2018). Solid waste is inadequately managed in developing countries due to the absence of skilled manpower, irregular waste collection, inadequate equipment and funds, and lack of adequate legal provisions (Al-Khatib *et al*., 2015). In developing nations, like Ethiopia, the majority of the cities collect only 20–80% of the generated waste by spending about half of their budgets, where 80–95% of that budget is spent on waste collection and transportation (Awunyo-Vitor *et al*., 2013; Guerrero *et al*., 2013; World Bank, 2022). This urged the need for proper SWM in order to meet sustainable solid waste management (SSWM) goals. To meet these goals, a combination of various methods, such as material recovery, is highly needed (Pujara *et al*., 2019).

Ethiopia, like many other developing countries, is facing the outcome of inadequate solid waste management (Gorfnesh Lema *et al*., 2019). According to Habtom Kahhsay (2022), the national municipal solid waste (MSW) generation has increased from 9,700 tons per day in 2015 to 12,200 tons per day in 2020. Kaza *et al*. (2018) projected that the annual MSW generation in Ethiopia will be 10 million tons by 2030 and 18 million tons by 2050. The daily per capita waste generation in the country ranges from 0.28 to 0.83 kg/person/day (Selamawit Mulat *et al*., 2019). For the success of the country's municipal solid waste management (MSWM) systems and environmental protection, Ethiopia has established several proclamations and agencies. For instance, the establishment of Negarit Gazeta Proclamation N^{o}. 513/2007 for solid waste management (Negarit Gazeta of the FDRE Proclamation No. 513/2007) and Ethiopian Evironmental Protection Authority (EEPA). However, poor waste management practices have been reported across the country. For instance, 20–30% of the waste generated remained uncollected in Addis Ababa, the capital city (Mesfin Tilaye and Meine Pieter van Dijk, 2014).

A university is a place where a huge number of students and staffs spend a significant period of time, thus generating solid waste from different sources (Adeniran *et al*., 2017). Both national and international bodies expect universities to participate in the socio-economic and environmental wellbeing of communities through the adoption of sustainable development policies (Adeniran *et al*., 2017). Although universities brought many environmental challenges along with enrollment expansion (Pan *et al*., 2022), they are now recognized as leaders of sustainable development (Leal Filho *et al*., 2019). The majority of MSW generated from universities is recyclable (Al-Shatnawi *et al*., 2020); however, it is left for informal sectors such as scavengers in developing countries (Marshall and Farahbakhsh, 2013).

According to the Ministry of Education (MoE) (2018), there are 49 public universities and 128 private recognized higher institutions in Ethiopia. In Ethiopian universities, SWM is among the major issues for institutional sustainability (Helelo *et al*., 2019). However, to the best of the researcher's knowledge, only few studies on solid waste have been conducted in the university campuses of the country. Therefore, the ambition of this study is to assess the solid waste composition, generation rate, and management practices at the UoK since no study has attempted to do so before. This study is the seventh of its type at the national level and the first at the regional level (Somali Region), and can contribute to the efforts of the university's sustainable development plans. The study findings can also benefit both the local and scientific communities.

1.2. Statement of the Problem

SWM is among the major challenges of developing countries, particularly urban and other densely populated areas, including university campuses. In Ethiopian higher institutions, SSWM has become a challenging issue because of the expansion of educational programs (Helelo *et al*., 2019). However, only few studies were conducted at Hawassa University (Helelo *et al*., 2019; Hunachew and Dessalegn, 2014), Harmaya University (Ashenafi Yimam, 2018), Kotebe University (Gebreeyessus *et al*., 2019; Adane Sirage *et al*. 2022), and Bahir Dar Institute of Technology (Tadele Assefa *et al*., 2016). The UoK main campus, the only one currently functional compound, is characterized by a higher number of population, due to the annual increase of the number of students (graduate and undergraduate) and staffs (academic, administrative, health, campus security, etc.). The university's population increase caused the increase of the solid waste generated. The used materials and stuffs are discarded at the roads, dormitory areas, academic buildings, administrative buildings, cafeterias, etc., making the campus aesthetically unpleasant.

The university is climatically characterized by a very hot temperature, sometimes exceeding 35^{o}C. Accordingly, the higher temperature influenced the solid waste generated in the campus. According to Adeleke *et al*. (2021), microbial reactions accelerate in higher-temperature areas where food waste is mainly generated, resulting in an unpleasant smell and increased pathogenic organisms. The university generated a large portion of food waste, which caused the increase of pathogen-carrying insects, which can be observed around the student cafeteria. Additionally, wastes such as water and juice bottles are littered in various parts of the compound when dealing with the hot temperature.

The temporary storage areas such as open waste containers in the campus became breeding sites for mosquitoes, which raised malarial incidences. The area where the university is found is endemic to malaria due to its topographic and climatic conditions (Abduselam Abdulahi *et al*., 2020) and *Anopheles Stephensi* in Ethiopia was firstly detected in this area (Tamar Carter *et al*., 2018). Therefore, the open waste storages in the study area can contribute to malaria and other pathogenic disease.

The SWM system of the university performs some essential elements such as collection, transportation, and disposal. However, various factors including lack of reliable generation data and improper storage and disposal influenced the proper management of the waste. The waste is regularly generated in the campus more than it is collected. Open dumping disposal method in an un-engineered endpoint near public areas is practiced, which can endanger humans, animals, and the environment in general.

In response, the university officials made efforts to tackle the waste problem. Some of their attempts included the employment of large numbers of SWM workers and placing of trash bins at waste generating sites. However, these efforts did not solve the solid waste problem in the campus, necessitating the need for measures that involve profound investigation. Unfortunately, despite these challenges, no study attempted to assess the size and severity of the problem. These aggregate problems created the motivation for carrying the present study on assessment of solid waste composition, generation rate, and management practices at UoK, as well as evaluation of the KAP of the population of the university towards SWM. The findings of this study can be used to fill the above-indicated gaps and can be reliable source of future and further researches.

1.3.Objectives of the Study

1.3.1. General Objective

The general objective of the current study is to assess the solid waste composition, generation rate, and management practices at the main campus of UoK.

1.3.2. Specific Objectives

The specific objectives of this study include the following:

- ❖ To identify the Sources of Solid Waste at the university;
- ❖ To determine the Characteristics of the solid waste generated at the UoK;
- ❖ To measure the generation rate of the Solid Wastes at the UOK;
- ❖ To appraise the recyclability of Solid Wastes at the university;
- ❖ To evaluate the KAP of the Respondents from the university towards SWM; and
- ❖ To ascertain the associations between the socio-demographic characteristics of the Respondents and their KAP related to SWM.

1.4.Research Questions

This study investigated the following research questions:

- What are the SWM practices at the UoK?
- Where are the major solid waste sources at the university?
- What are the characteristics of the solid waste generated at the UoK?
- How much solid waste is generated at the university?
- What is the recyclability of the solid waste generated at the university?
- How is the KAP of the respondents towards SWM?
- Are there any associations between the socio-demographic characteristics of the respondents and their KAP towards SWM?

1.5.Significance of the Study

The outcome of this study can have several benefits for both the local and scientific communities. These advantages include environmental, health, and scientific benefits. Firstly, the waste components determination of the study can definitely help the development of effective waste management strategies, which facilitate the university's environmental goals. The findings identified and measured the recyclable materials disposed of as if they were worthless, which can reduce the volume of waste generated in the university if properly utilized. Secondly, the study findings identified factors influencing the use of Personal Protective Equipment (PPE), which can lead authorities and policymakers to pay attention to these factors. Finally, the findings can be reliable sources of scientific data, which can help further studies and the regulatory bodies of UoK and other public universities in the Somali Region.

1.6.Scope of the Study

The study was restricted to the solid waste composition, generation rate, and management practices at UoK. As part of the management practices, the KAP of the selected respondents was also examined. Additionally, the study was limited to solid waste rather than liquid waste. The study was conducted on the UoK Main Campus, the only campus of the university.

2. LITERATURE REVIEW

2.1. Definitions and Concepts

The United Nations Environmental Program (UNEP) (UNEP, 1989) defined waste as material or substance that is intended to be disposed of. Solid wastes are the substances sent down in open spaces, discarded at workplaces, and put on curbs, which are mainly in a solid state (Hoornweg *et al*., 2013). The control and management of these wastes require a system known as the SWM system. The SWM system involves the collection, treatment, and disposal of obsolete solid materials. However, failure to perform this system can lead to environmental pollution and human health effects (Nathanson, 2023).

The proper management of these wastes can be achieved through integrated solid waste management (ISWM). ISWM is a system involving the generation, segregation, transfer, treatment, recovery and disposal in an integrated form. This approach emphasizes the management of solid waste from all sites and involves all population (Memon, 2010). The approach leads to achieve an effective SSWM. SSWM is an approach that describes the long-term proper management of solid waste in an environmentally sustainable manner. It has an aim of addressing issues about the human health and environmental contamination (Emara, 2023).

2.2. Sources and Types of Solid Waste

Solid waste is described as useless things abandoned by human activities that are mainly in a solid state (Christensen, 2010). These wastes can be classified into several categories based on their source, composition, treatment, and others (Meena *et al*., 2023). On the basis of its sources, solid waste can be municipal waste, industrial waste, construction and demolition waste, residential waste, Agricultural waste, commercial waste, or special waste (Table 1). Municipal wastes are those originating from fruit and vegetable markets, road sweepings, and other sites; industrial waste from industrial activities; construction and demolition waste, such as stones, from building areas (Santana *et al*., 2022; Dinh *et al*., 2022; Ahmad *et al*., 2022; Al-Zboon & Masoud, 2021). Special wastes (e.g., electronic waste, biomedical waste, etc.) come from different sources such as healthcare centers, residential waste from household activities, agricultural waste from agricultural areas, and commercial waste from business and other commercial centers.

Table 1. Types of solid waste based on their sources (Nandan *et al.*, 2017)

Source	Types of solid waste
Municipal	General wastes, sludge, pieces of trees, etc.
Residential	Food waste, papers, plastics, glasses, etc.
Industrial	Hazardous wastes, ashes, special wastes, etc
Construction & demolition	Stones, wood, steel, concrete, etc.
Agriculture	Hazardous and non-hazardous wastes (e.g., pesticides, organics, etc.).
Commercial & institutional	Paper, plastics, food wastes, glass, metals, etc.

2.3. Municipal Solid Waste

The main sources of municipal solid waste (MSW) include institutional (from hospitals, universities, and other public buildings), residential (from household activities), commercial (from business centers) (Radwan & Khan, 2023), recreational centers, road sweepings, etc. The major classes of these MSWs are papers, boards, organics, glasses, plastics, metals, and textiles, collected from several places such as dormitories, markets, offices, and residential buildings (Al-Salem *et al.*, 2022). As a result, these MSWs contribute to public health and environmental problems. Therefore, MSWM is very important because it makes cities beautiful, smooth, and enjoyable (Esmaeilian *et al.*, 2018). However, the majority of least-developed countries collect only 39% of their MSW, while high and low-middle-income nations collect 96% and 51%, respectively (Kaza *et al.*, 2018).

2.4. Categories and Characteristics of Solid Waste at University Campus

The solid waste generated in university campuses can be categorized into various categories with different physical, biological, and chemical characteristics. The categories originate from several sources on the campuses. The following Table 2 summarizes the categories, characteristics, and sources of solid waste generated at university campuses.

Table 2. Wastes generated on university campuses and their characteristics (Ugwu *et al*., 2021)

Category	Characteristics	Source of origin
Garbage (Food leftover, Fruits and Vegetables, and leaves and peels)	Organic and biodegradable, combustible when dried, and recyclable.	Student and staff residencies, cafeterias, Kitchens and restaurants
Paper and Cardboard (carbon papers, tissue papers, cartons, cement bags, wrappers, and Cardboards)	Combustible when dried, biodegradable when wet, and recyclable.	Student and staff residencies, classrooms, offices, photocopying and printing centers, and mini markets
Plastic, polythene and packaging bags (plastic material – cans, caps, bags, bucket, waterproof bags, pipettes, burettes, etc.)	Non-biodegradable, recyclable, and their residues hardly decay when burnt.	Markets, medical centers, and laboratories.
Metals (metal cups, cans, plates and spoons, aluminum pots, scrap electronic equipment etc.)	Non-biodegradable, non-combustible, and recyclable	Residential areas, markets, and vehicles.
E-Waste (electric cables, printers' cartridge, and mobile accessories)	Non-biodegradable, recyclable, and some parts are combustible	Residential and commercial areas
Sanitary waste (pads, diapers and cotton wools)	Non-biodegradable and non-recyclable	Mainly residential areas

2.5. Solid Waste Management System

SWM is defined as the process of managing solid waste properly and perfectly. According to UNEP (2020), effective solid waste management includes collection, segregation, storage, transportation, treatment, and disposal (Table 3). Effective performance of SWM needs suitable planning and execution of these methods (Sondh *et al*., 2022). For the accomplishment of this management system, collaboration and cooperation among several groups are required (Budihardjo *et al*., 2023) since the success of this system relies on inclusion and participation (Awino & Apitz, 2023). However, challenges such as inadequate awareness, lack of finance, and absence of technologies hinder the proper implementation of SWM (Hettiarachchi *et al.*, 2018).

