Development of an Integrated Solid Waste Management Plan:

The Case Study of Student Residences of PMB Campus, UKZN

Sandisiwe Mahlamvu

(214514076)

Submitted in partial fulfilment of the requirements for the degree

of

Master of Science in Engineering in Waste and Resource Management

Collage of Agriculture, Engineering and Science

School of Engineering

University of KwaZulu-Natal

South Africa

November 2022

ABSTRACT

Over the years, the solid waste generation rate has rapidly increased due to population growth. Many countries face the challenge of finding ways to manage this waste. South Africa has signed the 17 Sustainable Development Goals (SDG) that must be achieved by the year 2030; this calls for government, private and educational institutions to work together to achieve sustainability as a country. However, research on the quantification and characterization of municipal solid waste in the context of South African universities is limited.

This research investigated how municipal solid waste is managed by the University of KwaZulu-Natal Pietermaritzburg campus and recommended sustainable solid waste management strategies (separation at source, recycling, and compositing). Also, the impact of Coronavirus on solid waste and ways of mitigating its spread post-pandemic was considered.

The main result of this research was to determine the current waste management strategy employed by the UKZN-PMB campus. It was found that solid waste is sent to the landfill site, which is not sustainable because the Campus has a potential recycling rate of 96%. An average of 52,6kg of waste was generated daily, and each student generated approximately 0,168kg daily. Also, student participation plays a vital role in separating waste at source to encourage the adoption of sustainable practices. The survey showed that 92.7% of the students were willing to separate their waste. It may be deduced that making Higher education institutions sustainable benefits the institutions and contributes towards the bigger picture of sustainable cities.

DECLARATION

I, Sandisiwe Mahlamvu, student no. 214514076, declare that

- This dissertation reflects my work and has not been submitted in part or whole to any other University.
- Where other sources (text, graphics, and tables) have been used, original Author(s) have been acknowledged through in-text incitation and detailed in the Reference section.

The research was conducted at the University of KwaZulu-Natal, Pietermaritzburg Campus, under the supervision of Prof. Cristina Trois, co-supervised by Dr Surabhi. The research aimed to develop a solid waste management plan for UKZN-PMB Campus.

[redacted]……. 29/03/2023…….

Student Date

……. …….

Co-Supervisor Date

……. …….

Supervisor Date

ACKNOWLEDGEMENT

"Trust in the Lord with all your heart, and lean not on your own understand, in all your ways submit to Him, and He will make your path straight" – Proverb 3: 5-6

First and foremost, I would like to give gratitude to God for giving me the strength to finish this dissertation, including the following people who played a significant role in my journey:

- My Supervisors, Prof. Cristina Trois and Dr Surabhi Srivastava, I appreciate all your effort in making sure that I complete my dissertation. If it were not for your financial and professional guidance, none of this would have been possible; thank you for the encouragement.
- Thank you to my friends for supporting me, especially during data collection; I will always carry you in my heart. Extending my appreciation to the His People Church family for praying with me and encouraging me during the difficult times.
- Last but not least, I dedicate this dissertation to my mother (Zuziwe Mpetshwa), grandmother (Getrude Mpoyi) and siblings (Aviwe, Sihle, Yanga, and Zosuliwe); your unwavering support carried me. Thank you for believing in me and showing me unconditional love throughout the journey.

TABLE OF CONTENTS

Page

ABSTRACT I

DECLARATION II

ACKNOWLEDGEMENT III

TABLE OF CONTENTS II

LIST OF FIGURES VI

LIST OF TABLES VIII

LIST OF ABBREVIATIONS IX

1. CHAPTER ONE: INTRODUCTION 10

1.1 Motivation 11

1.2 Significance of the Study 12

1.3 Research Questions 13

1.4 Aims and Objectives 13

1.5 Research Structure 14

1.5.1 Framework 15

1.6 Chapter Summary 16

2. CHAPTER TWO: LITERATURE REVIEW 17

2.1 Sustainability in Universities 17

2.1.1 Talloires Declaration (TD) 18

2.1.2 Sustainable Development Goals 19

2.1.3 Green University 20

2.2 Waste Management in other Universities 21

2.2.1 Australian National University (ANU): International case study 22

2.2.1.1 Recycling and waste management 22

2.2.2 African Universities 24

2.2.2.1 Cape Town University (UCT): South African university case study 24
2.2.2.2 Waste management at UKZN (Pre-pandemic) 27
2.3 Impact of COVID-19 on Waste Management 28
2.3.1 Waste Management at the University of KwaZulu-Natal (Howard Collage) 30
2.3.2 Impact of COVID-19 at UKZN 31
2.3.2.1 Waste management at UKZN during the pandemic 31
2.4 Waste in the South African Context 33
2.5 Waste characterisation 34
2.6 Waste management hierarchy 36
2.6.1 Application of waste management hierarchy in universities 38
2.6.2 Zero waste 38
2.7 Stakeholder engagement 39
2.8 South African waste legislation 40
2.9 Sustainable Waste Management Strategies 41
2.9.1 Separation at source 41
2.9.2 Recycling 43
2.10 Composting 43
2.11 Anaerobic digester 44
2.12 Chapter Summary 45
3. CHAPTER THREE: METHODOLOGICAL APPROACH 46
3.1 Summary of Methodology 46
3.2 Waste Management at UKZN PMB Campus 47
3.2.1 Waste management: campus investigation 47
3.3 Waste Management at UKZN-PMB Residences 48
3.3.1 Waste generation and separation at source 48

3.3.2 Survey questionnaire 49
3.3.3 Survey sample size 49
3.4 Solid Waste Separation at Source Experiment 50
3.4.1 Materials 50
3.4.2 Experiment procedure 50
3.5 Characterization of the samples 52
3.6 Analysis of Data 53
3.7 Assumptions 54
3.8 Limitations 54
3.9 Chapter Summary 55
4. CHAPTER FOUR: A CASE STUDY OF PMB, UKZN 56
4.1 PMB Campus Waste Management Overview 57
4.1.1 Campus Observation 58
4.1.1.1 Condition of the bins 58
4.1.1.2 Littering around campus 60
4.1.2 Waste Management Initiatives on Campus 61
4.1.3 Impact of COVID-19 on Waste Management 61
4.2 Denison Residence 63
4.2.1 Tower Residence, Block 1, 2, and 3 Residence 64
4.2.1.1 Residence description - Block 1, 2, and 3 Residence 64
1.1.1 Current Solid Waste Management 65
4.2.2 Waste Management Initiatives at Denison Residence 67
4.3 Chapter Summary 67
5. CHAPTER FIVE: RESULTS AND DISCUSSION 68
5.1 Survey Results 68
5.1.1 Social Demographic 68

5.1.2 Knowledge and understanding of waste management 69
5.1.3 Waste management and COVID-19 70
5.1.4 Student's observations about the UKZN waste management practices 71
5.1.5 Student's waste management behaviour 72
5.2 Waste Analysis 73
5.2.1 Waste generated per building 74
5.2.2 Waste generation rate 75
5.2.3 Waste generation based on gender 76
5.2.4 Wet and Dry Waste Composition 76
5.2.5 Waste Stream Analysis 77
5.2.6 Total Waste Composition 78
5.2.7 Recycling Potential of the University Residence Solid Waste 79
5.3 Discussion 81
5.3.1 Current waste management strategy in PMB Campus 81
5.3.2 Student participation 81
5.3.3 Waste generated 82
5.3.4 Conceptual integrated waste management plan 83
6. CHAPTER SIX: CONCLUSSION AND RECOMMENDATION 86
REFERENCES 89
APPENDICES 92

LIST OF FIGURES

Figure 1.1 Total Recycling in UKZN PMB Campus in 2010 (UKZN, 2020). 11

Figure 2.1 Diagram of the different dimensions for a sustainable University (Fissi *et al.*, 2021). 21

Figure 2.2 Waste management stakeholders 23

Figure 2.3 UCT's environmental sustainability strategy (UCT, 2021). 26

Figure 2.4 Ansel May residence waste composition (Langa, 2019). 27

Figure 2.5 Survival time of COVID_19 of surfaces (Kulkarni and Anantharama, 2020). 29

Figure 2.6 Waste management strategies under COVID-19 (Das *et al.*, 2021a). 30

Figure 2.7 Sphiwe Zuma residence survey results Vallabh (2020)..... 32

Figure 2.8 Waste composition for Sphiwe Zuma residence (Vallabh, 2020). 32

Figure 2.9 Waste composition at the University of Nigeria (Ugwu *et al.*, 2020). 36

Figure 2.10 Waste Management Hierarchy (NEMA, 2014). 37

Figure 2.11 Stalk-holders involved in separation at source. 40

Figure 2.12 Different types of waste bins (RU, 2020). 42

Figure 2.13 Rhodes University two bag system (RU, 2020). 42

Figure 2.14 Anaerobic digestion process (Dehkordi *et al.*, 2020). 44

Figure 3.1 Notice about waste separation. 51

Figure 3.2: Separated waste from student residence PMB campus. 52

Figure 4.1 Google Earth photo showing different UKZN PMB Campuses..... 56

Figure 4.2 On campus residences around main campus. 57

Figure 4.3 Source of solid waste in PMB Campus. 57

Figure 4.4 Three types of bins around Campus. 58

Figure 4.5 Condition of the bins around campus. 59

Figure 4.6 Wheelie bin that was designated for glass recycling. 59
Figure 4.7 Repurposed bins at Agriculture Campus. 60
Figure 4.8 Littering observed around campus. 61
Figure 4.9 COVID-19 sanitising station. 62
Figure 4.10 Google Earth photo of Denison Residence. 63
Figure 4.11 New Denison Building Residences, PMB Campus. 64
Figure 4.12 Men and Women's Tower. 65
Figure 4.13 Bins located inside the residences, at the corner and in the kitchen respectively. 65
Figure 4.14 The summary of solid waste management in UKZN residences that is currently employed. 66
Figure 4.15 Denison waste collection points. 66
Figure 5.1 Respondent's knowledge of waste management. 70
Figure 5.2 Student's knowledge of COVID-19 transmission through waste. 70
Figure 5.3 Results on the disposal of masks. 71
Figure 5.4 Student's observations about the university's waste management practices. 72
Figure 5.5 Respondents on plastic shopping bags when going to do shopping. 73
Figure 5.6 Waste generated by each residence building. 75
Figure 5.7 Student waste generation based on gender. 76
Figure 5.8 Dry and wet waste composition 77
Figure 5.9 Dry waste composition. 78
Figure 5.10 Total waste composition. 79
Figure 5.11 Recycling potential at Denison Residence. 80
Figure 5.12 Summary of the UKZN conceptual Integrated Waste Management Plan. 85

LIST OF TABLES

Table 2.1 Initiatives that have been developed to foster sustainability in HEIs [Adopted: (Lozano *et al.*, 2013)] 18

Table 2.2 SDGs that universities need to align with regard solid waste management [Adopted:(UN, 2022a)]. 20

Table 2.3 Key actions and targets set by ANU 23

Table 2.4 Summary of legislation and policies of waste management in South Africa 40

Table 3.1 Dry waste component categories. 52

Table 5.1 Number of respondents based on gender 68

Table 5.2 Number of respondents based on year of study. 69

Table 5.3 Amount of waste that was collected from five Denison buildings 74

Table 5.4 Waste generation rates per student per day at Howard Collage residences 75

Table 5.5 Comparison of waste recycling potential analysis of this study with the Howard research 80

LIST OF ABBREVIATIONS

COVID-19	Corona Virus
EA	Environmental Affairs
Edtea	Economic Development and Environmental Affairs
EMP	Environmental Management Plan
GHG	Greenhouse Gases
HEIs	high education institutions
IWMP	Integrated Waste Management Plan
MRF	Materials Recovery Facility
MSW	Municipal Solid Waste
NEMA	National Environmental Management Act
NWMS	National Waste Management Strategy
PMB	Pietermaritzburg
PPE	Personal Protective Equipment
SDGs	Sustainable Development Goals
TD	Talloires Declaration
TVET	Technical and Vocational Education and Training
UCT	University of Cape Town
UKZN	University of KwaZulu-Natal
UKZN-HCC	University of KwaZulu-Natal Howard College Campus
UN	United Nations
WHO	World Health Organization

1. CHAPTER ONE: INTRODUCTION

The improper handling of solid waste has a devastating impact on the environment and human health. Therefore, an integrated solid waste management plan must be developed and implemented in Higher education institutions (HEIs) to avoid waste being sent to the landfill site (Dahlawi and El Sharkawy, 2021). Also, Higher education institutions need to consider the impact of the Corona Virus (COVID-19) on solid waste management, as it may be easily transmitted from waste collection, transport, and disposal if not correctly handled (Das *et al.*, 2021b).

Currently, the solid waste management process at the University of KwaZulu-Natal (UKZN) is linear and not sustainable. Waste is collected from the point of generation and sent to the landfill site. The waste on campus and in residences is not sorted, and standard open bins are placed at random points; this will negatively impact the health of students and staff (post-pandemic effect).

The universities, the harbour for knowledge transmission from research to teaching, cannot ignore the challenges associated with solid waste management (Adeniran *et al.*, 2017). Also, universities can be considered "mini-cities" or small towns because they have several campuses and residences (Gallardo *et al.*, 2016). South Africa has 26 public universities, 50 public TVET colleges, and over 300 private colleges. The University of Kwa-Zulu Natal (UKZN) alone has five campuses and more than 40 000 (fourth thousand) students (UKZN, 2020) .

Universities need proper waste management programmes and collection resources to encourage waste recovery, reduction, and recycling (Lozano *et al.*, 2013). A study at the University of Lagos showed that approximately 32.2 tons of solid waste were produced daily at the Unilag Akoka campus, and 75% of the total waste produced was recyclable (Adeniran *et al.*, 2017).

Researcher Moqbel (2018) performed a solid waste characterization study at the University of Jordan. The results showed that the university produces 8113 kg of waste daily, and 87% of the waste generated is recyclable.

Middle East Technical University (METU), one of Turkey's largest campuses, also did a study to determine the amount of solid waste generated. The study showed that the

university generates between 5.8-10.3 tons/day on a weekly basis, and it was also found that 13% of the collected waste is recyclable (Bahçelioğlu *et al.*, 2020).

The common factor in the studies mentioned above is that the Researchers have identified that universities have a high potential to recycle solid waste and divert it from being sent to the landfill site by implementing waste management strategies. These strategies include recycling, waste to energy, and composting (Mbuligwe, 2002;Taghizadeh *et al.*, 2012).

Limited information on waste management strategies implemented by African universities has been published. Therefore, it is time for South African universities to accept their institutional responsibility and contribute toward sustainability by designing and implementing proper integrated solid waste management strategies.

1.1 Motivation

The data on the UKZN website shows the amount of general waste recycled in 2010, which is now outdated. Refer to Figure 1.1 below. This research aims to characterize and quantify the waste streams generated by Pietermaritzburg (PMB) Campus residences to recommend an informed waste management strategy that will divert recyclables from being sent to the landfill site and curb the spread of Coronavirus.

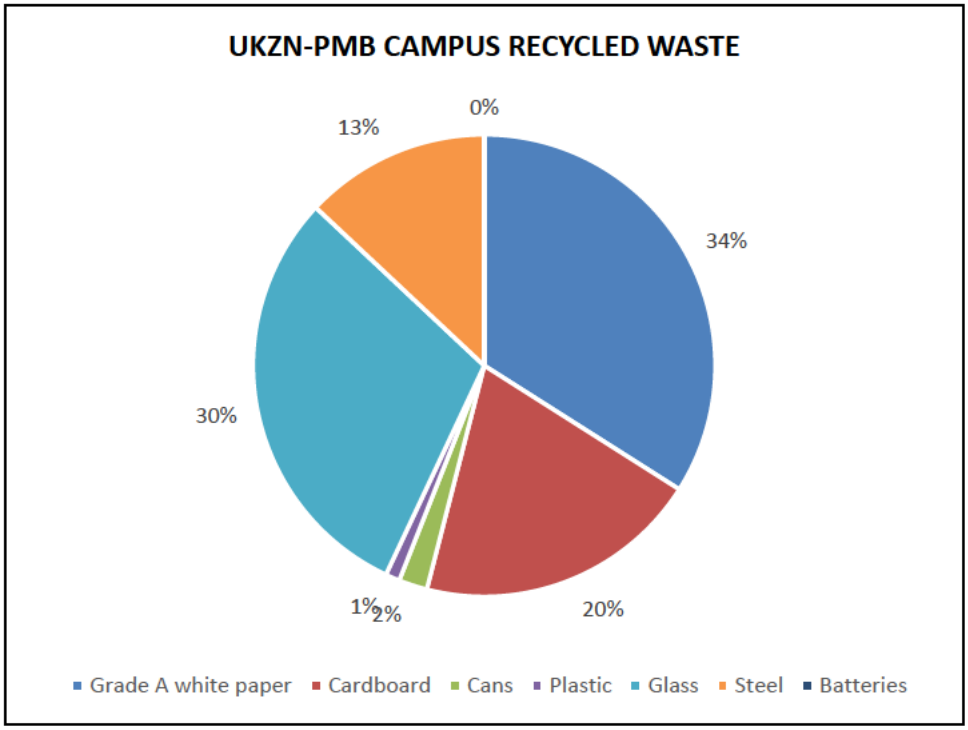


Figure 1.1 Total Recycling in UKZN PMB Campus in 2010 (UKZN, 2020).

The University of Kwa-Zulu Natal Pietermaritzburg Campus separates its general waste into general municipal solid waste (This includes paper, plastic, food waste, etc.) and garden refuses waste (tree leaves and grass). However, the university collects both waste streams and sends them to the New England Landfill site without separating them to identify the recyclables, especially the general waste stream.

The New England Road landfill site has been met with various challenges as it has reached its life span; however, it is still in operation; the municipality has been trying to establish a new landfill site for over two decades and has yet to be successful.

According to Magubane (2021), the New England landfill has caught fire numerous times, releasing toxic fumes into the air and endangering people's lives residing near the landfill site. To assist PMB in managing its waste, Environmental Affairs (EA) committee has urged the municipalities and Economic Development and Environmental Affairs (Edtea) to educate the public about recycling and its benefits.

To mitigate these challenges and heed the call from the EA committee, higher education institutions around PMB need to adopt an integrated solid waste management plan, which will alleviate the municipalities' pressure concerning waste management.

1.2 Significance of the Study

The significance of this study is embedded in the University of KwaZulu-Natal's purpose, which is to inspire greatness through excellence, transformation, innovation/entrepreneurship, and good service culture. Four goals and four enablers surround this resolution; goal number two of the university is to become a globally ranked university responding to significant societal, economic and environmental challenges, and this can be achieved by fulling enabler number four which speaks to a sustainable future (quality and sustainable infrastructure, revenue streams and environment). Thus, by the university transforming the way it manages its solid waste by adopting more sustainable strategies, it would be fulling its purpose.

Not only will UKZN become sustainable for itself, but it will be making a significant contribution to the sustainability of the society it surrounds. This impact will subsequently influence implementation of the sustainable development goals (SDGs). Furthermore, universities play a significant role in shaping and impacting society through the students groomed to become world leaders. Thus, there must be a shift and transformation in the

old university paradigms and adaptation to the new frameworks in the context of solid waste management.

1.3 Research Questions

- Is the current solid waste management at the University of KwaZulu-Natal PMB Campus sustainable?
- How much solid waste does the UKZN PMB campus produce?
- How much solid waste does the university recycle?
- Which solid waste management plan could work for the UKZN PMB campus?
- What environmental awareness programmes does PMB Campus have to educate students?

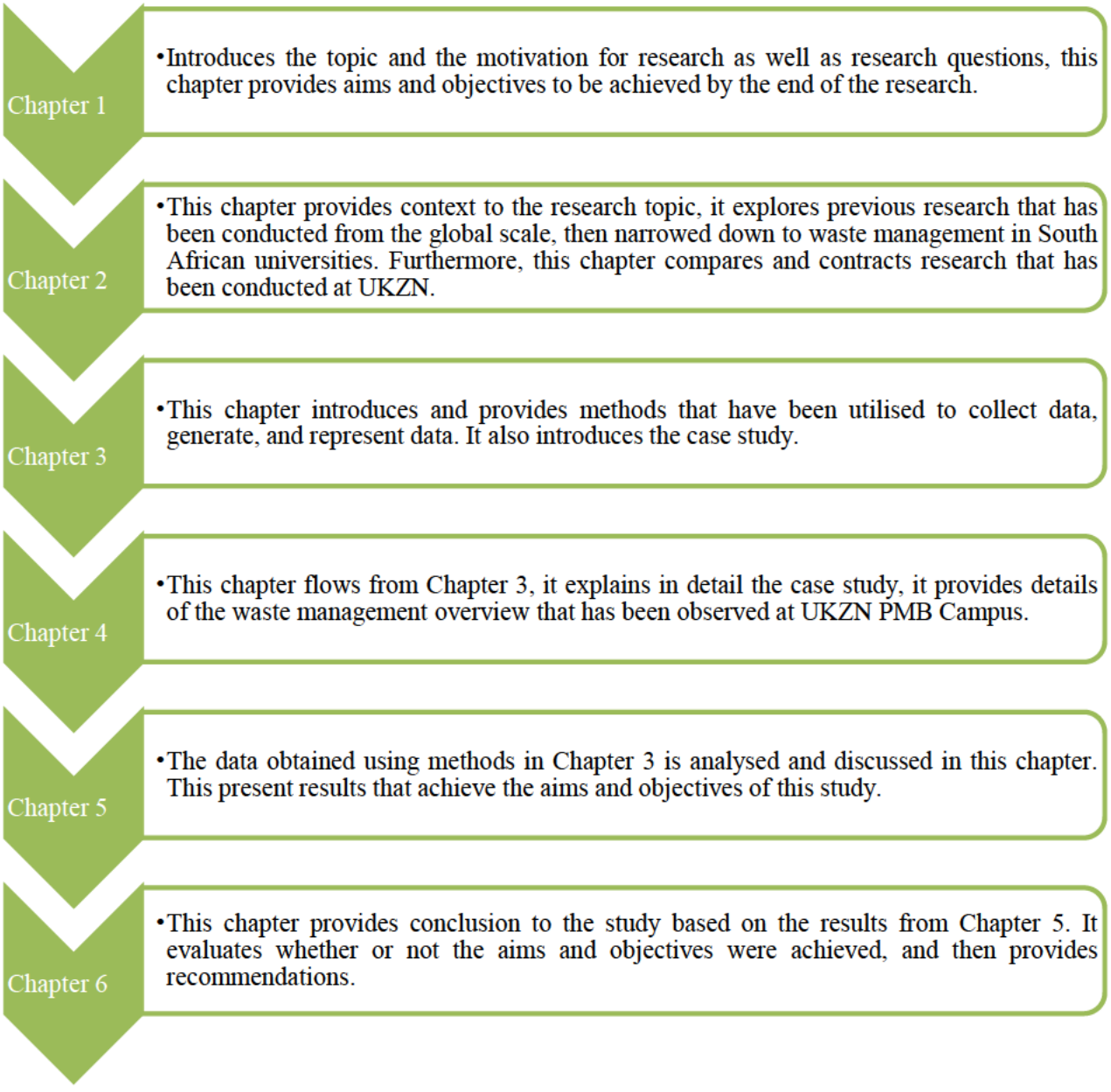
1.4 Aims and Objectives

This project aims to develop a solid waste management plan that employs green strategies for the University of KwaZulu-Natal that will be sustainable.
The objectives of this project are to:

- Evaluate the current solid waste management strategies implemented.
- Determine the amount of solid waste produced and recycled by PMB campus residences
- Propose a solid waste management plan for the UKZN PMB campus.
- Develop a waste management awareness program among students.

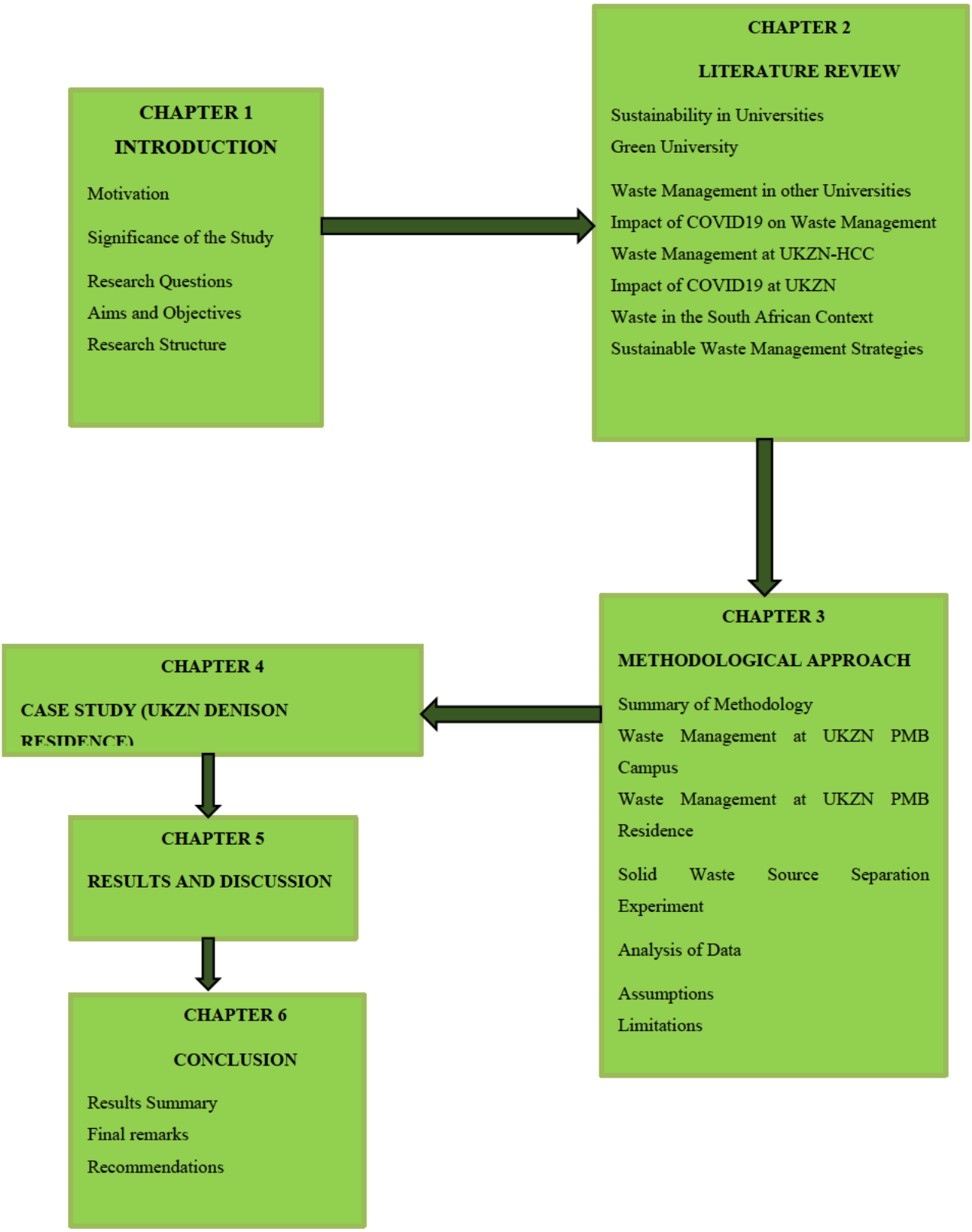
1.5 Research Structure

This section provides a brief description of the chapters compiled in this research; the dissertation is written using a Civil Engineering style guide.



1.5.1 Framework

The diagram below is the research framework that will be followed to achieve the project's objectives.



1.6 Chapter Summary

This chapter introduces the research topic and outlines the motivation and relevance of the study. The rationale of this research is to evaluate the current waste management strategies at the University of KwaZulu-Natal PMB Campus, to provide an informed decision on sustainable waste management. Chapter 2 reviews the literature of previous studies that have been conducted in order to provide contexts for this research topic.

2. CHAPTER TWO: LITERATURE REVIEW

The environment is taking strain due to the manufacturing of non-degradable items. While manufacturing these products, harmful gases such as carbon dioxide, methane and nitrogen are released into the atmosphere. The presence of these gases in the atmosphere leads to climate change.

Researchers and scholars are now racing against time to find strategies to promote sustainable living, including waste management strategies. For the longest time, waste was the municipality's problem; however, in recent years, private institutions have also been participating in handling their waste and reducing the carbon footprint. The question is, "what does sustainability look like in South African high education institutions?"

A high education institution (HEI) may be considered "sustainable" when it is managed concerning green economic, social, and environmental practices, and its functions through teaching, research, and community engagement are fulfilled in a way that encourages a transition of society to a sustainable lifestyle (Velazquez et al., 2006).

This chapter aims to provide context to the topic by critically reviewing the available literature and studies undertaken to comprehend waste management in universities.

2.1 Sustainability in Universities

In 1972 the first conference that identified the lack of environmental management as a significant issue was held in Stockholm. At the conference, education was recognized to have a significant role in fostering environmental protection and conservation. Over the years, countries have convened to develop academic declarations, charters, and partnerships to encourage sustainability in high education institutions. Table 2.1 shows initiatives developed to foster sustainable development in HEIs.

Table 2.1 Initiatives that have been developed to foster sustainability in HEIs [Adopted: (Lozano *et al.*, 2013)]

YEAR	DECLARATIONS, CHARTERS & PARTNERSHIPS
1990	Talloires Declaration, France
1991	Halifax Declaration, Conference on University Action for Sustainable Development, Canada
1992	Association of University Leaders for a Sustainable Future founded, USA
1993	Kyoto Declaration, International Association of Universities Ninth Round Table, Japan
1993	Swansea Declaration, Association of Commonwealth Universities' Fifteenth Quinquennial Conference, Wales
1994	COPERNICUS University Charter, Conference of European Rectors (CRE), Geneva
1996	Ball State University Greening of the Campus conferences were in 1997, 1999, 2001, 2003, 2005, 2007, and 2009
1999	Environmental Management for Sustainable Universities (EMSU) conference first held in Sweden. Following conferences in 2002 (South Africa), 2004 (Mexico), 2006 (U.S.A.), 2008 (Spain), and in 2010 in The Netherlands
2000	Global Higher Education for Sustainability Partnership (GHESP)
2001	Lüneburg Declaration on Higher Education for Sustainable Development, Germany
2004	Declaration of Barcelona
2005	Graz Declaration on Committing Universities to Sustainable Development, Austria
2009	Abuja Declaration on Sustainable Development in Africa: The role of higher education in SD, Nigeria Higher Education
2009	Torino (Turin) Declaration on Education and Research for Sustainable and Responsible Development, Italy
2019	U7+ Alliance of World Universities, Paris

2.1.1 Talloires Declaration (TD)

In October 1990, university presidents, chancellors, and rectors gathered at the conference in Talloires, France, to voice their concerns and create a document that outlines crucial actions which institutions of higher education must take to create a sustainable future.