Table 3. Solid waste management steps and their definitions (by the author)

SWM step	Definition
Collection	This method is defined as the process of gathering solid waste from the generation site to treatment site.
Segregation	It is the process of segregating and categorizing solid waste at source for further treatment
Storage	Storage is the method of storing generated solid waste temporarily before it is transported using containers and other equipment.
Transportation	It is the method of transporting wastes from collection areas to dumpsites and landfills with the help of transporting equipment and/or manpower
Treatment	Treatment is the process of treating wastes in order to reduce their effects on the environment and human health
Disposal	This method is the final stage of SWM where ultimate disposal takes places.

2.6. Sustainable Solid Waste Management Methods

An effective SSWM system includes the 4Rs (recycling, reduce, reuse, and recovery) policy (Kabera & Nishimwe, 2019). Recycling is the process of converting waste materials into new things or items (Villalba, 2020). The projected recyclable percent of waste is 80%; however, 90–95% of these wastes are dumped into dumpsites (Gaeta-Bernardi & Parente, 2016). Some of these recyclable wastes include papers, cardboard, metals, textiles, and electronics (Bui *et al.*, 2022). Reducing the production of waste can lower the adverse environmental and human health effects. Reuse is the process of taking waste products or their segments and using them again in their original form (Villalba, 2020). The application of this 4Rs policy can contribute to the effective functioning of SSWM. Therefore, local authorities and companies are encouraged to practice SSWM through this 4Rs policy (Li *et al.*, 2023).

2.7. The Effects of Improper Solid Waste Management

The increasing generation and heterogeneity of MSW coupled with improper management is causing huge human health and environmental hazards. According to Kaza *et al*. (2018), the majority (70%) of the world's waste is disposed of in dumps and landfills. Additionally, the waste is indiscriminately dumped in open spaces, drainages, and water bodies (Baralla *et al*., 2023). Consequently, this indiscriminate disposal can cause human health hazards such as infectious and waterborne diseases. In addition to these human health hazards, environmental pollution such as surface and ground water pollution, air pollution (Mazhar *et al*., 2021), and increased methane (Mohammed *et al*., 2021) can also occur. Furthermore, solid wastes play a vital role in the abruptly increasing climate change by emitting greenhouse gases such as methane (the second-largest contributor to global warming after carbon dioxide) and nitrous oxide (the dominant ozone-depleting substance).

2.8.Solid Waste Generation and Status in Ethiopia

MSWM became a critical issue in the major cities of Ethiopia due to the increasing economy and rapid urbanization (Eshetu Gelan, 2021). The major sources of these wastes were reported to be households and agriculture (Fiseha Bekele, 2021). However, SSWM practices such as the 4Rs policies are very weak. But the country's MSWM has mostly concentrated on the collection, transportation, and disposal of solid waste (Lemesa Hirpe and Chunho Yeom, 2021). Although the country mostly targets waste collection, only less than half of the waste generated is collected, and 95% of the collected waste is irrespectively thrown away either at dumpsites in the edges of cities or at temporary sites (Tigistu Haile and Tamiru Abiye, 2012). Moreover, traditional burning in the open air and illegal dumping were commonly practiced. To overcome these SWM problems, Ethiopia adopted environmental policies, proclamations, and regulations. However, the implementation and enforcement of these policies were not properly practiced (Lemesa Hirpe and Chunho Yeom, 2021).

The amount of MSW generated in Ethiopian major cities has been reported. For example, the daily per capita MSW generation is 0.45 kg in Addis Ababa (Ali Mohammed and Eyasu Elias, 2017), 0.49 kg in Jigjiga (Dimtse, 2016), 0.45 kg in Bahir Dar (Biruk Abate, 2017), and 0.27 kg in Mekelle (Marsie. *et al*., 2017). However, poor SWM practices have been reported in the country (Lemesa Hirpe and Chunho Yeom, 2021; Fiseha Bekele, 2021)). Several other studies have reported only very few practices of waste segregation at source. For instance, 72.8% of the households in Assella (Gorfnesh Lema *et al*., 2019), 65.5% in Jigjiga (Tewodros Manyazewal and Tesfaye Walelgn, 2019), 55% in Gelemso (Hailu Eshete *et al*., 2023), 94.1% in Dilla (Workineh Mengesha and Dereje Diriba, 2022), and 74.6% in Fiche (Teferi, 2022) do not segregate solid waste at source. In contrast, 70% of the households in Addis Ababa segregate solid waste at source due to their higher awareness (Nigatu Regassa *et al*., 2011).

In Ethiopia, like many other developing countries, the solid waste generated is dominated by organic waste. According to Fiseha Bekele (2021), about 67.4% of the solid waste generated in Ethiopia is organic. However, only 5% of that waste undergoes recycling in a non-standard form (Ali Mohammed and Eyasu Elias, 2017). Different aspects, such as social, policy, political, financial, technical, and institutional aspects, challenged MSWM in the country (Lemesa Hirpe and Chunho Yeom, 2021). Consequently, MSW became a major issue in Ethiopia and affected public health, the environment, and economic activities (Mengist Hailemariam and Assegid Ajeme, 2014).

2.9. Recent Studies on Solid Waste in Several University Campuses

Recent studies have been conducted on solid waste in different university campuses around the globe. Some of these studies reported the generation rate, recyclability, and composition of solid waste generated in these campuses (Table 4). Therefore, the findings of these studies are summarized in the following table.

Table 4. Recent solid waste studies conducted on several university campuses.

The studied campuses	Country	Summary of the findings	Sources
Hawassa University	Ethiopia	✓ A total of 46705.7 kg/week of solid waste was generated ✓ 0.3275kg/capita/day ✓ More than 92% recyclable ✓ Composed of food leftover, plastics, wood, jerrycans, metals and others	(Helelo *et al*., 2019)

Bahir Dar Institute of Technology	Ethiopia	✓ Generated 1,280kg/day in the 1st study period and 672 in the 2nd study period ✓ 38.93% Recyclable ✓ Composed of papers and cardboards, plastics, glasses, metals, organics, construction waste, hazardous waste and others.	(Tadele Assefa *et al.*, 2016)
University of Lagos	Nigeria	✓ The daily estimated solid waste generation was 32.2 tons ✓ 75% recyclable ✓ Included polyethylene bags, papers, organic waste, plastics, inert materials, and others	(Adeniran *et al.*, 2017)
University of Nigeria	Nigeria	✓ 2,218.66 kg/six month was generated ✓ The per capita generation rate was 0.06 kg/day ✓ 96.58% was recyclable ✓ Composed of glass, textiles, rubber, wood, e-waste, sanitary, medical, and metal wastes	(Ugwu *et al.*, 2020)
University of Jordan	Jordan	✓ 8113 kg/day was generated ✓ 87% recyclable ✓ Consisted of plastics, papers, cardboards, glass, yard waste, and food	(Moqbel, 2018)
University of Venda	South Africa	✓ 0.82 kg/capita/day was generated ✓ 61.7% recyclable ✓ Composed of plastics, papers, glass, cans, food leftover, and others	(Owojori *et al.*, 2020)

2.10. Regulations, Policies, and Proclamations Related to Solid Waste Management in Ethiopia

FDRE established several environmental regulations, policies, and proclamations that emphasize on MSWM and other environmental issues. Some of these are summarized below:

- The 1995 FDRE constitution: Articles 44(1) and 92(4) describe the environmental rights and responsibilities of the government and citizens. Article 44(1) indicates that "all persons have the right to a clean and healthy environment." On the other hand, article 92(4) addresses that "the government and citizens shall have the duty to protect the environment" (FDRE Constitution, 1995).
- The 1997 Ethiopian Environmental Policy: Sub-article 7 and 8 of Article 3 urge various waste management policies, including solid waste recycling, safe disposal, proper sanitary landfill identification, and formulation of waste management guidelines and regulations and their implementations (FDRE Environmental Protection Authority, 1997).
- Public Health Protection Proclamation No. 200/2000: Under this proclamation, Article 12 indicates that "any person shall collect waste at an especially designated place and in a manner, which does not affect the health of the society" (FDRE Public Health Proclamation No. 200/2000).
- Environmental Pollution Control Proclamation 300/2002: Article 5(1) of this proclamation states that "all urban administrations shall ensure the collection, transportation, recycling, treatment, or safe disposal of municipal waste through the institution of an integrated municipal waste management system" (FDRE Environmental Pollution Control Proclamation No. 300/2002).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The UoK is one of the youngest universities in Ethiopia and the second public university in the Somali Region after Jigjiga University. It was established in 2015 as a public university.

3.1.1. Geographical Location

The university is located in the eastern part of Ethiopia. It is found in Kabridahar city, a city located at about 379.9 km and 1001.4 km distance from Jigjiga (the capital city of the Somali region) and Addis Ababa (the capital city of Ethiopia), respectively. It has a latitude and longitude of 6°44'25.0"N and 44°16'38.0"E, respectively. The university campus is geographically bounded in the north by the airport of Kabridahar, south by Dala'ada Village, east and north-east by Kabridahar city, and west by an open land.

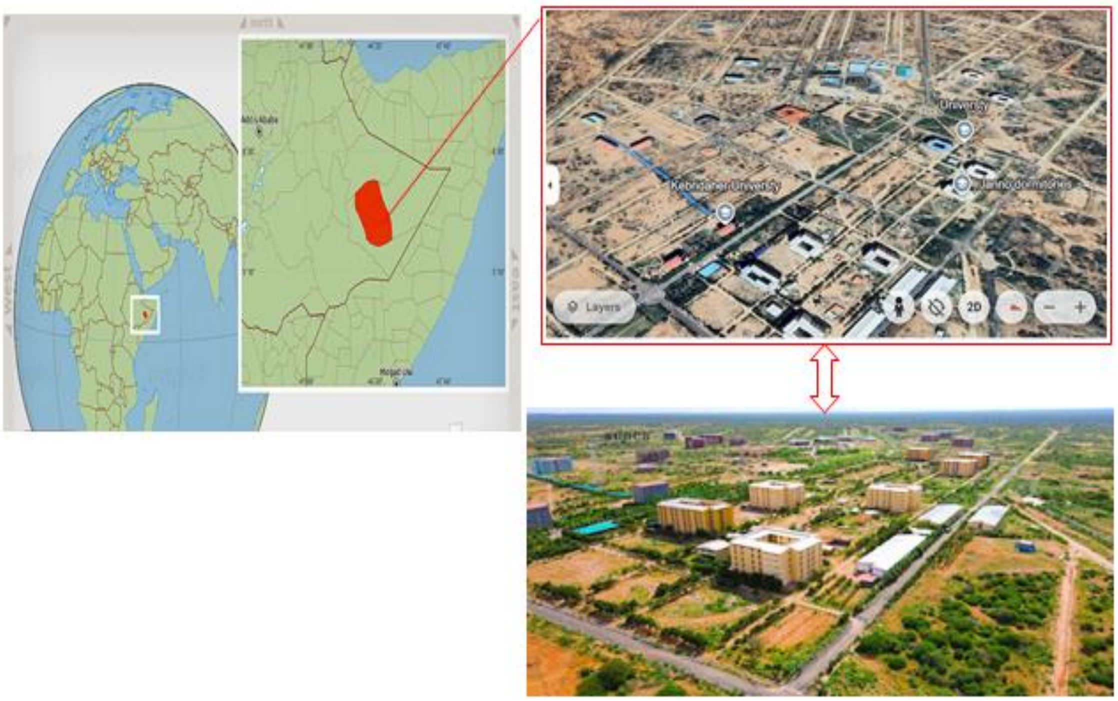


Figure 1: Map of the Study Area

3.1.2. Climate and Topography

The UoK is located in an area that falls under Ethiopia's Bereha Agro-Climatic Zone (a hot lowland zone below 500 meters in altitude) with varying temperatures throughout the year. The temperature exceeds 35^{o}C in the hottest months (March to May) and ranges from 20^{o}C to 25^{o}C during the coolest months (November to February). Similar to the other parts of the Somali Region, the area characterized a bimodal rainfall pattern. One of them is locally known as 'Gu' (spring), and the other one is known as 'Deeyr' (autumn). The spring season takes place from April to June, while the autumn season occurs from October to December. The average annual precipitation ranges from 200 to 400mm. The study area is topographically found in a lowland area with a few foothills of a higher altitude and has an average elevation of 521 meters above sea level (m.a.s.l.).

3.1.3. Population Characteristics

The population of the university consists of students (graduate and undergraduate students) and staffs (academic and administrative staffs). According to data obtained from the university, the total number of the students in 2023/2024 academic year is 4083, of which 3928 (with 70.14% males, and the remaining fraction (29.86%) is accounted by females) are undergraduate students, while the rest 155 (with 90.33 and 9.67% are males and females, in that order) are postgraduate students. There are 862 administrative staffs (top administrators offices staffs, student service directorate staffs, beautification and cleaning directorate staffs, health workers, campus security staffs, and others) and 421 academic staffs (academic and registration affairs staffs and faculty members), making the university's total population 5366. The University's night-time population is mainly students due to the absence of staff residences in the campus.