In the gathering, the role of universities was defined as "Universities educate most of the people who develop and manage society's institutions. For this reason, universities are

responsible for increasing the awareness, knowledge, technologies, and tools to create an environmentally sustainable future".

The participants at the conference further agreed that the professionals, decision-makers at major institutions, and the public must be given the training, expertise, and tools to encourage environmentally sustainable actions.

From this conference, the Talloires Declaration (TD) was created. TD is a ten-point action plan incorporating sustainability and environmental literacy in teaching, research, operations, and outreach at colleges and universities.

Following are the ten-action declaration points:

1. Increasing awareness of environmentally sustainable development
2. Create an institutional culture of sustainability
3. Educate for environmentally responsible citizenship
4. Foster environmental literacy for all
5. Practice institutional ecology
6. Involve all stakeholders
7. Collaborate on interdisciplinary approaches
8. Enhance the capacity of primary and secondary schools
9. Broaden service of outreach nationally and internationally
10. Maintain the movement

More than 500 university leaders have signed the declaration in over 50 countries. In South Africa, TD was signed by Rhodes University, University of Cape Town, University of Natal, University of Western Cape, and Witwatersrand. However, when the University of Natal merged with the University of Durban-Westville to form the University of KwaZulu-Natal (UKZN), the Talloires Declaration was not signed by the "new" university. Therefore, UKZN is not part of the universities on the TD list.

2.1.2 Sustainable development goals

In 2015 United Nations (UN) member states, including South Africa, agreed to adopt the 2030 Agenda for sustainable development (UN, 2022b). The agenda has 17 Sustainable Development Goals (SDGs), and universities aligning with these SDGs will respond to the real-life problem surrounding sustainable development. One is taking accountability

for their solid waste management; Table 2.1 below outlines the immediate goals universities will directly contribute to regarding solid waste management.

Also, the benefits associated with the universities adopting the SDGs include access to new funding schemes when demonstrating impact as a sustainable university. Increase network and relations with external stakeholders (government, community, and cooperation partners).

Table 2.2 SDGs that universities need to align with regard solid waste management [Adopted:(UN, 2022a)].

GOALS	TARGETS
	Support efforts to reduce the adverse per capita of cities, paying special attention to air quality and waste management.
	Support efforts to achieve the environmentally sound management of all wastes through their life cycle, to significantly reduce their release to air, water and soil, and to substantially reduce waste generation through prevention, reduction, recycling and reuse.
	Support efforts to prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities.

2.1.3 Green university

For the university to be holistically green, sustainable, and aligned with Talloires Declaration (TD), it is comprised of four dimensions that are different yet interlinked, namely, campus operations, teaching, research, and lastly, community engagement. However, this study focuses on waste management, part of campus operations. Refer to Figure 2.1 below.

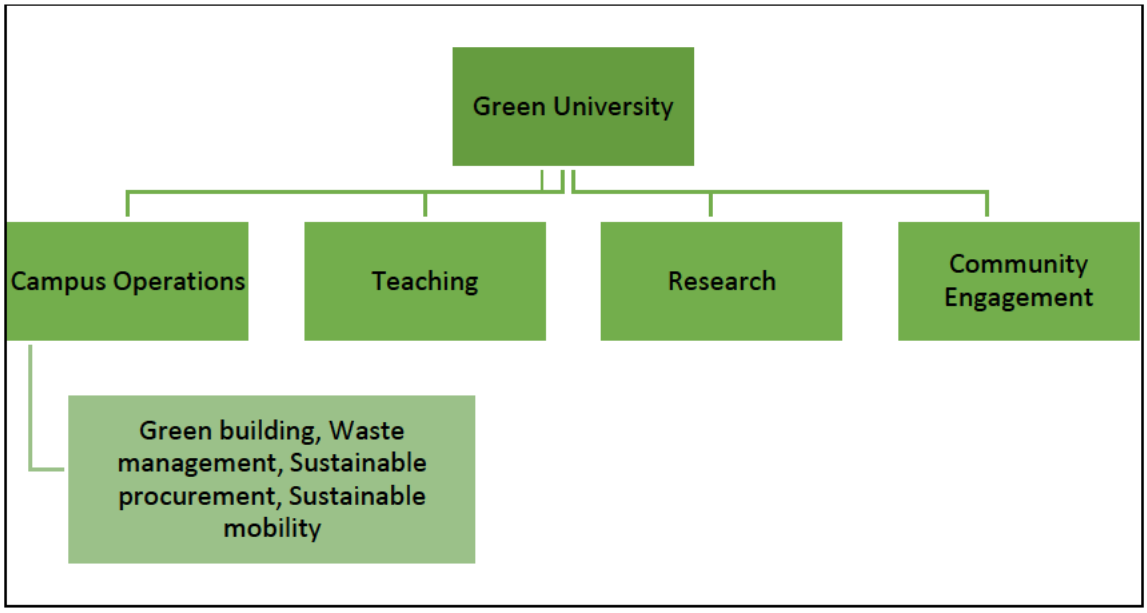


Figure 2.1 Diagram of the different dimensions for a sustainable University (Fissi *et al.*, 2021).

Waste management includes the collection, transport, and treatment (recycling or disposal) of office waste (paper, folders, cartridges), furniture (desks, chairs), laboratory or clinical waste (chemicals, equipment, wastewater), food waste from cafeterias and general waste from bins all over the campus (Armijo de Vega *et al.*, 2008).

For Higher Institutions to move towards sustainability, there needs to be a revision in the business model by developing an institutional framework (in terms of mission, vision, and policies) that makes the university's intentions clear concerning sustainability. Such a framework is the first step and foundation of a greener institution. Fissi *et al.* (2021) stated that universities could also demonstrate their accountability and transparency towards sustainability by providing a voluntary sustainability report every year.

2.2 Waste Management in other Universities

Universities are expected to be the champions of responsible solid waste management (Taghizadeh *et al.*, 2012). Besides, appropriate waste management brings benefits to the institution, such as reducing financial resources designated to waste management; it also sets an example to the students and the community, creating a positive reputation for the institution (Ramos *et al.*, 2015).

To understand the response of the University of KwaZulu-Natal (PMB) to waste management, it is of great importance to understand solid waste management within the

context of an international university, a Southern African university, and a South African university.

2.2.1 Australian National University (ANU): International case study

"*As Australia's National University, it is our responsibility to provide a bold response and clear actions to address global issues related to sustainability*" – Prof. Brian P Schmidt (Vice-Chancellor)

ANU is in Austria, one of the world's most well-developed countries; the university has two campuses, Acton and Di Riddell Student Centre. This university is part of the universities that signed the Talloires Declaration. To ensure that the university aligns with the declaration, it developed an Environmental Management Plan for 2017-2021 (EMP). The university has set ambitious targets for all ANU campuses in the EMP.

The university supports the United Nations' 17 Sustainable Development Goals (SDGs). In which the SDG promotes actions to improve humanity and protect the planet from degradation. The SDGs outlined in the EMP include water, recycling, waste management, pollution prevention, transport, landscapes and biodiversity, and heritage.

This section reviews the objectives, key actions, and targets ANU has set in the EMP for recycling and waste management.

2.2.1.1 Recycling and waste management

In industrialized countries, waste management in higher education institutions began more than 20 years ago (Gallardo *et al.*, 2016). ANU initiated its first waste reduction and recycling program in 1999. In 2016 the university could recycle 49% of its solid waste. The university recycles all its green (organic) waste onsite by composting, which is reused as mulch on the landscape.

To ensure that the university has accurate information on the solid waste produced, recycled, and landfilled, they have employed a waste management contractor, which improved their recycling program. The organogram below shows the stakeholders responsible for ensuring that the EMP within the university is successfully implemented.

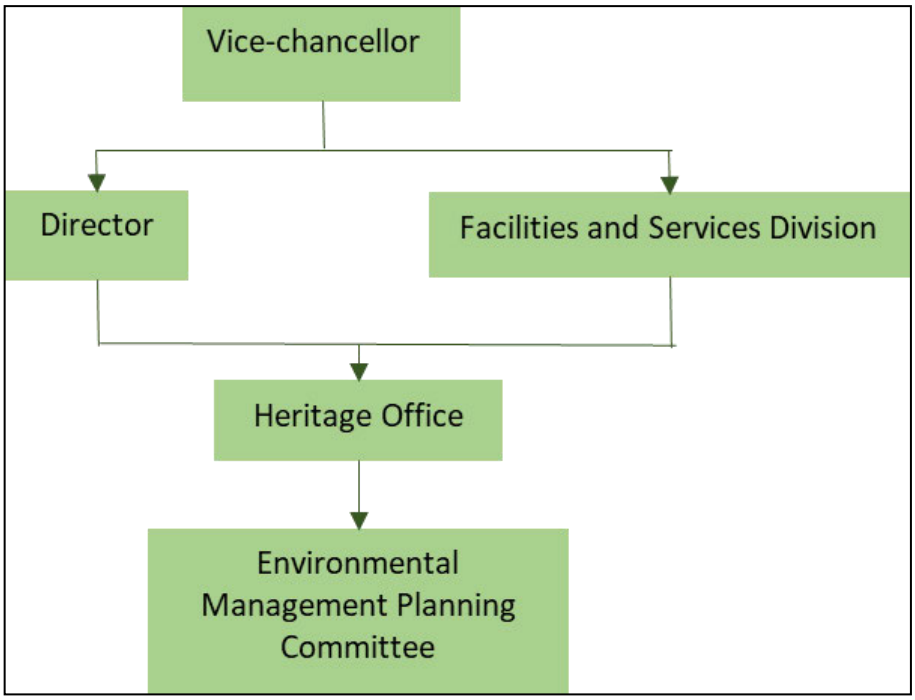


Figure 2.2 Waste management stakeholders

The university's primary objective toward waste management is its commitment to minimizing waste sent to the landfill site by reducing waste generation and increasing recycling.

Table 2.3 Key actions and targets set by ANU

KEY ACTIONS	TARGETS
Improve waste monitoring and reporting through the waste contract	Increase recycling rate to 85% by 2021
Continue to recycle and compost garden waste onsite	Divert 100% of e-waste from landfill by 2021
Create a campus-wide e-waste recycling system for computers and other electronic equipment	Achieve national best practice level for recycling construction waste
Provide centralized bins to promote recycling behaviour and the phasing out of under-desk bins from the office	Reduce waste to landfill by 20% per person by 2021

Revive the campus waste education program to complement the new waste contract	
Work with the University Contract and Procurement Office to increase the proportion of recycled products and materials purchased.	
Develop a strategy for the reuse or recycling of furniture when refurbishing or demolishing buildings	

2.2.2 African universities

Although there needs to be more published research, studies have been done in Africa to examine university waste management. The earliest publication in Africa is by Mbuligwe (2002), he presented his findings on institutional solid waste management conducted in Tanzania, where he looked at three universities. Based on the study, he concluded that between 71% and 86% of resource recovery could reduce solid waste across the three universities.

Another study was conducted at the University of Lagos, where the daily solid waste generation was estimated to be 32.2 tons. The recyclable potential of the waste constituted about 75% of the total waste generated (Adeniran *et al.*, 2017). The University of Covenant in Nigeria observed that the most significant fraction of the waste generated was from food waste, followed by polythene bags and plastic bottles. A generation rate of 60.50 g/user/day was obtained (Okeniyi and Anwan, 2012).

2.2.2.1 Cape Town University (UCT): South African university case study

"*Environmental sustainability is a key component of UCT's vision 2030 and a critical part of developing students that are ready to unleash their human potential*." – Vice-Chancellor

UCT was the first university in South Africa to commit to environmental sustainability by committing to Talloires Declaration in 1990. It then recommitted in 2001, the university did not keep up with the declaration, but its intent and commitment have

remained strong. In 2019 UCT VC signed the U7+ Alliance of World Universities committing the university to it being the driver of sustainability.

In 2011, the University of Cape Town (UCT) reported in the ISCN-GULF Sustainable Campus Charter that solid waste management had been the most successful initiative through its "Green Cleaning" campaign, which began in 2009. One of the university's goals was to reduce waste taken to the landfill site by 70% through recycling. In 2010 the waste was reduced by 66%, and 60% in 2011 (UCT, 2011).

UCT prides itself on being a higher educational institution with several world research hubs and departments closely aligned with environmental sustainability. Hence, to ensure that the university continues to make a significant contribution to matters of environmental sustainability, a Director for Environmental Sustainability was appointed in 2019. One of the Director's mandates was to develop UCT's environmental sustainability strategy.

Figure 2.3 below shows UCT's environmental sustainability strategy that has been developed. The four pillars of the strategy include UCT learning, research, governance, and operations. The summary/objective of each pillar is described below (UCT, 2021).

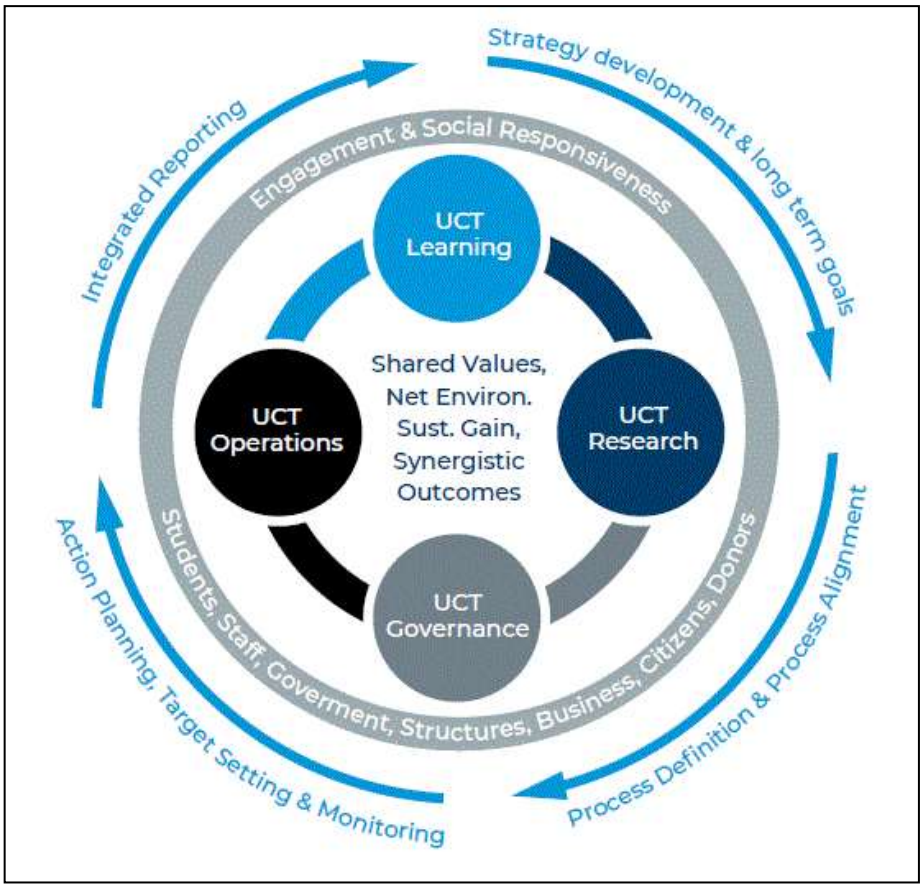


Figure 2.3 UCT's environmental sustainability strategy (UCT, 2021).

Learning at UCT – This aims to ensure that all students attending UCT receive basic training in environmental sustainability, hoping they will be encouraged to be active citizens in protecting the environment on and off campus.