3.1.4. Education and Health

The UoK started its first academic year with four faculties and fifteen departments and received 1200 undergraduate students in 2017/18. Currently, UoK consists of seven faculties with thousands of undergraduate and postgraduate students. There are two semesters in each academic year, namely first and second semesters. The first semester takes place from September to January, while the second one occurs from March to July.

The local community's access to education and health can contribute the understanding proper waste management practices and their significance for human health. Kabridahar town possesses public institutions built for the enhancement of education and health in the community. These institutions include UoK, Kabridahar Health Science College, Kabridahar Teachers Training College, Kabridahar Polytechnic College, Hospitals, and the Ethiopian Pharmaceutical Agency.

These institutions can have a vital role in the community's capability to practice proper waste management through giving trainings and providing waste collection and storage facilities.

3.1.5. Solid Waste Management of the Study Area

The SWM system at the university involves some basic elements of SWM, including collection, transportation, and disposal of the waste. The solid waste handlers collect and store the waste in designated points, consisting of 24 trash bins and 15 dumpsters (Table 5). Then, waste haulers collect the stored waste and transport it to disposal point using a vehicle. However, the transported waste is openly dumped in the university's dumpsite, which is found in about 2 km to the south and outside of the campus. Despite the existence of storage facilities where the solid wastes are stockpiled, no treatment such as recycling is carried out preceding trucking to the final disposal site. This open dumping practice can elevate the environmental and public health exposure to hazardous wastes.

3.2. Study Design and Duration

An institutional-based cross-sectional study design was employed to assess solid waste composition, generation rate, and management practices at UoK, as well as the KAP of the population of the university from November, 2023 to August, 2024.

3.3. Sampling Procedure

Different sampling techniques were utilized to select the measurement sites and respondents of this study.

3.3.1. Sampling Techniques for Selection of the Measurement Sites

Due to the small number of the population (buildings), total population sampling method was employed to include all the 28 buildings of the university. Onsite measurement of the waste took place at every building using the trash bins and/or dumpsters located at that building. All the trash bins and dumpsters from all the buildings were included (Table 5). Based on their activities, the university buildings were categorized into six structures. Structure is block(s) of buildings built for particular utility (Adeniran *et al*. 2017). These structures were; (1) academic and research (e.g., research, colleges, departments, classrooms, libraries, and laboratories), (2) administrative (university head, student service, and university’s police building), (3) cafeterias (student and staff cafeterias), (4) dormitories (undergraduate and postgraduate dormitories), (5) store, and (6) clinic buildings (Table 5).

3.3.2. Waste Measurement and Characterization

As shown in Table 5, there were 24 trash bins and 15 dumpsters placed at all the 28 buildings of the university. All of these waste containers were taken into this study. As usual, the solid waste generated from the university buildings is temporarily stored in these bins and dumpsters by waste handlers before ultimate collection. For measurement and characterization, the waste from each bin and dumpster was emptied into a pre-determined sorting point. The waste was manually hand-sorted with the help of PPE into categories. Each category was measured using a mechanical weighing scale to determine the waste generation rate in the study area. From the food waste, a pre-measured sample was taken and dried using an oven to remove the moisture content and prevent bias. Following the dried sample weighing, an extrapolation was made to calculate the total food waste generated in the campus.

To determine the recyclability of the waste generated, separation of recyclables from non-recyclables was conducted. The percentage of all recyclables was determined using the following formula:

$$\%\mathrm{RW} = \frac{\mathrm{TR}}{\mathrm{TNR}} * 100$$

Where %RW = Percentage of Recyclable Waste, TR = Total Recyclables and TNR = Total non-recyclables.

Table 5: The total number of trash bins and dumpsters placed at each building group

Building/block type	Tot. number of the blocks	Number of trash bins	Number of dumpsters
Academic & Research	10	6	3
Administrative	2	3	1
Cafeterias	4	5	4
Dormitories	10	5	6
Clinic	1	4	-
Store	1	1	1
Total	**28**	**24**	**15**

3.3.3. Sampling Techniques for Selection of the Respondents

Stratified Random Sampling Technique was employed to select respondents for a survey on the KAP of the university's population related to SWM. The university's population was stratified into three groups based on their occupation. These groups included students (mainly from dormitories, cafeterias, and academic areas), Administrative staffs (from administrative areas), and Academic staffs (from academic areas). The respondents were randomly selected from each group after proportional allocation of the sample size.

3.3.4. Sample Size Determination

Slovin's formula (1960) was used to determine the minimum sample size of the survey.

$$n = \frac{N}{1+(Ne^2)}$$

Where n = the minimum sample size, N = population number, e = margin of error

The required sample size was determined based on the number of the total population in the University to measure their KAP towards SWM.

$$\text{n} = \frac{5366}{1+(5366 * 0.05^2)} = 372.25 \approx 373$$

The calculated sample was proportionally allocated to each group, as Table 6 depicts.

Table 6: Proportional allocation of the sample size

Occupation	**Total No. of the population (N)**	**Respondents (n)**
Students	4083	284
Administrative staffs	862	60
Academic staffs	421	29
Total	5366	373

3.4. Data Types and Sources

Both quantitative and qualitative research methods were used to collect the data from the measurement sites and selected respondents. Quantitative data was acquired with recourse to Waste Measurement and Questionnaire Survey to ascertain the sources and nature of solid waste generated as well as the KAP of the selected respondents towards SWM in the study area, in that order. Qualitative data was collected by way of key informant interviews and direct observation in order to evaluate the composition and management practices of the solid waste generated. For higher data quality, both primary and secondary sources were used in the study. The primary data was obtained through separation plus direct weighing and KAP survey. The secondary data was obtained through existing documented files, including the number of the university population.

3.5. Data Collection Instruments

3.5.1. Weighing of Solid Waste

The daily generated solid waste at each building in the campus was determined using a mechanical weighing balance with a 300 kg measuring capacity. The data obtained for seven consecutive days was recorded.

3.5.2. Questionnaire Survey

A Questionnaire Survey was conducted to measure the KAP towards SWM of selected respondents from the university. The data was collected using a close-ended, self-administered questionnaire with a structured interview. The questionnaire instrument has been taken and modified from recent similar studies of experts (Rabeiy *et al*., 2023; Hailu Eshete *et al*., 2023). Before the actual data collection, a pilot test was conducted on certain respondents to check the validity of the questionnaire and prevent biases. Certain questions or statements were removed from the instrument due to their inconvenience after the pilot test.

The questionnaire consisted of two sections, including demographic and KAP sections. In the demographic section, the respondents were asked about their demographic variables, such as gender, education, age, and occupation. In the KAP section, the respondents were asked ten solid waste knowledge questions with "Yes" or "No" options and six attitude and six practice statements with three-point Likert Scale options. The questionnaire was randomly distributed to students and some staff respondents through face-to-face distribution. However, more than half of the administrative and academic staffs received the questionnaire by online means due to their irregular presence in the campus.

3.5.3. Key Informant Interview

A total of 15 key informants were purposively selected based on their position and involvement in the SWM system of the university. These informants included beautification directorate members, waste truck drivers, cafeteria workers, and student members. The informants were inquired about the current SWM practices at UoK through a Semi-Structured Interview.

3.5.4. Direct Observation

Direct field observation was performed to observe the waste management practices (from collection to disposal) of the university. The activity areas of the SWM workers were visited to closely and regularly check up on their waste handling practices. The dumpsite where the waste ends up was also visited to evaluate their possible risks to the environment and public health. The acquired data was recorded in a Checklist and triangulated with the responses of the respondents**.**

3.6. Data Entry and Analysis

The data was collected in a questionnaire and checklist and then screened for errors. The data, then, was entered in IBM SPSS Statistics V.25 for analysis. Both descriptive and inferential statistics were used for data analysis. Descriptive statistics such as frequency, percentage, and average mean were employed to describe the data. Inferential statistics such as Chi-square test and Crosstab analysis were used to examine the association between the socio-demographic characteristics and the KAP of the university's population towards SWM. The data was presented in the form of tables and figures.

3.7. Ethical Clearance

Ethical consideration is one of the most important issues in any scientific study, and it leads to obtaining reliable and high-quality data. Therefore, for the fruitful accomplishment of this study, ethical issues were taken into account. An authorized letter has been received and taken from Hawassa University, Department of Biology. Then, the officials of UoK were met with and requested for the approval of the study. Additionally, prior to data collection, the study participants were informed about the aim of the study and their consent was obtained. To assure confidentiality, informants were informed that their responses will be used for research purposes. Furthermore, only adult respondents were included in the study.

4. RESULTS AND DISCUSSION

4.1. Socio-Demographic Features of the Respondents

A total of 373 respondents selected from the population of UoK participated in this study with a 100% response rate. The following Table 7 depicts the respondents' demographic characteristics, such as gender, education, age, and occupation. It shows that the majority (64.9%) of the respondents were male. From all the respondents, 84.2% had bachelor's degree, while 11.8% had a postgraduate degree. Most of them (61.7%) were aged between 20 and 25, while only 6.1% were above 30 years old. The respondents were students (76.1%), administrative (16.1%), and academic staffs (7.8%).

Table 7: The respondents' socio-demographic variables

Variables	Category	Frequency	Percent (%)
Gender	Male	242	64.9
	Female	131	35.1
Education	Postgraduate degree	44	11.8
	Bachelor degree	314	84.2
	Diploma	10	2.7
	Secondary school	5	1.3
Age	< 20	47	12.6
	20-25	230	61.7
	26-30	73	19.6
	>30	23	6.2
Occupation	Student	284	76.1
	Administrative staffs	60	16.1
	Administrative staffs	29	7.8

4.2. Solid Waste Generation Rate

The UoK generated a total of 15207.7 kg (15.2 tons) per week with an average of 2172.5 kg per day (Table 8). The daily per capita waste generation was found to be 0.40 kg/capita/day. Ugwu *et al*. (2020) and Ashenafi Yimam (2018) found a similar quantity of waste at the University of Nigeria, Nsukka campus (2,218.66 kg per day), and Harmaya University campus (2788.68 kg per day), respectively. However, the current finding is three times lower than the quantity (6,672.24 kg per day) of waste generated at Hawassa University (Helelo *et al*., 2019). This difference can be attributed to the fact that the study at Hawassa University covered five campuses, while this study investigated only one campus.

The majority of the waste was generated from cafeteria (48.1%) and dormitory (25.1%) buildings, followed by academic and research (14.9%), administrative (8.9%), store (2.3%), and clinic (0.7%) (Figure 2). This result is consistent with that of Zhang *et al*. (2020), where cafeterias (45.3%) and dormitories (36.6%) were the first and second contributors to the solid waste generated in Henan Agricultural University in central China, respectively.

Table 8: The total and average wastes generated per week and their components

Category	**Total weight (Kg/week)**	**Mean (TW/week)**	**Percentage (%)**	**Std. dev.**
Organic Waste	8,293	1184.7	54.5	201.1
PET bottles	2,865.4	409.3	18.8	37.2
Papers & cardboards	2,484.9	355	16.3	68.3
Plastics	890	127.1	5.9	42.6
Metals	295.9	42.3	2	16.3
Textiles	247.6	35.4	1.6	12.8
Glass	75	10.7	0.5	5.4
Medical Waste	42.1	6.0	0.3	2.5
Miscellaneous	13.8	2	0.1	0.8
Total	**15,207.7**	**2172.5**	**100**	**387**

As illustrated in Table 9, the waste generated on the UoK campus was influenced by duty days of the week. During the weekdays (from Monday to Friday), the volume of waste generated increased due to the comparatively higher activities of the students and staffs in the campus. However, the generated amount on the weekend (Saturday (12.9%) and Sunday (11.2%) was low in comparison to the workdays (Table 9). This waste generation difference between the weekdays and weekends can be attributed to not only the reduction of teaching-learning activities on the weekend but also the absence of staff residential buildings in the campus, as this causes many staffs to spend their holidays outside the campus. This finding contrasts the results of Noman *et al*. (2023) and Zargar *et al*. (2023), who found that a higher amount of waste was generated on the weekends compared to the weekdays. The difference can be linked to the difference in the study population and methodologies employed.

Table 9: The amount of waste generated for seven consecutive days in the campus

Category	**The quantity of solid waste generated for seven days (kg)**							
	Working days					**Weekend**		
Days	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**	**Total**
Organic waste	1,526	1,344.2	1,101	1,227.5	1108.6	1,072.2	913.5	8,293
PET Bottles	480.3	401.8	420.5	417.6	397.2	388	360	2,865.4
Paper & cardboards	318.5	392.3	411.8	408.4	326	400.6	227.3	2,484.9
Plastics	132.3	209.5	123.4	119.9	136.7	73.7	94.5	890
Metals	62.5	25.7	48	50.7	41	15.7	52.3	295.9
Textiles	35	19.7	47.5	46.1	38.5	16	44.8	247.6
Glass	11.3	13.1	21.1	9.9	5.1	5.8	8.7	75
Medical Waste	9.5	8	5.5	7	3	2.5	6.6	42.1
Miscellaneous	3	1	1.3	3.1	2	1.2	2.2	13.8
Total	**2578.4**	**2414.8**	**2180.3**	**2290.2**	**2058.4**	**1975.7**	**1709.9**	**15,207.7**

4.3. Waste Characterization

Determination of waste composition is a pre-requisite for proper waste management. The university's waste is composed of nine different categories, as shown in Figure 1. The organic waste (54.5%) and PET bottles (18.8%) represented the largest portion, while medical (0.3%) and miscellaneous (0.1%) wastes were insignificant in the waste composition. The dominance of organic waste over other wastes was also observed in other university campuses in the country, such as Kotebe Metropolitan University (93.4%) and Hawassa University (81.5%) by Gebreeyessus *et al*. (2019) and Helelo *et al*. (2019), respectively. Although PET bottles are types of plastic waste, they were considered an independent category due to their large quantity in the waste stream. The PET bottles were the second largest portion after organic wastes (Figure 1). This is due to the fact that the university characterized a very hot temperature where the people consume a lot of packaged water and soft drinks. Zawde Tadesse *et al*. (2022) reported that 45% of 160 respondents from 3 kebeles identified plastic bottles and bags as a major portion of waste generated at Kebridehar City, a city where the university is found. The composition of the waste generated at each building group is depicted in Table 10.

Table 10: waste components generated from the different building groups

Source	Categories (Kg/week)										
	Organic Waste	PET bottles	Paper & cardboards	Plastics	Metal	Textile	Glass	Medical waste	Miscellaneous	Total	%
Academic & Research	37.3	911.2	1150.5	35.6	102.1	7.9	8.8	0	3	2,256.4	14.9
Administrative	45.6	553	680.9	40.9	24.5	11.1	3.4	0	2.6	1,362	8.9
Cafeterias	6659.3	507.2	49.7	47.2	5.9	25.4	14.5	0	3.3	7,312.5	48.1
Dormitories	1542.5	863.9	497	522.4	160.4	202.5	30.3	1.1	4.3	3,824.4	25.1
Store	8.3	11.5	87	225.1	3	0	8.7	0	1	344.6	2.3
Clinic	0	17.2	19.9	18.7	0	0	9.3	41	0	106.1	0.7

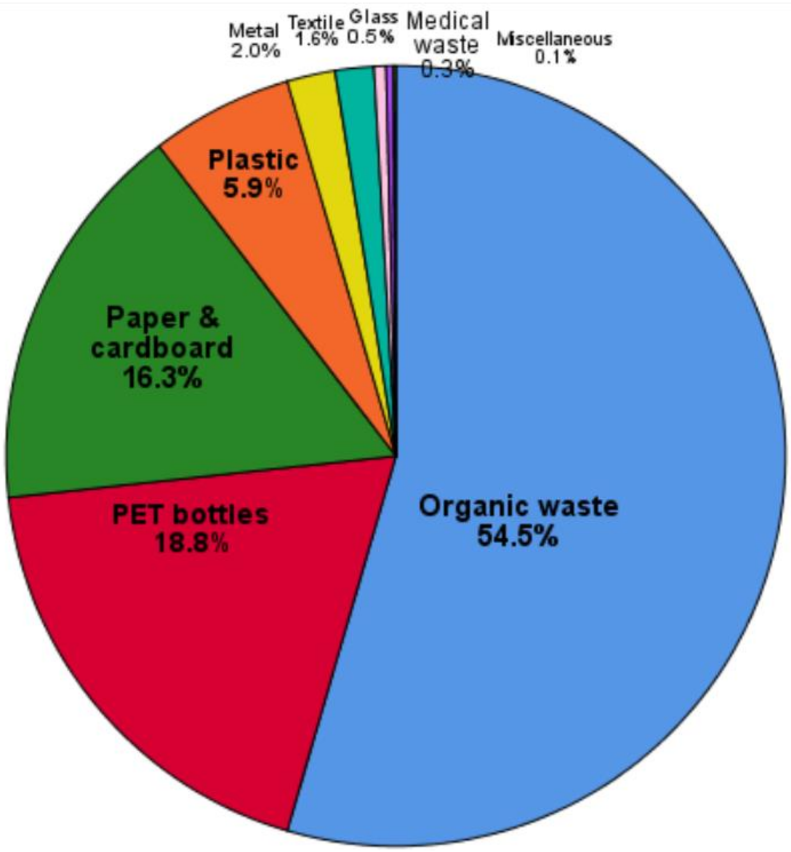


Figure 2: the overall waste composition in the UoK campus

4.4. Major Solid Waste Sources in the Campus

4.4.1. Academic and Research Buildings

Academic and research areas were among the major significant solid waste sources on the campus. These buildings consisted of 10 building blocks with six trash bins and three dumpsters (Table 5). Of the total waste generated in the UoK, 14.9% was generated from the academic and research buildings (Table 10). Paper and cardboards (51%), and PET bottles (40.4%) were the dominant wastes in these building groups. This is due to the fact that the activities of teaching, learning, and researching, which consume a lot of papers, are performed in these areas. Additionally, staffs and students use more PET drinking bottles due to the hotness of the area. The volume of other waste types, such as organics (1.6%), plastics (1.6%), metals (4.5%), textiles (0.4%), glass (0.4%), medical (0%), and miscellaneous (0.1%) wastes, was not high in these buildings. Figure 3 illustrates that the waste from these buildings is composed of recyclables (98.3%), compostable (1.6%), and non-recyclables (0.1%).

4.4.2. Administrative Areas

Administrative buildings generated 8.9% of the total waste on the campus (Table 10). Similar to the academic and research areas, administrative buildings mainly generated paper and cardboards (50%) and PET bottles (40.6%). The presence of meeting and training halls in these areas can be correlated with this large amount of paper and bottle waste. The dominance of paper waste and plastic bottles in the administrative buildings was also found in the University of Venda, South Africa, which accounted for 55.6% and 19.2%, respectively (Owojori *et al*., 2020). Adeniran *et al*. (2017) also reported that the volume of PET generation on the Unilag Akoka campus was positively correlated with the administrative structures. The recycling potential of the waste from the administrative buildings is presented in Figure 3.

4.4.3. Cafeteria Buildings

Cafeterias, for both students and staffs, were identified as the most significant solid waste source on the campus. About half (48.1%) of the waste generated in UoK was from these buildings (Table 10). This finding is in agreement with that of Zhang *et al*. (2020), revealing that cafeterias generated 45.3% of the whole waste in Henan Agricultural University and were the biggest waste generators. These buildings generated a huge amount of organic waste (91.1%) and were four times more organic waste-generating than all other sources together. However, other waste types, including PET bottles (6.9%), paper & cardboards (0.7%), plastics (0.6%), metal (0.1%), textiles (0.4%), glass (0.2%), medical (0%), and miscellaneous (0.04%), were uncommon in this area. The waste from this area was highly compostable (Figure 3).

4.4.4. Dormitories

Dormitory buildings were found to be the second most important generator of solid waste on the UoK campus (Table 10). The residences on the campus were only students due to the absence of staff residential buildings. The dormitories comprised of ten buildings with eleven bins and dumpsters. These buildings generated one-fourth (25.1%) of the total waste generated on the campus (Figure 2). The major waste components in these areas were organics (40.3%), PET bottles (22.6%), paper & cardboards (13%), and plastics (13.7%), while other components collectively represented 10.4%. More than half (59.5%) of the waste generated in the dormitories was recyclable (Figure 3).

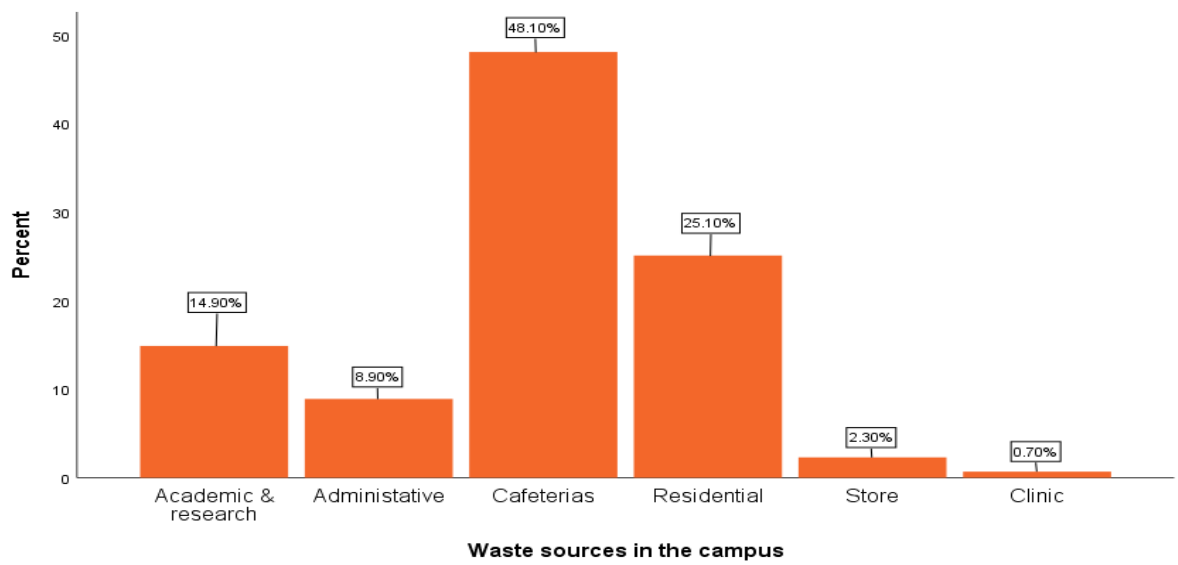
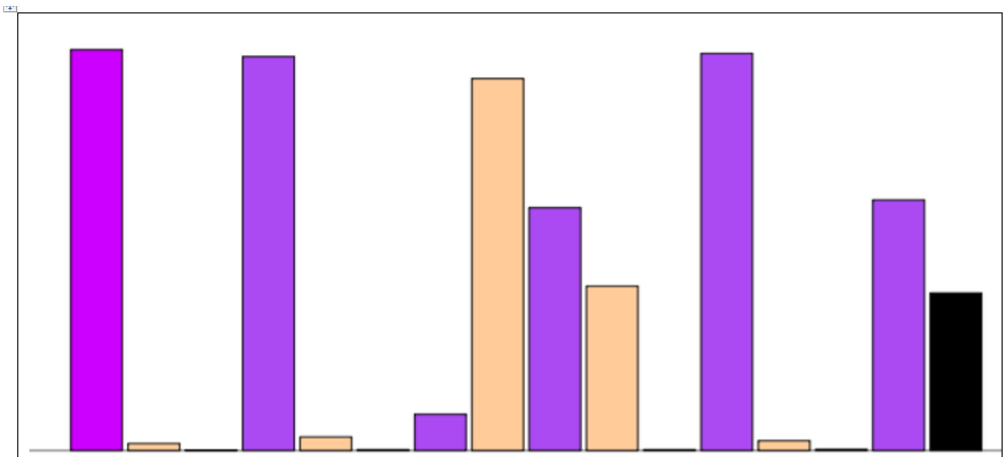


Figure 3: The percentage of waste generated at solid waste sources in the campus

4.5. Recyclable and Compostable Potential of Solid Waste Generated

The results revealed that there is significant potential for recycling and composting within the waste generated on the campus. Out of the total waste generated, 45.1% was recyclable, 54.5% compostable and 0.4% non-recoverable. The recyclable waste consisted of PET bottles, paper and cardboard, plastic, metal, textiles, and glass, while the compostable waste included organics such as food leftovers and kitchen waste. The non-recoverable waste predominantly consisted of medical and miscellaneous waste. This finding almost agreed with the result obtained at Bahir Dar Institute of Technology, where the generated waste consisted of 38.9% recyclables, 57.4% compostable, and 3.6% non-recyclables (Tadele Assefa *et al.*, 2016). However, in terms of recyclability, this finding is lower than the result at Imam Abdulrahman Bin Faisal University, where 80% of the generated waste was recyclable, 19% compostable, and 1% non-recyclable (Dahlawi & El Sharkawy, 2021). Some of the building groups, including academic and research, administrative, and store, had high recycling potentials of 98.2%, 96.5%, and 97.3%, respectively (Figure 3). Unfortunately, none of the recyclable wastes were recovered, and they were instead sent to and burned in an open dumpsite.



	Academic & research	Administrative	Cafeterias	Residential	Store	Clinic
Recyclables (%)	98.2	96.5	8.9	59.5	97.3	61.4
Compostable(%)	1.7	3.3	91.1	40.3	2.4	0.0
Non-recyclable(%)	0.1	0.2	0.0	0.2	0.3	38.6
Total	100	100	100	100	100	100

Figure 4: Recyclable and compostable potential of the solid waste generated at each building group

4.6. Solid Waste Management Practices in the University of Kabridahar

Based on these findings, the SWM system at the university performed collection and transportation to the disposal site. However, lack of waste separation at source was observed, which resulted in recyclables such as papers being mixed and contaminated with other wastes. Similarly, in the University of Lagos, paper wastes were wet and soiled with other wastes, leading to a reduction in their proportion (only 15%) within the total waste generated (Adeniran *et al*., 2017). Another study also found the absence of separation in a university of developing economy and suggested that this can lead to the contamination of recyclables such as papers (Owojori *et al*., 2020). This causes waste pickers to perform extra cleaning when exploiting recyclables, which can increase the risk of exposure to pathogens and chemicals.