Research at UCT – Intensify, strengthen, and promote existing environmental sustainability-related research.

- Strengthen links and awareness of environmental sustainability in any research that occurs at UCT.

Governance at UCT – Appropriate governance structures to be created or modified to support UCT's strategy for environmental sustainability.

- Integrate environmental sustainability into governance and operations at UCT and craft a vision statement that speaks about environmental sustainability as part of the development of the 2030 vision.

Operations at UCT - UCT aims to reduce energy consumption, carbon emissions, water consumption, and waste-to-landfill to a net-zero state by approximately 2050 for the university.

2.2.2.2 Waste management at UKZN (Pre-pandemic)

Green UKZN is an initiative at the University of KwaZulu-Natal that aims to make the university holistically sustainable. This initiative has conducted studies that focus on waste management, even though the results still need to be published. These studies have been conducted by the Faculty of Civil Engineering students for their final year dissertations.

In 2019, Sihle Langa conducted a study on *Integrated Zero Waste Management*. The aim was to understand waste management at UKZN and the possibilities of the university being zero-waste and sustainable.

The research was conducted at Ansel May's residence; according to Langa, the residence housed 170 male students from all disciplines. It had four floors, and each floor had four black bins, 16 in total, and one cleaner responsible for each floor.

Sihle Langa's results showed that the residence produced 48% of compostable results, 48% of recyclable waste, and 4% non-recyclable. Figure 2.4 below shows the general waste composition for Ansel May, and food composition is the highest fraction.

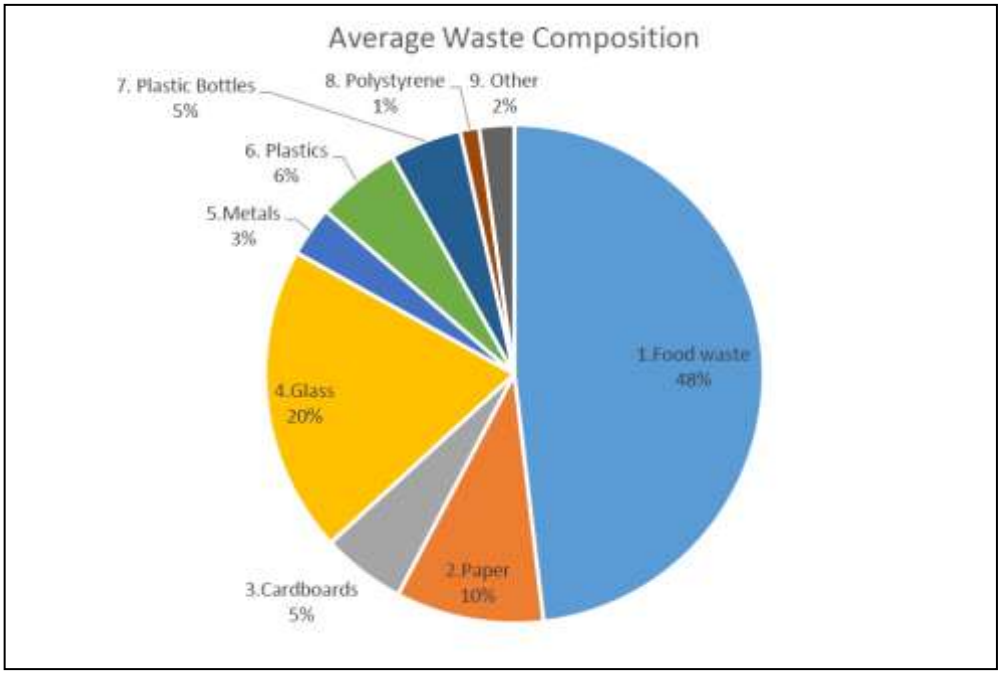


Figure 2.4 Ansel May residence waste composition (Langa, 2019)

Sihle Langa concluded that the university needed an efficient waste management plan because waste was improperly handled. Furthermore, the university needed to develop and set goals for IWMP, and these targets would need to be revised after the stipulated time frame has been reached.

According to (Shriram, 2018), below are the waste management initiatives that Howard College has tried to implement:

- Ten years ago, Howard College had a waste recovery facility, a recycling initiative that ended in 2012 due to contractual and payment disputes. The university had outsourced a company for their services and, in return, got cost reductions based on the profits from the recovered material.
- DSW had a contract with a private contractor on behalf of the university to separate waste at the collection point. The initiative ended in 2016 due to mismanagement at the MRF and health concerns for the nearby offices.
- In 2015/2016, the university introduced a paperless learning system, where lecturers no longer handed out printed notes. Instead, they were uploaded on the university's e-learning web page for students to access. This initiative was to embrace the digital era and encourage reducing paper usage.

Both Nadir and Sihle concur that the university has excellent potential to implement zero-waste strategies; however, for it to succeed, the management will need to change its attitude toward investing in waste management. Moreover, zero-waste education would raise awareness about the university's sustainability and care for the environment.

2.3 Impact of COVID-19 on Waste Management

The novel Coronavirus (COVID-19) is transmitted through coughing, sneezing, contacting COVID-19-contaminated surfaces, and physical contact with COVID-19-infected individuals (Gardiner, 2020). The virus has affected 213 countries and more than 124 million people worldwide (Worldometer, 2020) since its discovery in Wuhan in late 2019. South Africa has had more than 1.54 million COVID-19 cases since the outbreak, including active cases, recoveries, and deaths. During this pandemic, the government's goal in every decision-making is to save lives (Sharma *et al.*, 2020). Most counties were put under strict lockdown conditions to help fight and mitigate the spread of COVID-19;

this positively impacted the environment, such as cleaner rivers, less littering, and clearer skies (Gardiner, 2020).

However, the waste generation dynamic has been altered, challenging the policymakers and workers involved in waste management (Sharma *et al.*, 2020). During this outbreak, hazardous waste such as medical waste, infected facemasks, gloves, and other protective personal equipment (PPE) are generated (Kulkarni and Anantharama, 2020). These materials need to be handled with care and discarded safely; if not managed properly, the contaminated PPEs can aggravate environmental and health problems (Zand and Heir, 2020).

Since coronavirus is an airborne disease, transmission is inevitable, and the risk of spread in solid waste is high. In Johannesburg, a waste recovery facility had to close due to the high number of infected employees. Research has determined that the survival of COVID-19 on waste material varies from a few hours to a few days; according to (Das *et al.*, 2021a), the virus on copper material, cardboard, plastic, and stainless steel may survive for 3h, 4h, 24h and 2-3 days respectively. (van Doremalen *et al.*, 2020) reported that the virus may survive up to 9 days on materials and surfaces such as metal, glass, and plastic.

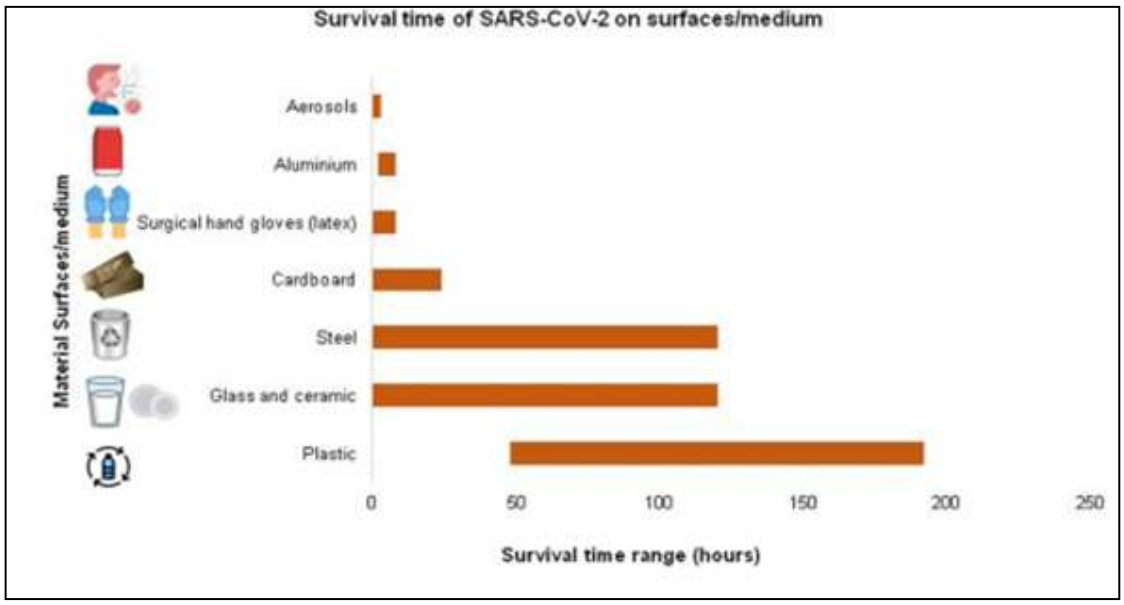


Figure 2.5 Survival time of COVID_19 of surfaces (Kulkarni and Anantharama, 2020).

World Health Organisation advised that face masks, tissue paper, and wipes generated during the pandemic are classified as medical waste and must be in yellow bin bags for identification (WHO, 2020). Combating the spread of COVID-19 through municipal solid waste disinfection and storing waste for 9 days before sorting is advisable and is now widely practised by many waste handling facilities (Das *et al.*, 2021a).

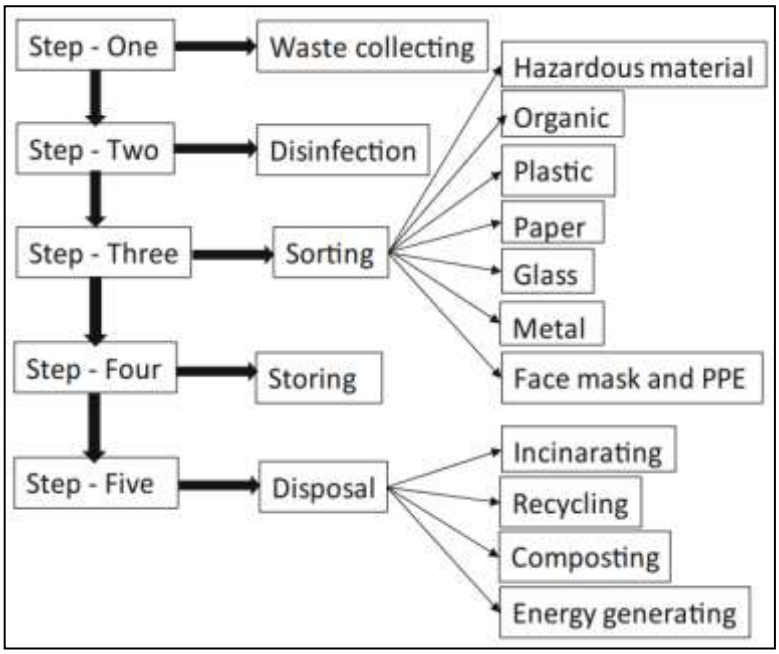


Figure 2.6 Waste management strategies under COVID-19 (Das *et al.*, 2021a).

Waste separation at the source is believed to be more important than ever during this time (Zand and Heir, 2020).

Universities are also of great concern when it comes to the management of waste during this period. Place trash bins and waste separation at the source to minimize disease transfer is vital.

2.3.1 Waste Management at the University of KwaZulu-Natal (Howard Collage)

This section critically reviews research conducted in 2018 (pre-pandemic) and 2020 (during the pandemic) and the recommendations made; it also compares and contrasts the findings. It is important to note that these studies were conducted at Howard College, one of the five UKZN Campuses.

2.3.2 Impact of COVID-19 at UKZN

The coronavirus has transformed the conventional way of teaching and learning in universities across the globe. At the prime of COVID-19 in South Africa, decisions about the education system had to be made to either cancel the 2020 academic year or develop innovative strategies to ensure that the student's right to quality education was not violated. Therefore, all universities had to implement online learning.

This new way of teaching and learning has had its predicaments, one being access to the internet. However, levels and regulations were later eased, and a staggered approach was used to ensure a safe return of no more than 66% of the UKZN population back on campus and residences.

It has been evident that the coronavirus has significantly impacted waste generated within the campus. From observation, there has been a reduction in the general waste generated. Nevertheless, a thorough investigation is still required to determine the exact impact COVID-19 has had on the waste generated. Also, waste management is of utmost importance because it can be a vehicle of COVID-19 transmission when mishandled.

2.3.2.1 Waste management at UKZN during the pandemic

In 2020, during the peak of COVID-19, Jateen Vallabh conducted a study on waste management in student residences during the global pandemic. The aim was to determine waste management strategies that the university can implement to ensure that COVID-19 is not transmitted through waste.

The research was conducted at Sphiwe Zuma Residence at Howard College. The residence comprises two identical blocks (A and B), which are six floors; the residence accommodates up to 264 students, both males and females, separated by floors (the bottom floor is for males, and the top floor accommodates females). At the time of the study, 20 students residing in the Sphiwe Zuma residence had tested positive for COVID-19; therefore, they were quarantined in their rooms.

Figures 2.7 below shows the results obtained by Jareen during the survey study, where 94% of students indicated that they used cloth masks that are reusable instead of disposal masks, thus sustainable. Students then indicated that the university did not place separate bins for the disposal of masks; therefore, 35% of the student discarded their masks in the regular bin, although they were willing to separate them.

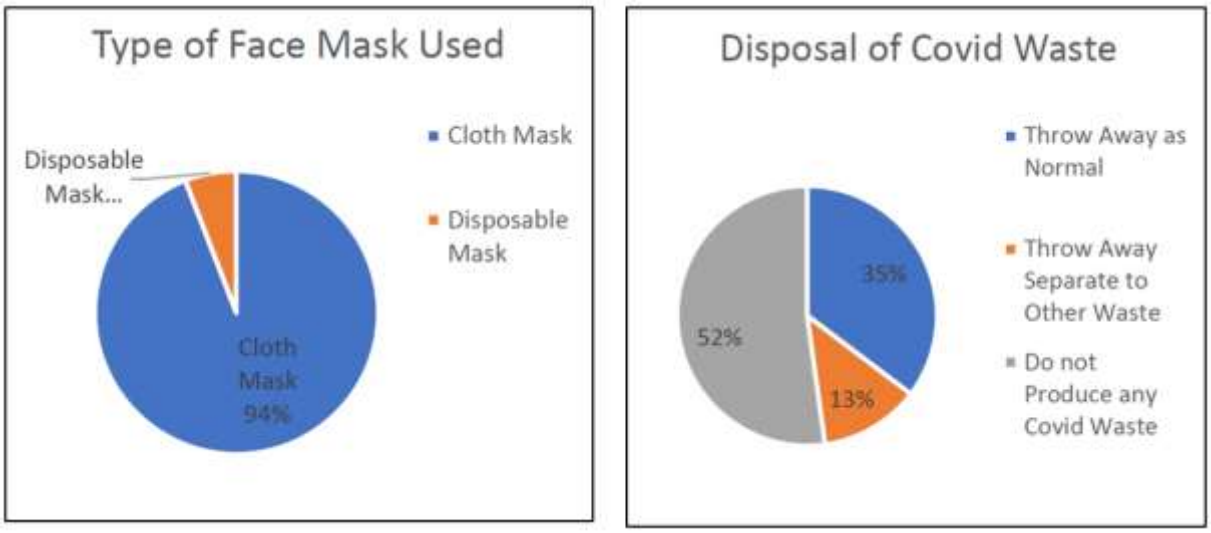


Figure 2.7 Sphiwe Zuma residence survey results (Shriram, 2018)

Figure 2.8 below represents the total waste composition produced by students at the residence, with food/organic waste being the highest waste fraction by 60%. Thus, making composting a viable option.