4.6.1. Collection

Solid waste handlers collected the generated waste from corridors, roadsides, backyards, and others on a daily basis. As shown in Table 5, trash bin(s) and dumpster(s) were placed at every building group on the campus. The waste handlers stored the collected waste in these bins and dumpsters temporarily until they were emptied into a vehicle for further disposal (Figure 4). During the critical observation, most of the waste handlers, including cleaners and personnel emptying dumpsters into the vehicle, used their bare hands to handle the waste. The distribution of PPEs such as gloves and awareness rising among these workers are highly needed to prevent cross-contamination.

Figure 5: the bins and dumpsters located at the buildings

4.6.2. Transportation and Disposal

Transportation and disposal methods play a vital role in effective waste management. In this study, waste haulers utilized a vehicle (Figure 5) to collect the stored waste. However, it was observed that the collected waste was disposed of and burned in a non-designed open disposal point located near the university compound (Figure 5). This disposal site, located between the university compound and the airport of Kabridahar town, is considered unsuitable due to its proximity to these areas and the possible environmental and health risks associated with open burning of waste. Furthermore, the presence of camels, which are the most commonly domesticated animals in the study area, was observed in and around the disposal site. This shows the need for immediate relocation of the dumping site of the university to reduce environmental and health impacts.

Figure 6: Waste vehicle disposing of waste at the dumpsite of UoK

4.6.3. Food Leftover Management

Food waste was the largest portion in the organic waste stream. Unlike other wastes that are directly disposed of in the dumpsite, food leftovers from the cafeterias were reused for livestock feeding. According to the responses from cafeterias' key informants, the food leftovers were taken away by ranchers. However, due to the remnants from food leftover collection, flies and other pests were observed around the student cafeterias. This highlights the need for proper food waste management practices to avoid the transmission of pathogens and ensure public health. The practice of reusing food leftovers by ranchers was also observed in other universities, such as Hawassa University (Helelo *et al*., 2019). Even though the practice of reusing food waste by ranchers is an environmentally sustainable approach, contaminated food remains may spread infections from person to cow (anthroponosis) and then from cow to person (zoonosis).

4.7. Knowledge, Attitude, and Practices of the University's population towards SWM

As part of SWM, the KAP of the population of UoK was investigated using a questionnaire survey.

4.7.1. Knowledge of the Respondents Related to SWM

The knowledge section consisted of ten positively designed questions with Yes (coded with 2) or No (coded with 1) options that assessed waste classification, recycling, segregation, and the use of PPE. As shown in Table 11, more than 80% of the study participants were aware of waste classification (K1) and the advantage of PPE (knowledge 10). About 70-80% of the respondents responded "yes/aware" to K2, K3, K4, K5, K6, K7, and K8. K9, on solid waste composting, received the lowest "yes" responses (58.7%) of the participants (Table 11).

To evaluate the SWM knowledge status of the population of UoK, a benchmark of very good, good, and poor was designed. The awareness status was considered "very good" if the average mean of the respondents' responses is greater than or equal to 1.80, "good" if the mean is between 1.50 and 1.79, and "poor" if the mean is below 1.50 (Table 11). Based on Table 11, the respondents showed "very good" awareness on solid waste classification (K1), the effect of improper SWM (K2), and the importance of PPE use (K10). The respondents also had "good" awareness on most of the knowledge questions (K3, K4, K5, K6, K7, K8, and K9). For instance, on K8, 73.2% of the respondents indicated the importance of separation in SWM (Table 11), agreeing with the findings of Worku Adefris *et al*. (2023), where 73% of the respondents believed separation reduces waste. The average mean of all questions was 1.74, which means "good" knowledge. Therefore, the population of UoK (73.5%) had a "good" awareness of solid waste and its management. Similarly, previous studies in Qassim University (Rabeiy *et al*., 2023), Philippine State University (Barloa *et al*., 2016), and University of Dammam (Abubakar *et al*., 2016) also found good SWM awareness.

Table 11: Respondents' Knowledge on SWM

Term	Question	Yes(%)	No(%)	Mean	St dev.	Awareness
K1	Can solid waste be classified into organic waste such as food waste and inorganic waste such as papers and plastics?	80.7	19.3	1.81	0.395	Very good
K2	Does improper solid waste management cause human health risks (e.g., infectious diseases) and environmental pollution (e.g., water pollution)?	79.6	20.4	1.80	0.403	Very good
K3	Do solid wastes have economic value?	70	30	1.70	0.459	Good
K4	Are wastes such as papers, plastics, metals, textiles, etc. recyclable?	72.7	27.3	1.73	0.446	Good
K5	Can the reuse of solid waste reduce the amount of solid waste?	70	30	1.70	0.459	Good
K6	Does solid waste recycling protect the surrounding environment and preserve the natural resources?	74.3	25.7	1.74	0.438	Good
K7	Are universities expected to achieve sustainable solid waste management?	73.5	26.5	1.73	0.442	Good
K8	Does solid waste segregation at source help solid waste management?	73.2	26.8	1.73	0.444	Good
K9	Can compost or organic fertilizers be prepared from solid waste?	58.7	41.3	1.59	0.493	Good
K10	Does wearing personal protective equipment lower the risk of waste-related infections?	82	18	1.82	0.384	Very good

4.7.2. Association between Respondents' Knowledge and their Demographic Profile

A chi-square test and cross-tabulation analysis were conducted to determine any significant association between respondents' knowledge regarding SWM and their demographic features. As depicted in Table 12, respondents' awareness of waste classification (K1) was dependent on their education level, age group, and occupation in the university's population, where the chi-square test has shown a statistically significant association (p-value <0.05). There was a positive correlation between education level and waste classification awareness. Postgraduate degree holders exhibited the highest level of waste classification awareness (97.7%), followed by those with a bachelor's degree (78.9%), diploma (70%), and secondary education (60%). The finding is consistent with a previous study by Hashim *et al*. (2017), who found that solid waste awareness increases with educational level, where postgraduate students had more solid waste awareness than undergraduate students in Universiti Tecnologi Malaysia. In the age group, the respondents above 30 years old (95.6%) and those between 26 and 30 years (90.4%) had higher waste classification awareness than those between 20 and 25 years (77.8%) and those under 20 years (72.3%). These findings align with previous studies by Zheng *et al*. (2023) and Beshel *et al*. (2024), which found that elderly individuals, women, and those with higher education are more likely to partake in waste classification and management, thus being more aware of waste categorization. Furthermore, in the occupation category, students (63.3%) had lower waste classification awareness compared to administrative (88.3%) and academic staffs (96.5%). This can be attributed to the lower education level of the students.

The results also revealed that knowing the effects of improper SWM (K2) had a statistically significant relationship with respondents' age (p-value <0.05), where older-aged respondents were more aware of the consequences of improper SWM compared to younger individuals (Table 12). The higher experience among elders can lead them to be more knowledgeable on the detrimental effects of inadequate SWM.

Table 12 also shows that participants' awareness of the economic value of solid waste (K3) was affected by their education status, age, and occupation (p-value <0.05). According to the cross-tabulation analysis, as the educational level of the respondents increased, their awareness of the economic value of solid waste also increased. Postgraduate holders (97.7%) had more awareness of the economic value of solid waste, compared to those with bachelor degrees (68.1%), diplomas (30%), and secondary education (20%). This finding indicates that individuals with higher levels of education are more likely to understand the economic benefits of recycling and properly managing solid waste. The awareness of the economic value of solid waste was low among the respondents aged under 20 years old (36.1%) and 20 to 25 years old (71.3%) compared to those aged between 26 and 30 years old (78%) and above 30 years old (100%). This shows that younger individuals may have an inadequate understanding of the economic value of solid waste, underscoring the need for educational initiatives to promote awareness among this age group. Additionally, academic staffs were 1.09 and 1.52 times more aware than administrative staffs and students, respectively.

As Table 12 indicates, respondents' awareness of the importance of waste recycling (K6) had a statistically significant relationship with education and age variables (p-value <0.05). The study participants with postgraduate degrees (93.1%) were more aware of the importance of waste recycling than bachelor degrees (72.9%) holders; however, the participants with diplomas (40%) knew less than the secondary education holders (60%). Comparably, Nyampundu *et al*. (2020) found that awareness of SSWM, such as recycling, increased with an increase in education level. Middle-aged respondents were more familiar with the significance of waste recycling compared to both the old and young-aged groups. The knowledge question about infection-protectiveness of PPE (K10) was dependent on the respondents' gender (p-value <0.05), where males (85.5%) were more knowledgeable than the females (75.6%).

Table 12: Association between respondents' knowledge and their demographic variables

Term	**Chi-square test's significance (P)**			
	Gender	**Education**	**Age**	**Occupation**
K1	0.530	0.012	0.011	0.003
K2	0.373	0.275	0.008	0.737
K3	0.234	0.000	0.000	0.000
K4	0.156	0.185	0.208	0.100
K5	0.180	0.513	0.184	0.596
K6	0.357	0.002	0.005	0.053
K7	0.762	0.404	0.075	0.495
K8	0.445	0.073	0.535	0.342
K9	0.279	0.057	0.198	0.717
K10	0.017	0.086	0.515	0.075

4.7.3. Attitude of the Respondents and Association with Demographic Variables

Respondents' attitude towards six SWM and environmental issue statements was examined using a three-point Likert scale of agree (coded with 3), neutral (coded with 2), and disagree (coded with 1). The results are summarized in Table 13. Less than half (47.2%) of the participants agreed that good solid waste disposal is everyone's responsibility (A1), which suggests a significant portion of the respondents do not feel a sense of responsibility towards proper SWM. This finding is comparable with that of Alemtshay Shiferaw *et al.* (2023), where only 13.8% of respondents agreed that each person is responsible for waste management. However, it disagrees with other findings of Hailu Eshete *et al*., 2023, Rabeiy *et al*. (2023), and Fadhullah *et al*. (2022), where the majority of the study participants believed that everyone is responsible for SWM. The difference can be due to awareness differences among the different participants. Of the total respondents, 53.3% responded that universities have a vital role in addressing environmental issues (A2). The majority of the respondents believed that the application of the 4Rs policy can lead to SSWM (68.1%), improper institutional SWM can pose hazards (80.1%), community awareness raising decreases health hazards (61.4%), and regulations can help the university's SWM (67.6%) (Table 13).

The respondents' attitude regarding SWM was considered "very good" if the average of the responses is greater than 2.5, "good" if the average is between 2.00 and 2.5, "fair" if the average is from 1.50 to 1.99, and "poor" if the average is less than 1.50. As Table 13 shows, the attitude of the participants was "fair" and "very good" on A1 ("proper solid waste disposal is everyone's responsibility") and A4 ("institutional solid wastes can pose health and environmental hazards if improperly managed"), respectively. The respondents also showed a "good" attitude on the rest of the statements (A2, A3, A5, and A6). The average of all of the attitude statements was 2.28, concluding that the UoK population (62.9%) had a "good" attitude towards SWM. Similar results were found at Kotebe Education University (Adane Sirage *et al*., 2022), Foundation University (Baba *et al*., 2024), and University of Malaya (Hassan *et al*., 2022).

Table 13: Respondents' attitude on SWM

Term	Statement	Disagree (%)	Neutral (%)	Agree (%)	Mean	St dev.	Attitude
A1	Proper solid waste disposal is everyone's responsibility	50.7	2.1	47.2	1.97	0.990	Fair
A2	Universities play a crucial role in the environmental issues	44.0	2.7	53.3	2.09	0.983	Good
A3	The application of 4Rs (reuse, reduce, recycle, & recovery) policy can lead to achieve sustainable solid waste management	28.7	3.2	68.1	2.39	0.903	Good
A4	Institutional solid wastes can pose health and environmental hazards if improperly managed	19.6	0.3	80.1	2.61	0.795	Very good
A5	Increasing the community's awareness towards the effect of improper SWM decreases health risks.	33.5	5.1	61.4	2.28	0.935	Good
A6	The formulation of regulations and their implementations can help the solid waste management of the university	29.0	3.4	67.6	2.39	0.905	Good

The chi-square test was also used to identify statistically significant associations between the respondents' attitude and their demographic variables. From Table 14, A1 (feeling that proper solid waste disposal is everyone's responsibility) had a significant association with the gender variable (p-value <0.05), where women respondents (55.7%) were more likely to feel this responsibility compared to men respondents (42.5%). This is because women are more pro-environmental than men, as they often serve as home managers (Ahmadi S. 2018). A3 (the belief in the effectiveness of the 4Rs principles in achieving sustainable SWM) was found to have a significant association with the education variable (p-value <0.05) (Table 14). The crosstab analysis revealed that postgraduate (72.7%) and bachelor's degree (69.4%) holders were more likely to believe in the effectiveness of the 4Rs principles in achieving SSWM compared to diploma (30%) and secondary certificate (20%) holders. Kwakye *et al*. (2024) also found that education level influences the respondent's awareness and behavior in achieving proper waste management.

In A6, the participants standpoint towards whether "the formulation of regulations and their implementations can help the SWM of the university" was significantly associated with age and occupation categories (p-value <0.05) (Table 14). In the age category, the respondents aged 20-25 (70.4%) and 26-30 (69.8%) years believed that regulations can help the SWM of the university more than those aged above 30 (60.8%) and under 20 (53.2%) years. This finding shows that the respondents' attitudes towards the significance of regulations on the university's SWM neither increase with age nor decrease. This can be attributed to the fact that the middle-aged groups are mainly students who have experienced the importance of regulations as they regularly obey on the campus. In the occupation category, almost all of the administrative staffs (90%) believed the importance of regulations in the SWM of the university, while 31.1% of the academic staffs and 37.3% of the students did not believe. This is because the administrative staffs are the regulatory body of the university. A case study in the Kingdom of Saudi Arabia, Qassim University, similarly found that employees positively respond to environmental regulation more than academic staffs and students (Rabeiy *et al*., 2023).

Table 14: Association between respondents' attitude and their demographic variables

Term	**Chi-square test's significance (P)**			
	Gender	**Education**	**Age**	**Occupation**
A1	0.031	0.395	0.614	0.322
A2	0.081	0.095	0.533	0.677
A3	0.150	0.003	0.243	0.586
A4	0.364	0.753	0.445	0.667
A5	0.948	0.288	0.424	0.431
A6	0.290	0.196	0.044	0.002

4.7.4. Practice of the Respondents Related to SWM

Six practice statements with agree (coded with 3), neutral (coded with 2), and disagree (coded with 1) options were constructed to measure the respondents' waste management behavior, such as waste disposal and getting rid of, separation, reuse, and PPE usage. In Table 15, less than half of the respondents (43.2%) agreed that they discard waste at the designated bins or containers.

Of the total respondents, only 23.9% separate solid waste before disposal, while 74.5% do not separate it. The majority (59.2%) of the informants use PPE when contacting with or handling waste, while 55.2% have not utilized the reusable solid waste. A significant portion (75.1%) of the respondents did not throw away the solid waste in the streets and open spaces of the university (Table 15).

Similar to the attitude statements, the respondents' SWM practices were categorized into Very good (mean > 2.5), Good (mean = 2.00-2.50), Fair (mean = 1.50-1.99), and Poor (mean < 1.50). Table 15 indicates that the respondents had "Very good" and "Good" practices on the P5 statement, which is about irrespective throwing of waste on the campus, and P3 statement, which is about PPE usage, respectively. The participants' practice was "Fair" among P1, P4, and P6 statements. However, the practice of separating solid waste (P2) was "Poor". The mean of all practice statements was found to be 1.98, concluding that the university's population (44.8%) had "Fair" practice. A satisfactory SWM practice that needs 56.9% improvement was also observed among the undergraduate students of Philippine State University (Barloa *et al*., 2016).

Table 15: Respondents' practice on SWM

Term	Statement	Disagree (%)	Neutral (%)	Agree (%)	Mean	St dev.	Practice
P1	I always discard the waste at specified points/containers	43.7	13.1	43.2	1.99	0.933	Fair
P2	I initially separate solid waste to put it into the respective trash bins	74.5	1.6	23.9	1.49	0.854	Poor
P3	I use personal protective equipment when contacting with (handling) the waste	33.2	7.5	59.2	2.26	0.927	Good
P4	I take and use the reusable solid waste	55.2	5.9	38.9	1.84	0.957	Fair
P5	I do not throw away the solid waste in the streets and open spaces of the university	23.0	1.9	75.1	2.52	0.844	Very good
P6	I put hazardous wastes in special bins designed for them with the help of personal protective equipment	49.6	22.0	28.4	1.79	0.859	Fair

4.7.5. Association between Respondents' Practice and their Demographic Profile

Based on Table 16, the practice of discarding solid waste at a specified point (P1) was significantly associated with the occupation category (p-value <0.05). The crosstab analysis revealed that academic staffs (65.5%) had more proper discarding practice compared to administrative staffs (55%), and students (38.4%). This finding shows that there may be differences in waste management practices among individuals based on their occupation. Unlike administrative staffs and students, academic staffs, who are often responsible for teaching and guiding students, may have a better understanding of the significance of good waste management practices and more control over their work setting.

Gender and education variables had statistically significant effect (p-value <0.05) on the use of PPE when contacting with the waste (P3) (Table 16). In the gender category, male respondents (64.9%) were more likely to use PPE than the female respondents (48.8%). This can be attributed to the already recorded good knowledge among the male respondents about PPE infection-protectiveness. The result highlights the influence of knowledge in an individual's practice, as those with more knowledge are more likely to take preventive measures to protect themselves from possible health risks. In the education category, the crosstab analysis also showed that the respondents with postgraduate degrees (68.2%) and diplomas (60%) were inclined to use PPE when contacting with waste compared to those with bachelor degrees (58.6%) and secondary education (20%). This can be attributed to the knowledge and work responsibilities the respondents had. The postgraduate holders had both knowledge and work responsibilities, while the respondents with diplomas had work responsibilities, as 90% of them were employees. These can motivate them to use PPE more than those with bachelor degrees and secondary education.

As Table 16 illustrates, the practice of "not throwing away solid waste in the streets and open spaces of the university (P5)" had a statistically significant association with the gender variable (p-value <0.05). Women (83.9%) were more likely not to throw away waste on the campus compared to men (70.2%). This finding is consistent with that of Addis Taye *et al*. (2024), where gender and waste disposal method had a statistically significant relationship, indicating that women disposed of waste using nearby containers or door-to-door pickers while men used open spaces. Rabeiy *et al*. (2023) also observed that females had better waste-reusing practices than males, which can reduce the quantity of waste thrown away in the streets and spaces.

Table 16: Association between respondents' practice and their demographic variables

Term	Chi-square test's significance (P)			
	Gender	Education	Age	Occupation
P1	0.838	0.074	0.108	0.015
P2	0.107	0.671	0.484	0.530
P3	0.011	0.036	0.201	0.137
P4	0.106	0.061	0.308	0.423
P5	0.007	0.077	0.151	0.479
P6	0.537	0.055	0.547	0.204

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The Uok generated a total solid waste of 15.2 tons per week, with organics (54.5%) and PET bottles (18.8%) being the dominant waste. The waste generation was high during the weekdays, while it decreased in the weekends. The generated waste had recycling (45.1%) and composting (54.5%) potential, thus bringing economic and environmental benefits if properly utilized. Despite waste collection in bins and transportation by vehicle, the UoK lacked separation at the source, which can cause cross-contamination when scavenging. During waste collection, multiple solid waste handlers did not use PPE. Except that the food leftover was taken away by ranchers, other wastes were ultimately sent to and open-burned in an unsuitable dumpsite. Above all, the dumpsite was found to be an environmental and human health polluting site due to its unfitting location. The respondents had good SWM knowledge and attitude with an average percentage of 73.5% and 62.9%, respectively. Despite their good knowledge and attitude, the respondents' practice related to SWM was fair, with an average percentage of 44.8%. The respondents' demographic profile, including gender, education, age, and occupation, had statistically significant association with their KAP.

5.2. Recommendation

Based on the findings of this study the following recommendations were given

- ✓ The solid waste endpoint, where the waste is burned, was a very sensitive site since it was located near public areas. Therefore, an urgent relocation of the university's current dumpsite is needed. Studies on suitable solid waste site selection should be carried out by experts in the study area.
- ✓ Training on solid waste handling and PPE use should be given to the SWM handlers to increase their awareness of waste-related infections.
- ✓ The higher recycling and composting potential of the waste generated on the campus should be utilized to meet the university's development plans and the United Nations' SDGs by 2030. Separation at the source is a prerequisite for sustainable recycling and recovery on the campus.

6. REFERENCES

Abduselam Abdulahi, Abdo Wudad , Mohammedreha Abajihad, and Ferhan Mohammed. 2020. Malaria Hazard and Risk Analysis Using GIS and Remote Sensing in Korahey Zone of Somali Regional State, Eastern Ethiopia. *American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS)*, *68*(1), 20-39.

Abubakar, I. R., Al-Shihri, F. S., & Ahmed, S. M. 2016. Students' assessment of campus sustainability at the University of Dammam, Saudi Arabia. *Sustainability*, *8*(1), 59.

Adane Sirage Ali, Negase Bekela, & Mekdes Mengistu. 2022. Attitude, Awareness, Concern and Practice (AACP) towards Solid Waste Management among University Students: A Case Study in Kotebe Education University, Addis Ababa. *Int J Waste Resour*, *12*, 461.

Addis Taye, Engdawork Assefa, & Belay Simane. 2024. Analysis of practices and factors of solid waste management among urban households of Addis Ababa city, Ethiopia. *Environmental Challenges*, *14*, 100811.

Adebayo Bello, I., & bin Ismail, M. N. 2016. Solid Waste Management in Africa: A Review. *International Journal of Waste Resources*, *6*(2). https://doi.org/10.4172/2252-5211.1000216

Adeleke, O., Akinlabi, S., Jen, T. C., & Dunmade, I. 2021. Towards sustainability in municipal solid waste management in South Africa: a survey of challenges and prospects. In *Transactions of the Royal Society of South Africa* (Vol. 76, Issue 1). https://doi.org/10.1080/0035919X.2020.1858366

Adeniran, A. E., Nubi, A. T., & Adelopo, A. O. 2017. Solid waste generation and characterization in the University of Lagos for a sustainable waste management. *Waste Management*, *67*. https://doi.org/10.1016/j.wasman.2017.05.002

Ahmad, S. F. K., Ali, U. F. M., Isa, K. M., & Gopinath, S. C. B. 2022. Study on characterization of bio-oil derived from sugarcane bagasse (Saccharum barberi) for application as biofuel. *Clean Energy*, *6*(2). https://doi.org/10.1093/ce/zkac012

Ahmadi, S. 2018. Effects of the Environmental Attitude and Responsibility on Household Waste Separation: Evidence from Iranian Married Women. Open Psychol.J.11.

Alemtshay Shiferaw, Nuhamin Tesfa Tsega, Amare Alemu, Mastewal Endalew, & Bikes Destaw Bitew. 2023. On-Site Solid Waste Handling Practice and Associated Factors among Condominium Residents in Gondar City, Northwest Ethiopia, 2021: A Community-Based Cross-Sectional Study. *Journal of Environmental and Public Health*, *2023*(1), 5267790.

Al-Khatib, I. A., Kontogianni, S., Abu Nabaa, H., Alshami, N., & Al-Sari', M. I. 2015. Public perception of hazardousness caused by current trends of municipal solid waste management. *Waste Management*, *36*. https://doi.org/10.1016/j.wasman.2014.10.026

Al-Salem, S. M., Leeke, G. A., El-Eskandarany, M. S., Van Haute, M., Constantinou, A., Dewil, R., & Baeyens, J. 2022. On the implementation of the circular economy route for E-waste management: A critical review and an analysis for the case of the state of Kuwait. In *Journal of Environmental Management* (Vol. 323). https://doi.org/10.1016/j.jenvman.2022.116181

Al-Shatnawi, Z., Alnusairat, S., & Kakani, A. 2020. Towards zero solid waste in jordanian universities: The case of al-ahliyya amman university. *Environmental Research, Engineering and Management*, *76*(4). https://doi.org/10.5755/j01.erem.76.4.27369

Al-Zboon, K., & Masoud, T. 2021. Recycling of stone cutting waste in the construction sector: A review. In *Journal of Solid Waste Technology and Management* (Vol. 47, Issue 1). https://doi.org/10.5276/JSWTM/2021.56

Andrade, C. 2021. The inconvenient truth about convenience and purposive samples. *Indian Journal of Psychological Medicine*, *43*(1), 86-88.

Awino, F. B., & Apitz, S. E. 2023. Solid waste management in the context of the waste hierarchy and circular economy frameworks: An international critical review. In *Integrated Environmental Assessment and Management*. https://doi.org/10.1002/ieam.4774

Awunyo-Vitor, D., Ishak, S., & Seidu Jasaw, G. 2013. Urban Households' Willingness to Pay for Improved Solid Waste Disposal Services in Kumasi Metropolis, Ghana. *Urban Studies Research*, *2013*. https://doi.org/10.1155/2013/659425

Baba, J. S., Balolong, R. M. B., Barriga, O. G. P., Benong, C. B. S., Bungart, R. B., Devero, G. E. B., ... & Saguban, L. E. 2024. THE KNOWLEDGE, ATTITUDE AND PRACTICES AMONG EMPLOYEES OF FOUNDATION UNIVERSITY ON SOLID WASTE MANAGEMENT. *Ignatian International Journal for Multidisciplinary Research*, *2*(5), 2074-2088.

Baralla, G., Pinna, A., Tonelli, R., & Marchesi, M. 2023. Waste management: A comprehensive state of the art about the rise of blockchain technology. In *Computers in Industry* (Vol. 145). https://doi.org/10.1016/j.compind.2022.103812

Barloa, E. P., Lapie, L. P., & de la Cruz, C. P. P. 2016. Knowledge, attitudes, and practices on solid waste management among undergraduate students in a Philippine State University. *Journal of Environment and Earth Science*, *6*(6), 146-153.