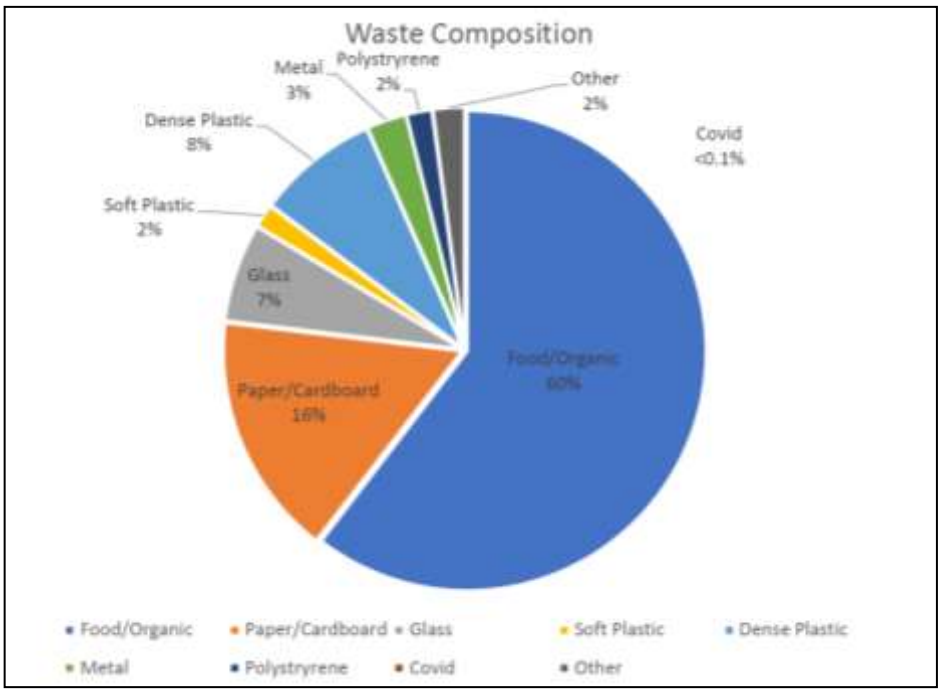


Figure 2.8 Waste composition for Sphiwe Zuma residence (vallabh, 2020a).

Jareen concluded that 96% of solid waste produced by the campus residences could be diverted from the landfill site; however, the university would need proper planning and educational campaigns before implementing any strategy.

Furthermore, at the time of the research, Jareen gathered that the university had measures to minimize the spread of COVID-19, but minimal measures were put in place to protect the waste-handling staff.

Comparing Sihle and Jareen's findings, in 2020, more food waste was produced than in 2019, and this could be due to the students spending most of their time at residence due to the COVID-19 restrictions. The other difference is the new waste composition, "covid waste", including health risks associated with handling waste.

2.4 Waste in the South African Context

Due to population growth, urbanization, and industrialization, waste is a global problem. In 2012, the global waste production was estimated to be 1.3 billion tonnes; in 2016, the estimated waste produced was 2.01 billion tonnes (Silpa *et al.*, 2018).

National Environmental Management: Waste Act, 2008 (Act No.59 of 2008) formally defines waste as follows:

"waste" means any substance, whether or not that substance can be reduced, re-used, recycled, and recovered –

(a) that is surplus, unwanted, rejected, discarded, abandoned, or disposed of.

(b) which the generator has no further use for the purposes of production;

(c) that must be treated or disposed of; or

(d) that is identified as a waste by the Minister by notice in the Gazette, and includes waste generated by the mining, medical or other sector; but –

(i) a by-product is not considered waste; and

(ii) any portion of waste, once reused, recycled, and recovered, ceases to be

waste.

Municipal Solid Waste (MSW), commonly known as "trash" or "garbage," is one of the significant contributors to greenhouse gas emissions (GHG) worldwide. Therefore, it is a significant concern in the GHG mitigation action plan and initiatives (Srivastava *et al.*, 2020). Although in recent years, MSW management has evolved from open disposal, open burning, and ocean dumping to more environmentally sustainable strategies such as sanitary landfilling, recycling, recovery, waste-to-energy, and composting. However, most emerging countries like South Africa still collect and dispose of MSW in landfills.

Abu Hajar *et al.* (2020) state that the recycling rate in these developing counties is about 0-41%. Most of the recycling activities are done by the social sector, known as informal recyclers or scavengers, for their financial benefit. With the rapid population growth and urbanization, handling waste becomes difficult, especially when it is the municipality's responsibility to collect, sort, and dispose of the waste; hence, landfilling has been the preferred method for many years.

South Africa faces a rapid increase in the volume of solid waste produced annually (NEMA, 2014). According to StatsSA (2011), only 10% of the 59 million tonnes of waste was recycled in 2011, while 90% of that waste ended up in landfill sites. In the 2018 State of Waste Report, 55 million tonnes of waste was generated in 2017, and 11% of that waste was diverted from the landfill site (NWMS, 2020). South Africa is faced with a rapid increase in solid waste and a shortage of suitable land to dispose of the waste, hence the urgent need for intervention (Ayeleru *et al.*, 2018).

For South Africa to overcome some of its waste management problems, the universities and colleges need to contribute to correct waste management and the design and implement new tools needed to reduce the amount of waste generated.

2.5 Waste characterisation

The characterization of waste depends on its composition; waste can be categorized as general waste, mining, and industrial hazardous waste. Act No.24 of 2014: National Environmental Management: Waste Amendment Act,2014 defines Hazardous and General waste as:

Hazardous waste – *"any waste that contains organic or inorganic elements or compounds that may, owing to the inherent physical, chemical or toxicological characteristics of that waste, have a detrimental impact on health and the environment and includes hazardous substances, materials or objects within the business waste, residue deposits, and residue stockpiles."*

General waste – "*as the waste that does not pose an immediate threat to man or the environment that is household and garden waste, builders' rubble and some dry industrial and business waste. However, it may produce leachate with decomposition and rain infiltration, which is unacceptable*".

In South Africa, MSW has been listed as the priority waste; a study in 2011 showed that out of the 49 million tons of waste, 40% was MSW (DEA, 2012). Organic waste is under the MSW, recyclable (paper, plastic, bottles, and cardboard), non-recyclable, and building material.

The university may generate either general or hazardous waste based on the information above. In the paper published by Armijo de Vega *et al.* (2008), he mentioned that solid waste characterization in universities is the first step in planning integrated waste management. Knowing the waste composition allows for defining the strategies for separation, collection, and frequency of recycling (Gallardo *et al.*, 2016). Figure 2.9 below represents the waste streams found at the University of Nigeria Nsukka Campus.

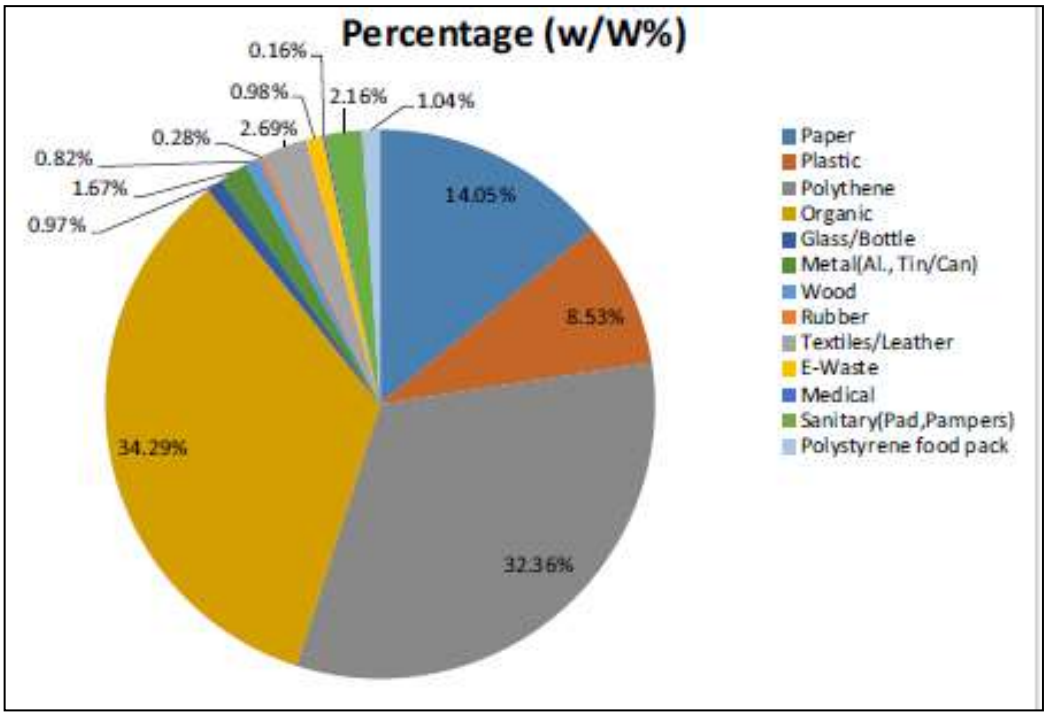


Figure 2.9 Waste composition at the University of Nigeria (Ugwu *et al.*, 2020).

2.6 Waste management hierarchy

The waste hierarchy is the strategy developed by the European Union to manage waste. The hierarchy's primary purpose is to use waste as a resource and divert it from landfills. The South African Waste Act of 2008 adopted this strategy, which informs waste management in South Africa. Figure 2.10 below shows the waste management hierarchy, and each strategy is explained in detail.

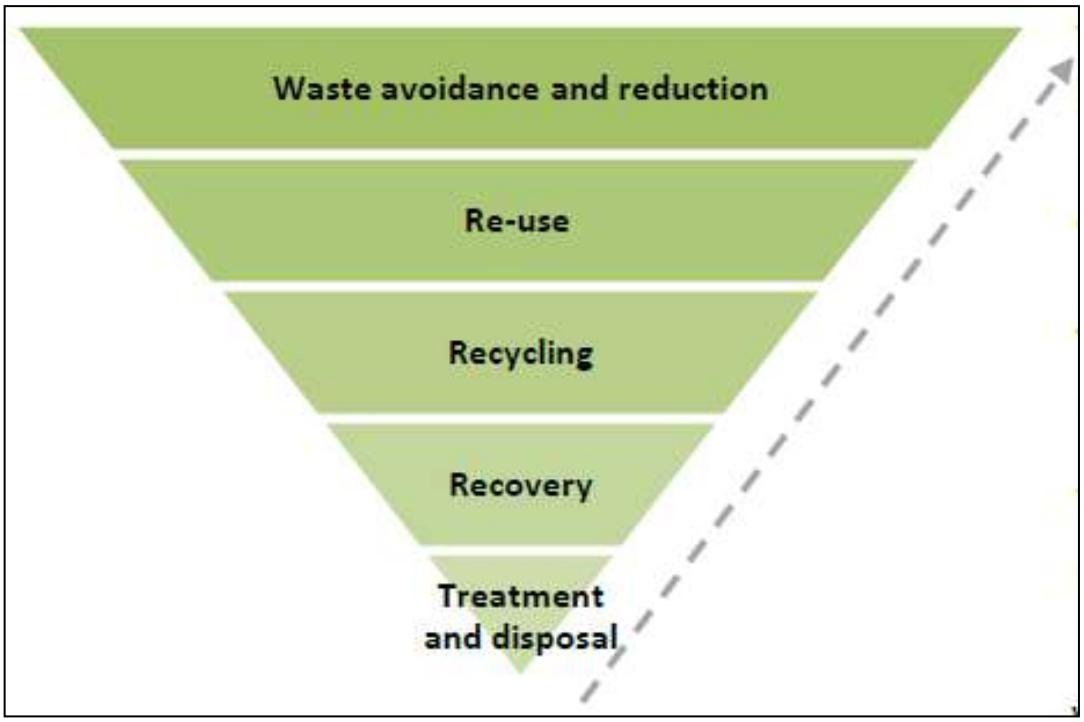


Figure 2.10 Waste Management Hierarchy (NEMA, 2014).

Reduction or avoidance is the foundation of the hierarchy; it is the top waste management treatment preferred. The aim is not only to reduce the amount of waste discarded but also to minimize the waste composition, quality, and toxicity during the goods' design and production.

The next step in the hierarchy is reuse. If the product is discarded, it is encouraged that it should be reused; this will remove that commodity from the waste stream since the value of that product is not lost as it will still have the functions of the virgin product.

If the product cannot be reused, it is best to recycle it by turning it into a new product and adding more value or processing it when recycling waste is diverted from the landfill, saving air space.

Recovery is for materials that cannot be reused or recycled for energy recovery. Landfilling should be used as the last resort, as it is the least preferred management strategy. Although this method is the most affordable, it must consider the long-term environmental and health impacts.

2.6.1 Application of waste management hierarchy in universities

According to (Jibril *et al.*, 2012), institutions do not use the 3 R's (Reduction, Reuse, and Recycling) system in managing their waste generated. However, their waste management strategies should consider the national and international targets to reduce carbon monoxide (CO3) and methane (CH4) gas emissions. It is estimated that with every ton of mixed paper recycled, the energy that can be saved is equivalent to 185 gallons of gas (Jibril *et al.*, 2012).

For the waste management hierarchy to be fully implemented in higher education institutions, management staff, academics (lecturers), and students must do away with the "throw-away" culture of by-products. There needs to be a shift in how they view waste by re-engineering the current solid waste management practices from conventional to integrated approaches.

2.6.2 Zero waste

It has been established in this literature review that improper waste handling has a detrimental effect. Landfilling is the most inefficient and environmentally polluting waste management solution. The shortage of landfill sites has forced the authorities to look for alternative waste management systems (Zaman, 2015).

Zero waste has become an inspirational goal to combat waste problems; it is an innovative waste management tool that has been presented over the last decade though still under development (Zaman, 2015). The Zero Waste International Alliance (ZWIA) defines zero waste as:

"…a goal that is ethical, economical, efficient, and visionary, to guide people in changing their lifestyles and practices to emulate sustainable natural cycles, where all discarded materials are designed to become resources for others to use. Zero waste means designing and managing products and processes to systematically avoid and eliminate the volume and toxicity of waste and materials, conserve and recover all resources, and not burn or bury them" (ZWIA, 2004).

Currently, the zero waste strategy aims toward zero landfills by diverting waste (Ayeleru *et al.*, 2018); however, Matete and Trois (2008) urged that zero waste is more than reusing and recycling waste materials. However, zero waste maximizes recycling, minimizes

waste, reduces consumption, and ensures that the products produced can be reused, repaired, or recycled back into nature.

The study by Matete and Trois (2008) concluded that zero waste is not dependent on the waste stream. It can be implemented within the waste management systems in South Africa. They further concluded that for zero waste to be significant, educational campaigns should be designed to reinforce a more positive attitude towards waste minimization and recycling.

2.7 Stakeholder engagement

National Environmental Waste Act (2011) emphasizes the importance of working together as a country to implement a waste management hierarchy and achieve the Waste Act objectives. The government cannot do it alone; therefore, coordinated action by households, private institutions, community organizations, businesses, NGOs, parastatals, and three spheres of government is required to achieve these objectives.

Implementing the waste management hierarchy requires a mental shift in consciousness, attitudes, and behaviour for businesses, organizations, and households. Industry, organizations, and households have a critically important role in managing waste streams, including higher education institutions. Managing waste collectively will alleviate the strain on the government. The stakeholders involved within the university context are shown in the diagram below.