Bernhard L. 2005. Local History of Ethiopia. Noradic Africa Institute Library. Available at: https://nai.uu.se/download/18.39fca04516faedec8b248e01/1580829012596/ORTKAT05.pdf

Beshel, C. A., Asor, L. J., Ojong, A. A., Betiang, P. A., & Ironbar, V. E. 2024. Age, gender, and self-concept as predictors of solid waste management among residents in cross river state, Nigeria. *International Journal of Management and Sustainability*, *13*(2), 320-336.

Biruk Abate Fenta. 2017. Waste management in the case of Bahir Dar City near Lake Tana shore in Northwestern Ethiopia: A review. *African Journal of Environmental Science and Technology*, *11*(8). https://doi.org/10.5897/ajest2017.2340

Budihardjo, M.A., Priyambada, I.B., Chegenizadeh, A., Qadar, S., Puspita, A.S. 2023. Environmental Impact Technolgy for Life Cycle Assessment in Municipal Solid Waste Management. *Global J. Environ. Sci. Manage*. 9(SI): 145-172.

Bui, T. D., Tseng, J. W., Tseng, M. L., & Lim, M. K. 2022. Opportunities and challenges for solid waste reuse and recycling in emerging economies: A hybrid analysis. *Resources, Conservation and Recycling*, *177*. https://doi.org/10.1016/j.resconrec.2021.105968

TamarCarter, Solomon Yared, Araya Gebresilassie, Victoria Bonnell, Lambodhar Damodaran, Karen Lopez, Mohammed Ibrahim, Seid Mohammed, Daniel Janies. 2018. First detection of Anopheles stephensi Liston, 1901 (Diptera: culicidae) in Ethiopia using molecular and morphological approaches. *Acta tropica*, *188*, 180-186.

Chen, D. M. C., Bodirsky, B. L., Krueger, T., Mishra, A., & Popp, A. 2020. The world's growing municipal solid waste: trends and impacts. *Environmental Research Letters*, *15*(7). https://doi.org/10.1088/1748-9326/ab8659

Christensen, T. H. 2010. Solid Waste Technology & Management. In *Solid Waste Technology & Management* (Vols. 1–2). https://doi.org/10.1002/9780470666883

Dahlawi, S., & El Sharkawy, M. F. 2021. Assessment of solid waste management practice in the university campus. *International Journal of Sustainability in Higher Education*, *22*(3), 561-575.

Dimtse, D. 2016. Solid waste management in Jijiga, Somali Region: baseline survey factsheet. In *RC / HoAREC Consortium* (Vol. 010).

Dinh, C. Le, Fujiwara, T., Asari, M., Duy, B. N., & Phu, S. T. P. 2022. Optimization of solid waste collection system in a tourism destination. *Global Journal of Environmental Science and Management*, *8*(3). https://doi.org/10.22034/gjesm.2022.03.09

Edjabou, M. E., Jensen, M. B., Götze, R., Pivnenko, K., Petersen, C., Scheutz, C., & Astrup, T. F. 2015. Municipal solid waste composition: Sampling methodology, statistical analyses, and case study evaluation. *Waste Management*, *36*. https://doi.org/10.1016/j.wasman.2014.11.009

Emara, K. 2023. Sustainable solid waste management in rural areas: A case study of Fayoum governorate, Egypt. *Energy Nexus*, *9*. https://doi.org/10.1016/j.nexus.2022.100168.

Amde Eshete, Alemayehu Haddis, & Embialle Mengistie. 2024. Investigation of environmental and health impacts solid waste management problems and associated factors in Asella town, Ethiopia. *Heliyon*, *10*(6).

Hailu Eshete, Asnake Desalegn, Fitsum Tigu. 2023. Knowledge, attitudes and practices on household solid waste management and associated factors in Gelemso town, Ethiopia. *PLoS ONE*, *18*(2 February). https://doi.org/10.1371/journal.pone.0278181

Esmaeilian, B., Wang, B., Lewis, K., Duarte, F., Ratti, C., & Behdad, S. 2018. The future of waste management in smart and sustainable cities: A review and concept paper. In *Waste Management* (Vol. 81). https://doi.org/10.1016/j.wasman.2018.09.047

Fadhullah, W., Imran, N. I. N., Ismail, S. N. S., Jaafar, M. H., & Abdullah, H. 2022. Household solid waste management practices and perceptions among residents in the East Coast of Malaysia. *BMC public health*, *22*, 1-20.

FDRE Constitution of the Federal Democratic Republic of Ethiopia; Addis Ababa, Ethiopia. 1995.Available online: https://www.refworld.org/legal/legislation/natlegbod/1995/en/18206 (accessed on 9 October 2024).

FDRE Environmental Pollution Control Proclamation No. 300/2002; Addis Ababa, Ethiopia. 2002. Available online: https://www.vertic.org/media/National%20Legislation/Ethiopia/ET (accessed 9 October 2024).

FDRE Environmental ProtectionAuthority. 1997. Environmental Policy of Ethiopia. Available online:https://www.epa.gov.et/images/Polices/ENVIRONMENT_POLICY_OF_ETHIOPIA.pdf (accessed on 19 October 2024).

FDRE Public Health Proclamation No. 200/2000; Addis Ababa, Ethiopia. 2000. Available online:https://www.lawethiopia.com/images/federal_proclamation/proclamations_by_number/200.pdf (accessed on 9 October 2024).

Workineh Mengesha Fereja and Dereje Diriba Chemeda. 2022. Status, characterization, and quantification of municipal solid waste as a measure towards effective solid waste management: The case of Dilla Town, Southern Ethiopia. *Journal of the Air and Waste Management Association*, *72*(2). https://doi.org/10.1080/10962247.2021.1923585

Gaeta-Bernardi, A., & Parente, V. 2016. Organic municipal solid waste (MSW) as feedstock for biodiesel production: A financial feasibility analysis. In *Renewable Energy* (Vol. 86). https://doi.org/10.1016/j.renene.2015.08.025

Gebreeyessus, G. D., Berihun, D., & Terfassa, B. 2019. Characterization of solid wastes in higher education institutions: the case of Kotebe Metropolitan University, Addis Ababa, Ethiopia. *International Journal of Environmental Science and Technology*, *16*(7). https://doi.org/10.1007/s13762-018-1953-y

Eshetu Gelan. 2021. Municipal Solid Waste Management Practices for Achieving Green Architecture Concepts in Addis Ababa, Ethiopia. *Technologies*, *9*(3). https://doi.org/10.3390/technologies9030048

Guerrero, L. A., Maas, G., & Hogland, W. 2013. Solid waste management challenges for cities in developing countries. *Waste Management*, *33*(1). https://doi.org/10.1016/j.wasman.2012.09.008

Habtom Kahhsay. 2022. Solid Waste Management and Recycling in Ethiopia. Available online: https://aaeafrica.org/ethiopia/solid-waste-management-and-recycling-in-ethiopia/ (accessed on 5 November 2023).

Tigistu Haile and Tamiru Abiye. 2012. Environmental impact and vulnerability of the surface and ground water system from municipal solid waste disposal site: Koshe, Addis Ababa. *Environmental Earth Sciences, 67*(1). https://doi.org/10.1007/s12665-011-1480-3

Mengist Hailemariam and Assegid Ajeme. 2014. Solid waste management in Adama , Ethiopia : Aspects and challenges. *Integrated Development for Water Supply and Sanitation*, *8*(9).

Harold G. Marcus and Assefa Mehretu. 2024. Soils of Ethiopia. *Encyclopaedia Britannica*. https://www.britannica.com/place/Ethiopia/Soils

Hashim, K., Rabe, N. S., Osman, M. M., & Zahari, R. K. 2017. Solid waste management practice and environmental awareness level of postgraduate and undergraduate students: Case study of UTM. *Advanced Science Letters, 23*(7), 6073-6077.

Hassan, N., & Rosli, N. S. 2022. Knowledge, Attitude and Practice on Waste Management among University Students in Malaysia. *Malaysian Journal of Tropical Geography (MJTG)*, *48*(2), 1-15.

Helelo, A. B., Senbeta, A. F., & Anshebo, S. T. 2019. Assessment of Solid Waste Management (SWM) practices in Hawassa University Campuses, Ethiopia. *Journal of Applied Sciences and Environmental Management*, *23*(6), 1081. https://doi.org/10.4314/jasem.v23i6.13

Hettiarachchi, H., Meegoda, J. N., & Ryu, S. 2018. Organic waste buyback as a viable method to enhance sustainable municipal solid waste management in developing countries. *International Journal of Environmental Research and Public Health*, *15*(11). https://doi.org/10.3390/ijerph15112483

Lemesa Hirpe and Chunho Yeom. 2021. Municipal solid waste management policies, practices, and challenges in ethiopia: A systematic review. In *Sustainability (Switzerland)* (Vol. 13, Issue 20). https://doi.org/10.3390/su132011241

Hoornweg, D., Bhada-Tata, P. & Kennedy, C. 2013. Environment: Waste production must peak this century. Nature 502, 615–617. https://doi.org/10.1038/502615a

Hunachew B. Mengesha, Dessalegn B. Y. 2014. Solid waste Characterization and Recycling Potential in Hawassa University, Ethiopia. *International Journal of Environmental and Ecological Engineering*, *8*(2).

Kabera, T., & Nishimwe, H. 2019. Systems analysis of municipal solid waste management and recycling system in east Africa: Benchmarking performance in Kigali city, Rwanda. *E3S Web of Conferences*, *80*. https://doi.org/10.1051/e3sconf/20198003004

Ashenafi Yimam Kassaye. 2018. Contemporary institutional solid waste management practices of Haramaya University, Eastern Ethiopia. *African Journal of Science, Technology, Innovation and Development*, *10*(2). https://doi.org/10.1080/20421338.2018.1443412

Kaza, S., Yao, L. C., Bhada-Tata, P., & Van Woerden, F. 2018. What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050. In *What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050*. https://doi.org/10.1596/978-1-4648-1329-0

Kwakye, S. O., Amuah, E. E. Y., Ankoma, K. A., Agyemang, E. B., & Owusu, B. G. 2024. Understanding the performance and challenges of solid waste management in an emerging megacity: Insights from the developing world. *Environmental Challenges, 14,* 100805.

Leal Filho, W., Skanavis, C., Kounani, A., Brandli, L. L., Shiel, C., Paço, A. do, Pace, P., Mifsud, M., Beynaghi, A., Price, E., Salvia, A. L., Will, M., & Shula, K. 2019. The role of planning in implementing sustainable development in a higher education context. *Journal of Cleaner Production*, *235*. https://doi.org/10.1016/j.jclepro.2019.06.322

Gorfnesh Lema, Million Getachew Mesfun, Amade Eshete, and Gizachew Abdeta. 2019. Assessment of status of solid waste management in Asella town, Ethiopia. *BMC Public Health*, *19*(1). https://doi.org/10.1186/s12889-019-7551-1

Li, C. H., Lee, T. T., & Lau, S. S. Y. 2023. Enhancement of Municipal Solid Waste Management in Hong Kong through Innovative Solutions: A Review. In *Sustainability (Switzerland)* (Vol. 15, Issue 4). https://doi.org/10.3390/su15043310

Tewodros Manyazewal and Tesfaye Walelgn. 2019. Solid Waste Management Practice and Level of Satisfaction from Related Services among Commercials and Institutions in Jigjiga City, Ethiopia. *International Journal of Environmental Sciences & Natural Resources*, *22*(2). https://doi.org/10.19080/ijesnr.2019.21.556057

Marshall, R. E., & Farahbakhsh, K. 2013. Systems approaches to integrated solid waste management in developing countries. *Waste Management*, *33*(4). https://doi.org/10.1016/j.wasman.2012.12.023

Marsie, GebruZinabu., Hayelom., AbrhaBirhanu., & Birega, GashawMeseker. 2017. Existing and Future MSW Generation Nexus Population and GDP Growth, the case of Mekele City, Ethiopia. *International Journal of Advanced Research*, *5*(1). https://doi.org/10.21474/ijar01/2845

Mazhar, M. A., Khan, N. A., Khan, A. H., Ahmed, S., Siddiqui, A. A., Husain, A., Rahisuddin, Tirth, V., Islam, S., Shukla, N. K., Changani, F., Yousefi, M., Hassaballa, A. E., & Radwan, N. 2021. Upgrading combined anaerobic-aerobic UASB-FPU to UASB-DHS system: Cost comparison and performance perspective for developing countries. *Journal of Cleaner Production*, *284*. https://doi.org/10.1016/j.jclepro.2020.124723

Meena, M. D., Dotaniya, M. L., Meena, B. L., Rai, P. K., Antil, R. S., Meena, H. S., Meena, L. K., Dotaniya, C. K., Meena, V. S., Ghosh, A., Meena, K. N., Singh, A. K., Meena, V. D., Moharana, P. C., Meena, S. K., Srinivasarao, Ch., Meena, A. L., Chatterjee, S., Meena, D. K., … Meena, R. B. 2023. Municipal solid waste: Opportunities, challenges and management policies in India: A review. *Waste Management Bulletin*, *1*(1). https://doi.org/10.1016/j.wmb.2023.04.001

Mesfin Tilaye and Meine Pieter van Dijk. 2014. Sustainable Solid Waste Collection in Addis Ababa: the Users? Perspective. *International Journal of Waste Resources*, *04*(03). https://doi.org/10.4172/2252-5211.1000158

Memon, M.A. 2010. Integrated solid waste management based on the 3R approach. J Mater Cycles Waste Manag 12, 30–40. https://doi.org/10.1007/s10163-009-0274-0

Ministry of Education (MoE). 2018. Ethiopian Education Development Road Map (2018-30), Unpublished Draft for Discussion, Addis Ababa, Ethiopia.