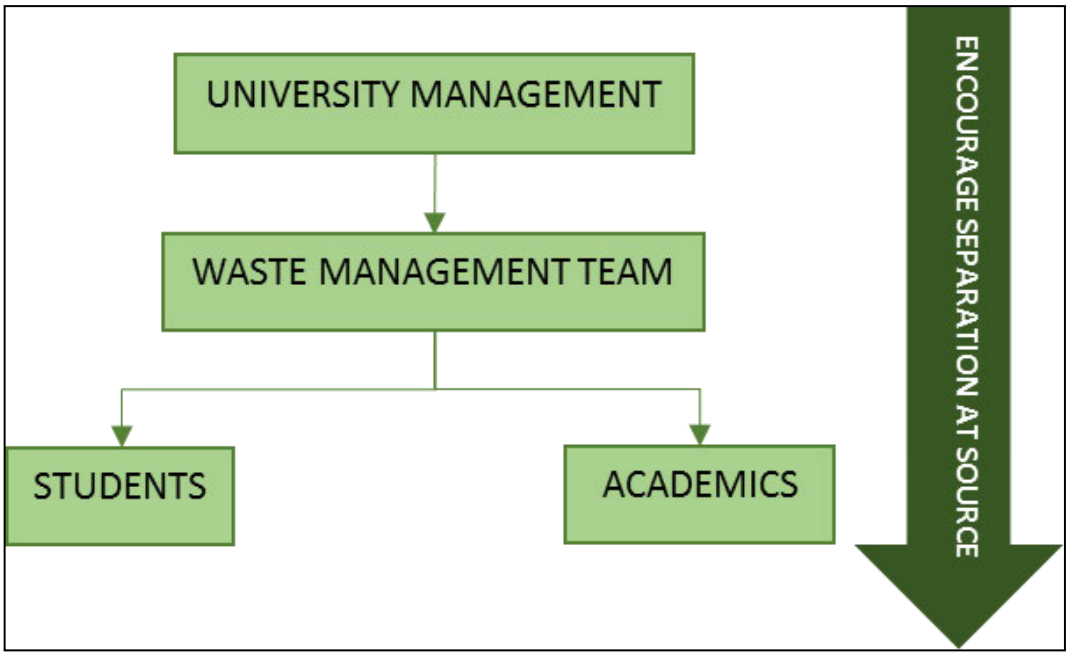


Figure 2.11 Stalk-holders involved in separation at source.

2.8 South African waste legislation

The Bill of Rights (Section 24 of Chapter 2) 1996 states that everyone has the right to a safe and clean environment that is not harmful to health and well-being. This right provides the foundation for environmental regulations and policies in South Africa. The First National Environmental Waste Act was established in 1998 (Act No. 107 of 1998). Over the years, there have been developments in the norms and standards that govern the waste sector of South Africa. Table 2.4 summarizes the waste policies of South Africa. For this study, only relevant policies are listed.

Table 2.4 Summary of legislation and policies of waste management in South Africa

Adopted (Engeldow, 2005; Nkala, 2012).

Year	Legislation/Policy/Regulation/Plan	Emphases
1996	Constitution 108 of 1996 – Bill of Rights	Refuse removal, disposal sites. Local Government function– governed by Provincial Government
1998	DEAT – National Environmental Management Act, 107 of 1998	Environmental Impact Assessment Regulations and Framework for the overall protection of the environment
1998	DWAF – Waste Management series 1998	Handling, classification, and disposal of waste

2000	DEAT –White Paper on Integrated Pollution and Waste Management for South Africa	Prevention of pollution, waste minimization impact management, and remediation
2001	Polokwane declaration (2001) on waste management	Develop a plan for Zero Waste by 2022
2010	DEA – Draft National Management Strategy	The revised focus from the cradle to the grave to cradle to cradle approach. A revised Integrated Waste Management Hierarchy has been proposed, including remediation. The strategy includes sections on health care risk waste, priority waste, e-waste, etc.
2010	DEA – Draft Waste Classification and Management Regulations	Regulate the classification and management of waste meeting the provisions within NEMWA, including licensing, transport, handling, storage, treatment, and waste disposal.
2011	Nation Waste Management Strategy	Aid the South African municipalities on ways to manage waste in a sustainable way.
2014	National Environmental Management: Waste Amendment Act, 26 of 2014 - DEA	Amendment of National Environmental Management: Waste Act, 59 of 2008.
2020	National Waste Management Strategy	Amendment of National Waste Management of 2011.

2.9 Sustainable Waste Management Strategies

This section explains different waste types of waste management strategies that the university may adopt.

2.9.1 Separation at source

Implementing the separation of waste at the source is regarded as one of the ways to foster recycling and reduce the complexity of waste streams and contamination. Waste at the source is separated according to the various types (packaging and paper waste, organic, and textile waste); this can be achieved using different colour-coordinated waste bins or plastics (see Figure 2.12 below).

Figure 2.12 Different types of waste bins (RU, 2020).

Rhode University also signed the Talloires Declaration Signatory list and adopted a multi-bag system to encourage recycling. Through this system, refuse is separated at the source with recyclable materials in clear bags and domestic waste in black or blue bags.

Figure 2.13 Rhodes University two bag system (RU, 2020).

Separation at source challenges includes inconvenience, lack of knowledge, and interest concerning the university's importance of recycling and sustainability. Sorting recyclables into multiple bins seems strenuous as compared to the convenience of putting all waste into one refuse bag.

2.9.2 Recycling

Recycling, also known as "renewing or reusing", is a waste management strategy that involves collecting and separating waste material to convert it into raw material for the formation of valuable products; it enhances the efficient use of material (Bui *et al.*, 2022).

The benefits of recycling include the reduction of pollution in the eco-system, requiring less energy, and helping conserve nature (Evode *et al.*, 2021). Recycling also saves landfill space because of the reduced volume of waste dumped into the landfill site, thus causing less harmful effects on the environment (Demirbas, 2011).

2.10 Composting

Composting is an aerobic process whereby degradable materials are degraded and transformed by the micro-organisms into organic and inorganic by-products (Awasthi *et al.*, 2020). Transformation of organic waste through composting is safe, and the by-products are used as bio-fertilizers and soil amendments.

Applying composting increases agricultural productivity and the organic matter content of the soil, providing it with sufficient nutrients to promote plant growth; this helps mitigate the issue of food insecurity, increases soil biodiversity, and reduces environmental risks associated with synthetic fertilizers (Awasthi *et al.*, 2020).

There are various composting methods; namely, Indian Bangalore composting, vessel, windrow, vermicomposting, and static and sheet composting (Ragazzi *et al.*, 2017). Composting is usually done in a controlled environment; therefore, it differs from the decomposition of organic matter.

Rhodes University adopted the vermicomposting method, where kitchen and garden waste are regenerated to produce compost; this allows the university to save money on transport for biodegradable waste and buy compost (RU, 2020).

2.11 Anaerobic digester

Anaerobic digestion (AD) is a process where-by organic matter decomposes under anaerobic conditions, through process takes place in the absence of oxygen with the aid of micro-organisms Surendra *et al.* (2014). At the end of an AD process a combustible biogas is produced and a digestate. The AD process takes a wide variety of biodegradable feedstock, such as, MSW, cattle manure, sewage sludge and agricultural crop residues. The biogas produced requires less cleaning, since it has high concentration of methane between 50-70%. The biogas is used for cooking, heating, and electricity.

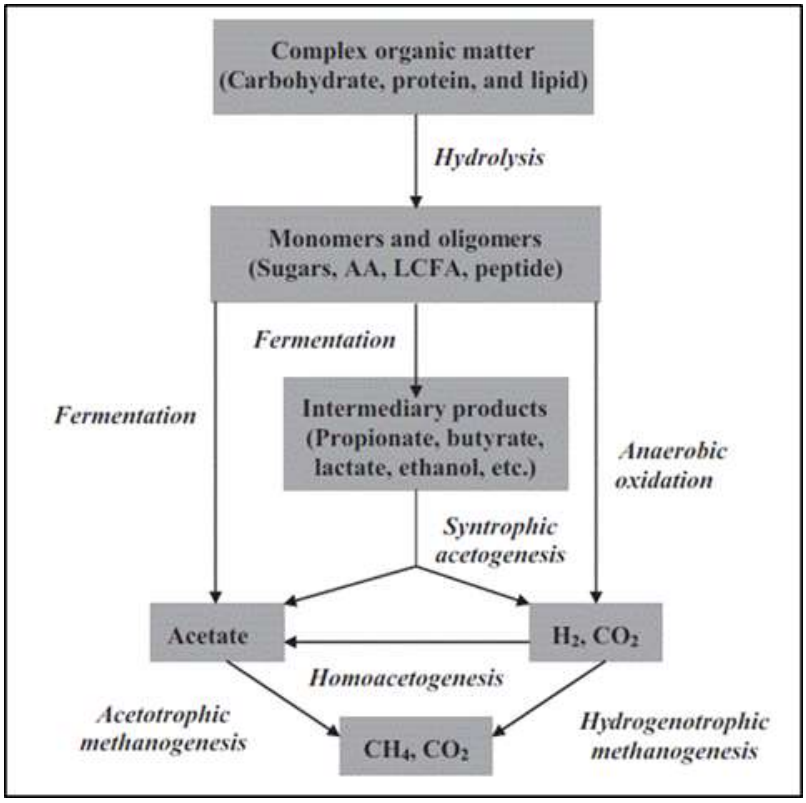


Figure 2.14 Anaerobic digestion process (Dehkordi *et al.*, 2020).

Guangzhou University reported a case study of potential biogas production using breakfast, lunch, and dinner kitchen waste produced by the canteen. The study assessed the anaerobic digestion performance under mesophilic and thermophilic conditions. According to the report, a potential biogas production yield at the university based on 5904.43 tons of kitchen waste per year is 1.08 million m^3, which is equivalent to 2.15 million KW h of electricity (Jiang *et al.*, 2018).

2.12 Chapter Summary

This chapter discussed sustainability in high education institutions, including declarations and initiatives developed to assist universities in addressing environmental issues. Also, this chapter critically evaluates how other universities manage their solid waste from an International, African, and South African context. Moreover, the impact of COVID-19 on waste management, waste in a general context and the sustainable waste management strategies that can be implemented in universities. The following chapter details the methodology used to achieve the aim of this research.

3. CHAPTER THREE: METHODOLOGICAL APPROACH

The methodology in this study includes a case study, visual observation analysis, survey in the form of questionnaires and interviews (google forms), solid waste stream characterization and analysis. Therefore, this research is comprised of quantitative and qualitative methods.

3.1 Research Method

A theoretical and Case Study methods were used in this dissertation. Through critical analysis of the literature ways in which waste in managed by other universities was identified. It was determined that solid waste management in South African university is not prioritized, this research gap informs this study.

UKZN-PMB Campus and Denison Residence are the case study involved in this research. PMB Campus was used as observation and Denison Residence was used to carry out the survey and waste characterization experiment. The case study enabled for the in-depth understanding of the problem of handling municipal solid waste in residences.

3.2 Summary of Data Collection

Survey questionnaires

1. To gather an understanding of the solid waste management concepts.
2. To better understand the students' willingness to participate in waste management campaigns.
3. To gather the student’s awareness about the university’s waste management practices.

Interview

1. Determine the current waste management strategies being implemented by the university.
2. To better understand the flow of waste from the point of generation until its end of life (landfilling).
3. To investigate if there have been any waste awareness campaigns/initiatives within the university PMB Campus and residences.

Observation

1. To observe if the university encourages waste separation at source, especially now during the "COVID-19" era.
2. Determine the condition and placement of bins within the residences and campus.
3. Observe the littering behaviour of the students.

Waste characterization

1. Determine the attitude and participation of students toward waste separation at the source.
2. Gather types of waste streams produced by the students at the residences.
3. Quantify the waste fractions produced to recommend appropriate waste management strategies.

3.3 Waste Management at UKZN PMB Campus

As stated in Section 2.3, COVID-19 has changed the traditional learning system for higher learning institutions worldwide, and South Africa is no exception. In the past two years, universities have embraced the virtual space as a learning and meeting medium, limiting the number of students on campus due to the strict restrictions to curb the spread of the virus.

Thus, the generation of solid waste at university campuses has drastically reduced, which makes it an area of less concern. However, currently (2022), the residences are running at total capacity to maintain the academic year, and that is where the bulk of municipal solid waste (MSW) is generated.

To better understand the solid waste management in student residences at PMB Campus, the Denison student residence was investigated to acquire solid waste data.

3.3.1 Waste management: campus investigation

It is necessary to note that there will be a world after COVID-19, and things will return to the "new normal" where students and lecturers will resume in-contact lessons. Hence, the university must be prepared for such a time regarding solid waste management. Therefore, a visual inspection was conducted, and the following was observed:

1. Sources of municipal solid waste at UKZN-PMB Campus
2. The number of bins around campus.
3. Distances between the bins.

4. Condition of the existing bins.
5. Littering around campus.
6. Hazardous (COVID-19) waste separation bins on campus.

Information regarding changes made to integrate COVID-19 when handling solid waste, the Safety, Health, and Environmental (SHE) manager of the PMB campus, was interviewed. Also, information regarding waste management initiatives and organizations within the campus was obtained from a member of Sustainable Living and, a Smart Garden and Green Campus member.

3.4 Waste Management at UKZN-PMB Residences

UKZN-PMB Denison Residence was used as the Case Study for solid waste management within the residences because Denison is one of the biggest accommodations at UKZN-PMB and accommodates students from all study levels (1st years to post-graduate level).

The following information about Denison Residence was obtained:

1. The boundaries of the residence.
2. The number of buildings within the residence.
3. The total number of students that the residence accommodates under the COVID-19 regulations implemented by the university.
4. Current waste storage point.
5. Frequency of waste collection.
6. Existing waste recycling practices.
7. The disposal method of "COVID-19 waste.

3.4.1 Waste generation and separation at source

To determine the amount and type of municipal solid waste produced by the students residing in residence and to perform the separation of waste at the source experiment, five buildings which are Block 1, Block 2, Block 3, Men's Tower and Women's Tower were selected. Because the Blocks are junior residences, they accommodate 1st and 2nd years, and the Towers are senior residences that house 3rd to post-grad students.

The data collected from these buildings were used to represent waste generated by all UKZN-PMB residents (on and off-campus). Before data collection, the following information about the buildings was obtained from the cleaning staff:

1. The number of floors, bedrooms and communal areas at the residence.

2. The total number of bins within the buildings.
3. Frequency of waste collection from the building.

3.4.2 Survey questionnaire

The survey questionnaire was created using google, as mentioned in Section 3.3.1, where five buildings were selected; therefore, the survey was distributed to the students living in the above building.

Students were approached in their rooms, where the study was explained, and then the link to the survey was shared via WhatsApp text, COVID-19 rules of keeping a 1.5m meter social distance adhered to. The survey ran concurrently with the experiment.

The survey questions were separated into the following sections:

a) Students' social demographic.
b) Students' knowledge and understanding of waste management.
c) Students' observation of the university's waste management practices.
d) Student's waste management behaviours.
e) Awareness about COVID-19 impact on solid waste.

3.4.3 Survey sample size

Since the population was known, the sample size was determined using Cochran's formula, detailed below, and the answer obtained was checked against Slovin's formula. For accuracy, the average of the two values was accepted as the number of responses that would yield accurate results.

The minimum number of respondents to the survey questions was determined using the formula below:

$$n = \frac{P(1-P)Z^2}{E^2}$$

Where:

n = required sample size

P = percentage occurrence of a state or condition

E = margin of error or maximum error required

Z = level of confidence.

The above formula is for an infinite population; therefore, since the population is known, it was adjusted using the following formula.

$$s = \frac{n}{1 + \frac{(n-1)}{N}}$$

Where:

s = Adjusted sample size N = known population size

3.5 Solid Waste Separation at Source Experiment

The separation at source experiment was conducted at Denison Residence, using five buildings. The experiment results were the representative spectrum of types of waste expected from all university residences.

The experiment was carried out to determine the following;

1. To observe the student's willingness to separate their waste.
2. To estimate the solid waste that students generate daily.
3. To identify the solid waste streams by characterizing the waste samples.
4. To obtain data that will assist in setting solid waste reduction goals for the university.

3.5.1 Materials

Following are the materials that were used for the experiment.

1. Weighing scale for weighing the waste.
2. Personal Protective Equipment (PPEs) – gloves and facemasks.
3. Plastic bins – for separation and handling of waste.
4. Pen and paper – for recording results.
5. Hand sanitizer – for COVID-19.

3.5.2 Experiment procedure

The experiment was carried out for 11 days (1 week and four days). Before the experiment began, the Residence Life Officer (R.L.O) was informed, and he then allocated the Residence Assistant (RA) to assist during the experiment. RA notified the Floor Representatives (FR) of each building, and they had to inform the students residing in the buildings about the experiment that was taking place. The cleaning staff was also

informed about the experiment; therefore, they did not remove the waste during the study period.

Waste was collected after 18:00 every day; therefore, the data collected was waste that was generated within 24 hours from the time of collection.

On the first day of collection, bins were not separated; thus, mixed waste was collected from the bins on each floor to observe the complexity of handling and separating it after collection.

Posters were created and posted next to the bins within the buildings requesting the students to separate their organic waste from the dry waste. An additional clear plastic bag was placed in the kitchens, designated for dry waste, while the bin fitted with the black plastic bag was designated for organic waste. The bin in the corner of each floor was designed for only dry waste. Refer to Figure 3.1 below.

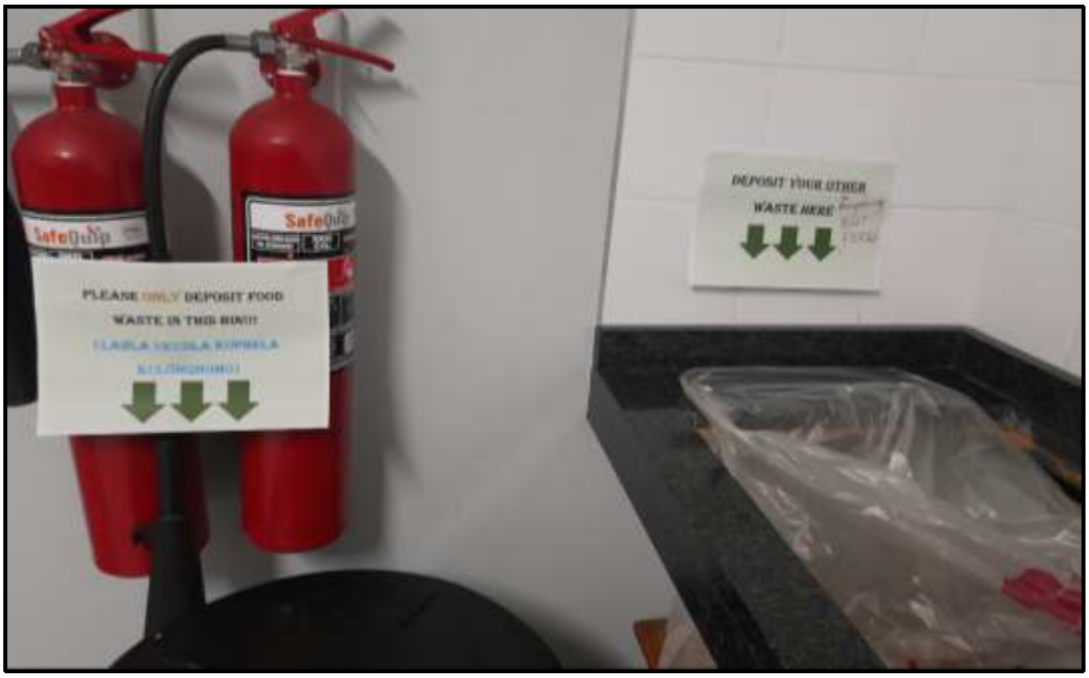


Figure 3.1 Notice about waste separation.

All plastic bags were removed from the bin during collection and replaced with new ones. During collection, students were continuously encouraged to keep separating their waste. The clear and black plastic bags were removed from the buildings and placed outsides for weighing and sorting. See Figure 3.2 below.

Figure 3.2: Separated waste from student residence PMB campus.

3.6 Characterization of the samples

Table 3.1 below represents different waste categories that the samples were identified using. During waste characterization, all the black plastics were considered organic (food leftovers, eggshells, spoiled fruits and vegetables), and the clear plastic bags had only solid waste (cardboard, paper, plastic, tins/cans, glass and metals, and COVID-19 waste). All plastic bags were weighed, and the clear bags were separated and analyzed into different solid waste categories. The results obtained are reported in this report under Chapter 5.

Table 3.1 Dry waste component categories.

Category	Description
Organic waste	Leftover food
	Eggshells
	Fruits and vegetable
Paper & Cardboard	Books
	Tissue paper
	Egg boxes & alikes
	Beverage cardboard
	Other board and paper
Plastic	Packaging plastic

	Soft and dense plastic
Metals	Aluminium cans
	Tins
Glass	Any glass
Other waste	COVID-19 (masks)
	Non-classified

3.7 Analysis of Data

A database was created on the Excel Spreadsheet using the categories from Table 3.1, and this database base was used to record the weight of each category of waste results (See Appendix A). For further analyses, the weight percentage of each category was calculated using the following formula and presented graphically. The results were compared to the previous waste management research studies at Howard College Campus.

Wet and Dry Waste

Both the wet (black bags) and dry waste (clear bags) were weighed separately, and the results were then summed up to obtain the total mass of the waste collected. To get the percentage of each waste stream, Equation 3.1 was used.

$$\%\text{Composition (dry/wet)} = \frac{\text{waste stream mass}}{\text{Total mass}} \times 100$$

Equation 3.1 Formula for calculating wet and dry waste composition

Dry waste sub-categories

The mass of each dry waste sub-category was recorded every day, and the results were then summed up to obtain the total mass of the sub-category. The results were then used to calculate the percentage using the formula below Equation 3.2.

$$\%\text{Composition (sample fraction)} = \frac{\text{Total fraction mass (sample)}}{\text{Total dry mass (sample)}} \times 100$$

Equation 3.2 Formula for calculating dry waste percentage composition

Rate of waste generation

To determine the rate at which students generated waste per day, Equation 3.3 below was used.

$$W_G = \frac{W_t}{P_e \times t_s} (\text{kg pe}^{-1}\text{d}^{-1})$$

Equation 3.3 Formula for rate of waste generated

Where:

W_G = Waste generation rate W_T = Total weight

P_e = number of people who contributed

= Time interval during which waste was stored

3.8 Assumptions

The following are the assumptions that were made during the study:

- All students residing in the building deposited waste into the bin every day.
- All the waste content in the black bin was organic
- The quantity, type of waste composition and waste generation rate obtained from the selected buildings were assumed to represent the whole Denison Residence and the residences of the UKZN PMB campus.
- It was assumed that the survey respondents answered honestly and accurately.

3.9 Limitations

The following are the limitations that were encountered:

- Lack of previous solid waste data being collected by the waste management team at UKZN PMB Campus.
- Difficulties in getting information due to management working from home.
- Lack of capacity to collect waste from all the Denison buildings. Hence, five buildings had to be used for this study.
- Some students failed/refused to separate their waste, regardless of the signs and shared information.
- Using transparent plastics and sticking them onto the wall because no additional bins were provided discouraged the students because they kept falling.
- The experiment had limited time constrain.

3.10 Chapter Summary

This chapter details the research methods used to attain the results necessary for this research; this includes the assumptions made during the experiment and the limitations experienced. The various methods outlined in this chapter aimed to achieve the objectives stipulated in Chapter 1. The next chapter discusses the case study of this research.

4. CHAPTER FOUR: A CASE STUDY OF PMB, UKZN

The University of KwaZulu-Natal (UKZN) is situated in Pietermaritzburg, also known as the Midlands, in the Scottville suburbs. It is 4.2 kilometres away from the central town. UKZN is comprised of three small campuses: the main campus, agricultural campus, commerce, law and management campus (see Figure 4.1), and a farm called Ukulinga Farm.

The university provides residence to approximately 4600 students, both on and off-campus, undergraduate and postgraduate students. There are seven on-campus residences and eight off-campus residences. All residences are self-catering; some accommodate male and female students in one building but are separated by a floor, while others are gender specific. Figure 4.2 shows the location of the residences around the campus.

Figure 4.1 Google Earth photo showing different UKZN PMB Campuses.

Figure 4.2 On campus residences around main campus.

4.1 PMB Campus Waste Management Overview

This section reports on the visual observation and interviews conducted at PMB Campus regarding solid waste management. Figure 4.3 below summarises the sources that generate solid waste in the university.

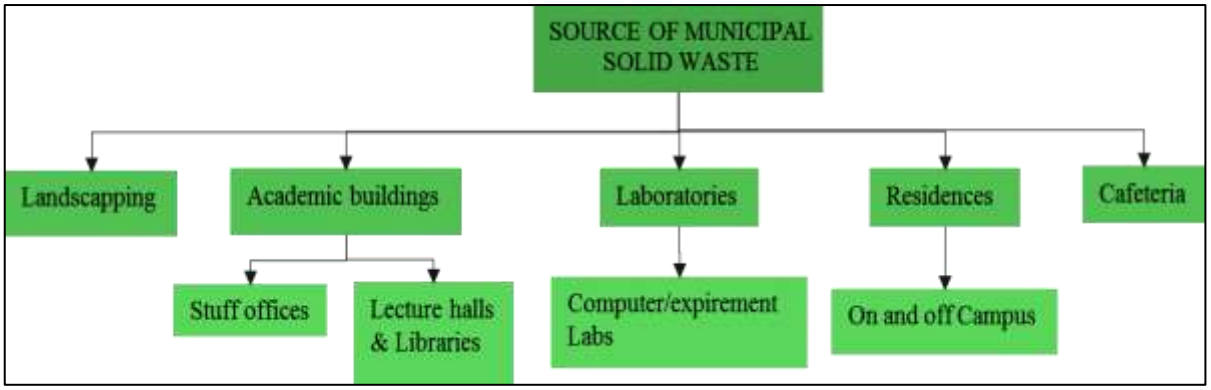


Figure 4.3 Source of solid waste in PMB Campus.

4.1.1 Campus Observation

The observation was conducted in the March, April, and May first semester of 2022. The main campus has three types of bins, as shown in Figure 4.4 below—the wood type of bin, concrete bin and stainless-steel bin. There are approximately 20 bins on the main campus, and the distance between the bins ranges from 10 meters to 56 meters. All these bins are used to dispose of all kinds of waste streams, and there is no bin colour coordination to encourage waste separation among students.

Some of the bins were fitted with black plastic bags, but not all of them. This poses a threat to the person collecting the waste. The bins were also observed to be of neutral colours; thus, they blended with their surroundings, making them hard to identify from a distance.

Figure 4.4 Three types of bins around Campus.

4.1.1.1 Condition of the bins

Some of the bins were observed to be in bad condition and concerning, as shown in Figure 4.5 below. The bin on the left has tilted because was mounting the pole broke; the black refuse plastic bag can be seen protruding underneath the bin on the right due to the bin having a hole. The green wooden bins were all observed to be in good condition.

Figure 4.5 Condition of the bins around campus.

At Agriculture Campus, it was observed that green wheelie bins were placed at a point that is designated as waste collection. It is evident that the campus once had a waste separation programme because one of the bins had a glass recycling sign. See Figure 4.6 below. One of the concrete bins had been repurposed and used as a pot plant. Refer to Figure 4.7 below.

Figure 4.6 Wheelie bin that was designated for glass recycling.

Figure 4.7 Repurposed bins at Agriculture Campus.

4.1.1.2 Littering around campus

The agriculture and commerce building had little littering compared to the Main Campus (refer to Figure 4.8 below). Therefore, both campuses may be regarded as zero-waste. Nonetheless, littering at the main campus may be due to the following reasons;

- The main campus caters to all faculties in terms of accessibility, compared to agriculture and commerce buildings which are discipline-specific.
- The main campus has two computer laboratories that most students prefer.
- Getting to the main campus is more convenient for students to study during the day.
- It is the only campus with cafeterias selling fast food and a common area for students to hang out.
- This may be due to students throwing around the bins instead of into the bin or monkeys when they scavenge for food in the bins.

It may be deduced that littering around campus is expected, although some areas have bins nearby. This behaviour solidifies the need to educate students about waste management to discourage littering.

Figure 4.8 Littering observed around campus.

4.1.2 Waste management initiatives on campus

In 2019 the students came together to form an organisation called Sustainable Living; the organisation aimed to do recycling, composting and application of waste to energy technology (anaerobic digesters); they were also aiming to educate surrounding primary and high school about waste management. The organisation was launched in February 2020; unfortunately, in March 2020, South Africa reported its first COVID-19 case, and soon after, there was a National shutdown. This led to the organisation being neglected as the prioritised changed.

The Agriculture Campus had a Green Campus campaign that was launched in 2016; the campaign aimed to educate students about recycling within the campus. According to the student that was part of the initiave, students eagerly participated in the campaign, and there were improvements in the recycling rate at the Agric campus; however, due to a lack of support from the management, the initiative had to be closed.

4.1.3 Impact of COVID-19 on waste management

The PMB Safety, Healthy, and Environmental (SHE) officer at the time of the interview, said that after the COVID-19 outbreak, they had to derive a waste management plan that integrated COVID-19. This included installing the sanitising stations when entering the campus (see Figure 4.10 below), and they gave protective gear to the cleaning staff.

They educated the students to wrap their face masks with either toilet paper or plastic (similar to the sanitary pads plastic) before discarding them. However, separation of COVID-19 waste was not implemented; how waste was handled did not change both on

campus and in residences. She mentioned that the biggest challenge as the SHE officer is the need for more interest and support from the university management regarding implementing solid waste management strategies.

Figure 4.9 COVID-19 sanitising station.

4.2 Denison Residence

Denison residence is approximately 166.73 m², and it is located along Golf Road in Scottsville. The residence has six sections, namely, Blocks, Upper Goldfield, Lower Goldfield, Towers (man and female tower), Wine lands, and Phase 5 and Phase 6, which is strictly medical school residence, refer to Figure 4.10 below.

Figure 4.10 Google Earth photo of Denison Residence.

At the time of the study, most rooms at Denison were occupied because the country had adjusted its COVID-19 levels from level three to level one. Therefore, restrictions were eased, allowing more students to return to residence.

4.2.1 Tower Residence, Block 1, 2, and 3 Residence

Tower residences and the New Blocks are the focus area of this study. The data collected from these residences was used to represent waste produced by the students on and off-campus residences.

4.2.1.1 Residence description - Block 1, 2, and 3 Residence

Block 1, 2, and 3 buildings, commonly known as "Daycare", are new; they were opened to the students in 2021 and only accommodated 1st and 2nd-year students. Blocks 1 and 2 are for females, while Block 3 accommodates male students. Each building has three floors, each floor has a kitchen, bathrooms and toilets and there is one laundry room, a TV room and a reception area. The floors have 12 sharing rooms; therefore, each building accommodates 72 students, which is 216 students. See Figure 4.11 below.