Ali Mohammed and Eyasu Elias. 2017. Domestic waste management and its environmental impacts in Addis Ababa City. In *African Journal of Environmental and Waste Management* (Vol. 4, Issue 3).

Mohammed, S., Gill, A. R., Alsafadi, K., Hijazi, O., Yadav, K. K., Hasan, M. A., Khan, A. H., Islam, S., Cabral-Pinto, M. M. S., & Harsanyi, E. 2021. An overview of greenhouse gases emissions in Hungary. *Journal of Cleaner Production*, *314*. https://doi.org/10.1016/j.jclepro.2021.127865

Moqbel, S. 2018. Solid waste management in educational institutions: The case of the University of Jordan. *Environmental Research, Engineering and Management*, *74*(2). https://doi.org/10.5755/j01.erem.74.2.21037

Selamawit Mulat, Walelegn Worku, and Amare Minyihun. 2019. Willingness to pay for improved solid waste management and associated factors among households in Injibara town, Northwest Ethiopia. *BMC Research Notes*, *12*(1). https://doi.org/10.1186/s13104-019-4433-7

Nandan, A., Yadav, B. P., Baksi, S., & Bose, D. 2017. Recent Scenario of Solid Waste Management in India. *WSN World Scientific News*.

Nathanson, J. A. 2023. Solid waste managemen. Encyclopedia Britannica. https: //www.britannica.com/technology/solid-waste-managemen. (accessed 3 January, 2024).

Negarit Gazeta of the Federal Democratic Republic of Ethiopia Proclamation No. 513. 2007. Solid Waste Management Proclamation, p.3524. 13th Year No. 13, Addis Ababa, 12 February 2007. *EMIS*. (2016/17).

Noman, A. A., Rafizul, I. M., Moniruzzaman, S. M., Kraft, E., & Berner, S. 2023. Assessment of municipal solid waste from households in Khulna city of Bangladesh. *Heliyon*, *9*(12).

Nyampundu, K., Mwegoha, W. J., & Millanzi, W. C. 2020. Sustainable solid waste management Measures in Tanzania: an exploratory descriptive case study among vendors at Majengo market in Dodoma City. *BMC Public Health*, *20*, 1-16.

Owojori, O., Edokpayi, J. N., Mulaudzi, R., & Odiyo, J. O. 2020. Characterisation, recovery and recycling potential of solid waste in a university of a developing economy. *Sustainability (Switzerland)*, *12*(12). https://doi.org/10.3390/su12125111

Pan, Y., Li, M., Guo, H., Li, Y., & Han, J. 2022. Influencing factors and reduction of domestic solid waste at university dormitory in Shanghai, China. *Scientific Reports*, *12*(1). https://doi.org/10.1038/s41598-021-04582-0

Pujara, Y., Pathak, P., Sharma, A., & Govani, J. 2019. Review on Indian Municipal Solid Waste Management practices for reduction of environmental impacts to achieve sustainable development goals. In *Journal of Environmental Management* (Vol. 248). https://doi.org/10.1016/j.jenvman.2019.07.009

Rabeiy, R., Almutairi, S., Birima, A., Kassem, L., & Nafady, A. 2023. A Cross-Sectional Study of Knowledge, Practice, and Management of Solid Waste Segregation in Higher

Educational Institutes: A Case Study in KSA. *Sustainability*, *15*(6), 5516. https://doi.org/10.3390/su15065516

Radwan N, Khan NA. 2023. A Systematic Review of Solid Waste Management (SWM) and Artificial Intelligence Approach. *Research Square*. https://doi.org/10.21203/rs.3.rs-2575251/v1

Nigatu Regassa, Rajan D Sundaraa, Bizunesh Bogale Seboka. 2011. Challenges and Opportunities in Municipal Solid Waste Management: The Case of Addis Ababa City, Central Ethiopia. *Journal of Human Ecology*, *33*(3). https://doi.org/10.1080/09709274.2011.11906358

Salim, H., Jackson, M., Stewart, R. A., & Beal, C. D. 2023. Drivers-pressures-state-impact-response of solid waste management in remote communities: A systematic and critical review. In *Cleaner Waste Systems* (Vol. 4). https://doi.org/10.1016/j.clwas.2023.100078

Santana, L. R. B., Walchhütter, S., Slavov, T. N. B., & Russo, P. T. 2022. Municipal solid waste management: analysing the principles of the Brazilian National Solid Waste Policy. *International Journal of Environment and Waste Management*, *29*(4). https://doi.org/10.1504/IJEWM.2022.10035736

Slovin, E. 1960. Slovin's Formula for Sampling Technique. https://prudencexd.weebly.com/

Sondh, S., Upadhyay, D. S., Patel, S., & Patel, R. N. 2022. A strategic review on Municipal Solid Waste (living solid waste) management system focusing on policies, selection criteria and techniques for waste-to-value. In *Journal of Cleaner Production* (Vol. 356). https://doi.org/10.1016/j.jclepro.2022.131908

Tadele Assefa Araga, Addisu wondimnew, Abraham M. Asmare. 2016. Quantification, Characterization and Recycling Potential of Solid Waste: Case Study Bahir Dar Institute of Technology. *International Journal of Science and Research (IJSR)*, *5*(6). https://doi.org/10.21275/v5i6.nov164799

Teferi, S. C. 2022. The Status of Household Solid Waste Management and its Associated Factors in Fiche Town, North Shewa Zone, Ethiopia. *Environmental Health Insights*, *16*. https://doi.org/10.1177/11786302221117007

Fiseha Bekele Teshome. 2021. Municipal solid waste management in Ethiopia; the gaps and ways for improvement. In *Journal of Material Cycles and Waste Management* (Vol. 23, Issue 1). https://doi.org/10.1007/s10163-020-01118-y

Zawde Tadesse Teshome, Zemenu Tadesse Ayele, Mohamed Ibrahim Abib. 2022. Assessment of solid waste management practices in Kebridehar city Somali regional state, Ethiopia. *Heliyon*, *8*(9).

Ugwu, C. O., Ozoegwu, C. G., & Ozor, P. A. 2020. Solid waste quantification and characterization in university of Nigeria, Nsukka campus, and recommendations for sustainable management. *Heliyon*, *6*(6). https://doi.org/10.1016/j.heliyon.2020.e04255

Ugwu, C. O., Ozoegwu, C. G., Ozor, P. A., Agwu, N., & Mbohwa, C. 2021. Waste reduction and utilization strategies to improve municipal solid waste management on Nigerian campuses. *Fuel Communications*, *9*, 100025. https://doi.org/10.1016/j.jfueco.2021.100025

UNEP. 1989. Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal. Basel Convention. http://www.basel.int/Portals/4/Basel%20Convention/docs/text/con-e-rev.pdf

UNEP. 2020. Waste Management an essential public service in the fight of to beat COVID-19. The *United Nations Environmental Programme (UNEP)* and *Basel convention*. Available online: https://www.unep.org/news-and-stories/press-release/waste-management-essential-public-service-fight-beat-covid-19 and https://www.basel.int/Default.aspx?tabid=8376 (accessed 11 November 2023).

United Nations (UN). 2015. Sustainable Development Goals. Available online: https://www.un.org/sustainabledevelopment/sustainable-development-goals/.(accessed 3 November 3, 2023)

Villalba, L. 2020. Material Flow Analysis (MFA) and waste characterizations for formal and informal performance indicators in Tandil, Argentina: Decision-making implications. *Journal of Environmental Management*, *264*. https://doi.org/10.1016/j.jenvman.2020.110453

Worku Adefris, Shimeles Damene, & Poshendra Satyal. 2023. Household practices and determinants of solid waste segregation in Addis Ababa city, Ethiopia. *Humanities and social sciences communications*, *10*(1), 1-10.

World Bank. 2022. Solid waste management. World Bank. Available online: https://www.worldbank.org/en/topic/urbandevelopment/brief/solid-waste-management (accessed on 9 December 2023)

Zargar, T. I., Alam, P., Khan, A. H., Alam, S. S., Abutaleb, A., Hasan, M. A., & Khan, N. A. 2023. Characterization of municipal solid waste: Measures towards management strategies using statistical analysis. *Journal of Environmental Management*, *342*, 118331.

Zhang, D., Hao, M., Chen, S., & Morse, S. 2020. Solid waste characterization and recycling potential for a university campus in China. *Sustainability*, *12*(8), 3086.

Zheng, R., Qiu, M., Wang, Y., Zhang, D., Wang, Z., & Cheng, Y. 2023. Identifying the influencing factors and constructing incentive pattern of residents' waste classification behavior using PCA-logistic regression. *Environmental Science and Pollution Research*, *30*(7), 17149-17165.

7. APPENDICES

Appendix 1. Checklist for the collection of the daily generated solid waste at every building

Block/building number ____________________					Block type/activity __________________			
Types of solid waste generated	The quantity of solid waste generated for seven days (kg)							
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Total
Organic waste								
Paper and cardboards								
PET bottles								
Plastics								
Textiles								
Glass								
Metals								
Medical								
Miscellaneous								
Total								

Appendix 2. A questionnaire designed to assess the knowledge and practice of the university's population

HAWASSA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

ECOTOXICOLOGY AND ENVIRONMENTAL HEALTH

Dear respondents, the aim of this questionnaire is to collect information about the knowledge and practices of population of the University of Kabridahar. The correct and honest information you provide will definitely contribute the effective accomplishment of this study. I assure you that your information will only be used for research purposes. Therefore, you are kindly requested to provide the correct response for the following information.

GENERAL INFORMATION

- Do not write your name.
- Please put"√" mark in boxes.
- Fill the questionnaire without discussing with your friends.

Date______________________________ Signature _____________________________

Part I. Respondents' of Personal Information

1. What is your position in the university's population?

A. Student ☐ B. Academic staffs ☐ C. Administrative staffs ☐

2. What is you gender?

A. Male ☐ B. Female ☐

3. What is your age? ____________

4. What is your education level?

A. No formal education (illiterate) ☐ B. Primary school ☐ C. Secondary school ☐

D. Diploma ☐ E. Bachelor degree ☐ F. Post-graduate degree ☐

Part II: Respondent's Knowledge towards SWM

No.	Knowledge question	Responses	
		Yes	No
1	Can solid waste be classified into organic waste such as food waste and inorganic waste such as papers and plastics?		
2	Does improper SWM cause human health risks (e.g., infectious diseases) and environmental pollution (e.g., water pollution)?		
3	Do solid wastes have economic value?		
4	Are wastes such as papers, plastics, metals, textiles, etc. recyclable?		
5	Can reuse reduce the amount of solid waste?		
6	Does solid waste recycling protect the surrounding environment and preserve the natural resources?		
7	Are universities expected to achieve SSWM?		
8	Does solid waste segregation at source help SWM?		
9	Can compost or organic fertilizers be prepared from solid waste?		
10	Does wearing personal protective equipment (PPEs) lower the risk of waste-related infections?		

Part III: Respondent’s Attitude towards SWM

No.	Attitude statement	Responses		
		Disagree	Neutral	Agree
1.	Proper solid waste disposal is everyone’s responsibility			
2.	Universities play a crucial role in the environmental issues			
3.	The application of 4Rs (reuse, reduce, recycle, & recovery) policy can lead to achieve sustainable solid waste management			
4.	Institutional solid wastes can pose health and environmental hazards if improperly managed			
5.	Increasing the community's awareness towards the effect of improper SWM decreases health risks.			
6.	The formulation of regulations and their implementations can help the solid waste management of the university			

Part IV: Respondent's practice towards SWM

No.	Practice question	Responses		
		Disagree	Neutral	Agree
1.	I always discard the waste at specified points/containers			
2.	I initially separate solid waste to put it into the respective trash bins			
3.	I use personal protective equipment when contacting with (handling) the waste			
4.	I take and use the reusable solid waste			
5.	I do not throw away the solid waste in the streets and open spaces of the university			
6.	I put hazardous wastes in special bins designed for them with the help of personal protective equipment			

Appendix 3. Key-informant interview questions

HAWASSA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

ECOTOXICOLOGY AND ENVIRONMENTAL HEALTH

Dear key informant, the aim of this questionnaire is to collect information about the composition and management practices of solid waste at the University of Kabridahar. The correct and honest information you provide will definitely contribute the effective accomplishment of this study. I assure you that your information will only be used for research purposes. Therefore, you are kindly requested to provide the correct response for the following information.

Date______________________ Position ________________ Signature_________________

1. How does the solid waste generated at the university is managed?

____

____

____

2. Does the university have its own solid waste landfills or dumpsites?

____

____

____

3. How often the solid waste generated at the university is collected and transported to landfills

____

____

____

4. What are the major constituents of solid wastes in the university?

____

____

____

5. Are there any plans of the university towards SSWM?

____

____

____

6. What are the challenges you come across when dealing with SWM?

____

____

____

7. What attempts the university has made to solve solid SWM challenges?

____

____

____