Figure 4.11 New Denison Building Residences, PMB Campus.

Residence Description – Towers

The Towers are twin residences, except they are gender-specific (men and female). They accommodate 3rd, 4th year and post-graduate students. The Towers have a single room, each accommodating 48 students, therefore, 96 students in total. The buildings have three floors, each floor has a kitchen, bathrooms and toilets, and there is one laundry room situated on the ground floor and a lounge as a common area.

Figure 4.12 Men and Women's Tower.

4.2.2 current solid waste management

Every student room has a 5-litre bin, and each floor has two big bins; one is placed in the kitchen, and the other is at the corner of each floor (refer to Figure 4.13 below). Therefore, in total, each building has six bins. That means in the Blocks, one bin caters to 12 students, and in the Towers, one caters to 8 students.

Figure 4.13 Bins located inside the residences, at the corner and in the kitchen respectively.

Figure 4.14 below is the flow diagram that illustrates and summaries the flow of waste from UKZN residences from the point to generation to its end of life. Figure 4.15 shows the wheelie bins located at specific points at Denison where the UKZN waste truck collects and removes the waste from the premises.

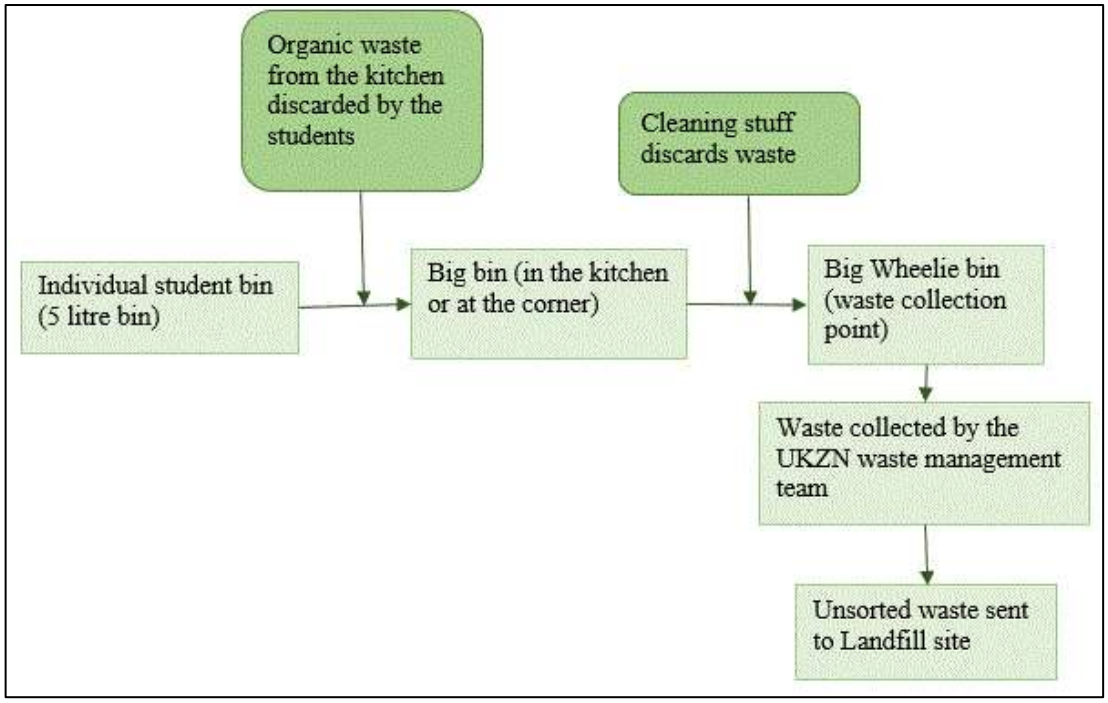


Figure 4.14 The summary of solid waste management in UKZN residences that is currently employed.

Figure 4.15 Denison waste collection points.

4.2.3 Waste Management Initiatives at Denison Residence

The Department of Student Residence Affairs and the Dean and Vice-chancellor initiated a smart garden project second-semester last year (2021). The project aimed to divert Denison residence organic waste and other waste materials such as old beds, plastics, and tyres from being sent to the landfill site.

The solid waste streams were used to prepare the garden, and the organic waste was used as fertiliser to improve the soil's organic matter. From the garden, the participants were able to produce improved yield and profitable fresh crops by combining organic and chemical-based substances to enhance the growth and development of crops. The main limitations of the project were the space and equipment; however, the project was a success.

4.3 Chapter Summary

This chapter provides description of the Case Study area which is UKZN-PMB Campus and Denison Residence. An observation around the campus was done to see the condition of the bins and how students dispose their waste. Information about the environmental initiatives in UKZN-PMB is also discussed. Furthermore, limitations that were experienced during the study are mentioned.

5. CHAPTER FIVE: RESULTS AND DISCUSSION

This chapter explains the outcome of Chapter 3 (methodology). The results are represented in tables, pie charts and bar graphs in various sections. The outcome is based on the data collected during and post-COVID-19 pandemic.

5.1 Survey Results

The sample size was determined using Cochran's formula, the margin of error used was 5%, the level of confidence selected was 95%, and the population proportion was 50%. The sample size was calculated to be 173; for accuracy, the sample size was also determined using Slovin's formula, where a value of 175 was calculated (see Appendix A). The average of the two values (174 respondents) was accepted as the number of responses that would yield accurate results.

The survey was distributed to 312 students, and 210 students responded; therefore, a 67% response rate was received. The survey questions were structured in a manner that allowed for the understanding of the student's views, attitudes, and behaviour regarding waste management.

5.1.1 Social demographic

There is little difference in the student's income and age, therefore the main social demographic factors considered as the year of study, and gender. Referring to Table 5.1 below, it can be seen that 40.95% of the respondents were male and 59.05% were female students, and this is because 3 out of the 5 residences were female accommodations.

Table 5.2 below shows that on average 20% of students from all levels of the study responded to the survey.

Table 5.1 Number of respondents based on gender

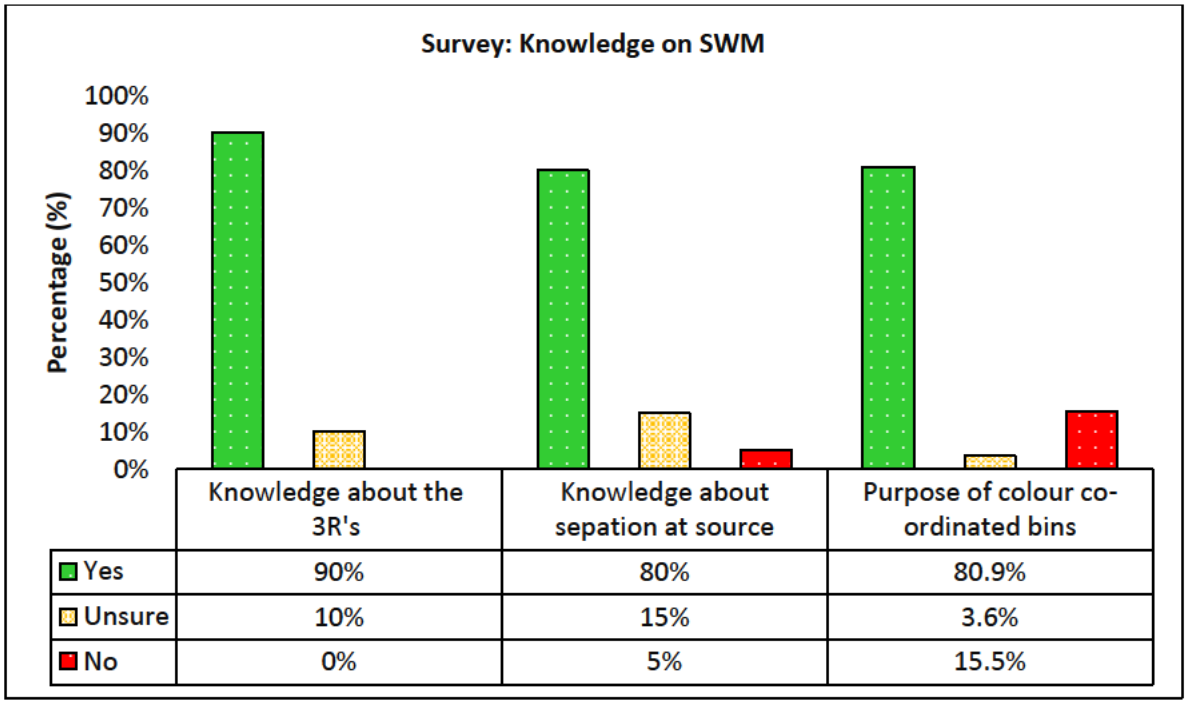
Gender	Percentage [%]	Number of Respondents
Male	40.95	86
Female	59.05	124
Total	100	210

Table 5.2 Number of respondents based on year of study.

Year of Study	Percentage [%]	Number of Respondents
1	20.9	44
2	20.0	42
3	21.8	46
4	19.1	40
Post-grad	18.2	38
Total	100	210

5.1.2 Knowledge and understanding of waste management

Figure 5.1 below illustrates the students' knowledge about the 3Rs, waste separation at source and bin colour coordination, and this was to evaluate their basic knowledge of solid waste management. 90% of the respondents indicated that they knew the meaning of the 3Rs: to Reduce, Re-use, and Recycle, while 10% of the students responded that they were unsure. 80.9% responded that they knew the purpose of bins being colour co-ordinated, 3.6% responded that they were unsure and 15.5% responded that they had no idea why bins needed different colours. On the question about the waste separation at source, 80% of the students responded that they knew what it meant, 15% were unsure, and 5% responded that it was their first time hearing about it.



	Knowledge about the 3R's	Knowledge about sepation at source	Purpose of colour co-ordinated bins
Yes	90%	80%	80.9%
Unsure	10%	15%	3.6%
No	0%	5%	15.5%

Figure 5.1 Respondent's knowledge of waste management.

5.1.3 Waste management and COVID-19

Referring to Figure 5.2 below, students were asked if they knew that waste could act as a transmission medium for COVID-19 since the virus can be transmitted through contact with contaminated surfaces. 40,4% of the students responded that they knew that waste could transmit the virus, 11,9% responded that they were unsure, and 47,7% said they did not know.

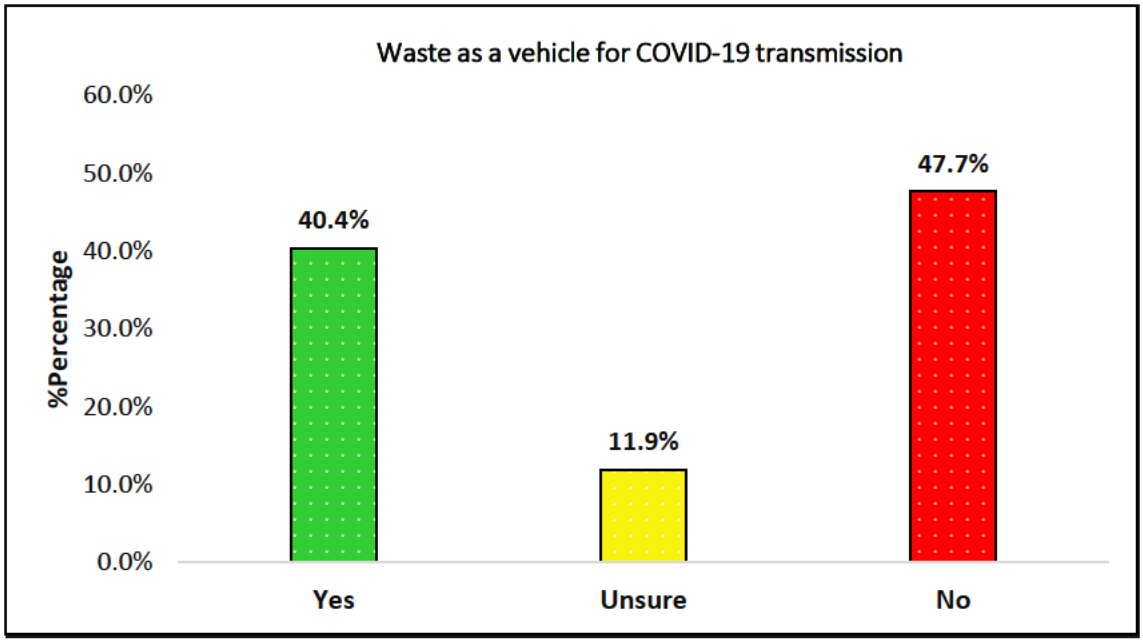


Figure 5.2 Student's knowledge of COVID-19 transmission through waste.

With face masks considered hazardous waste, it was essential to understand how students disposed of their disposable masks. 17,6% of the students responded that they wrapped it before throwing it into the bin, 19,4% responded that to throw it directly into the bin after wrapping it, and 63% of the students responded that they used the face-cloth masks; thus, they never dispose of them because they are durable.

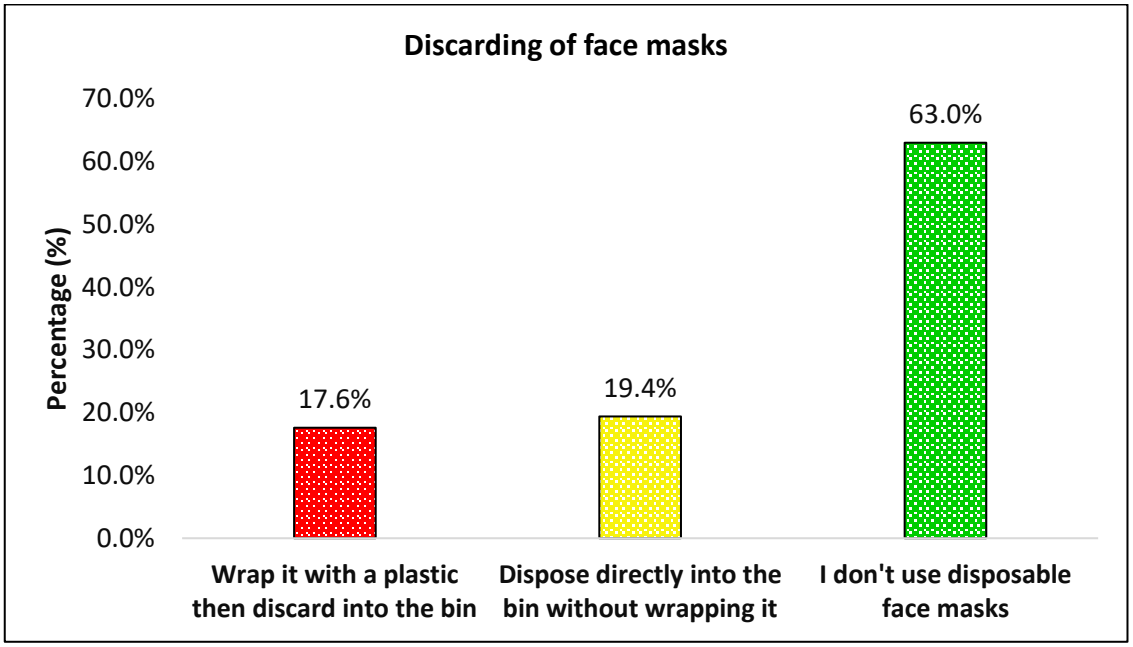
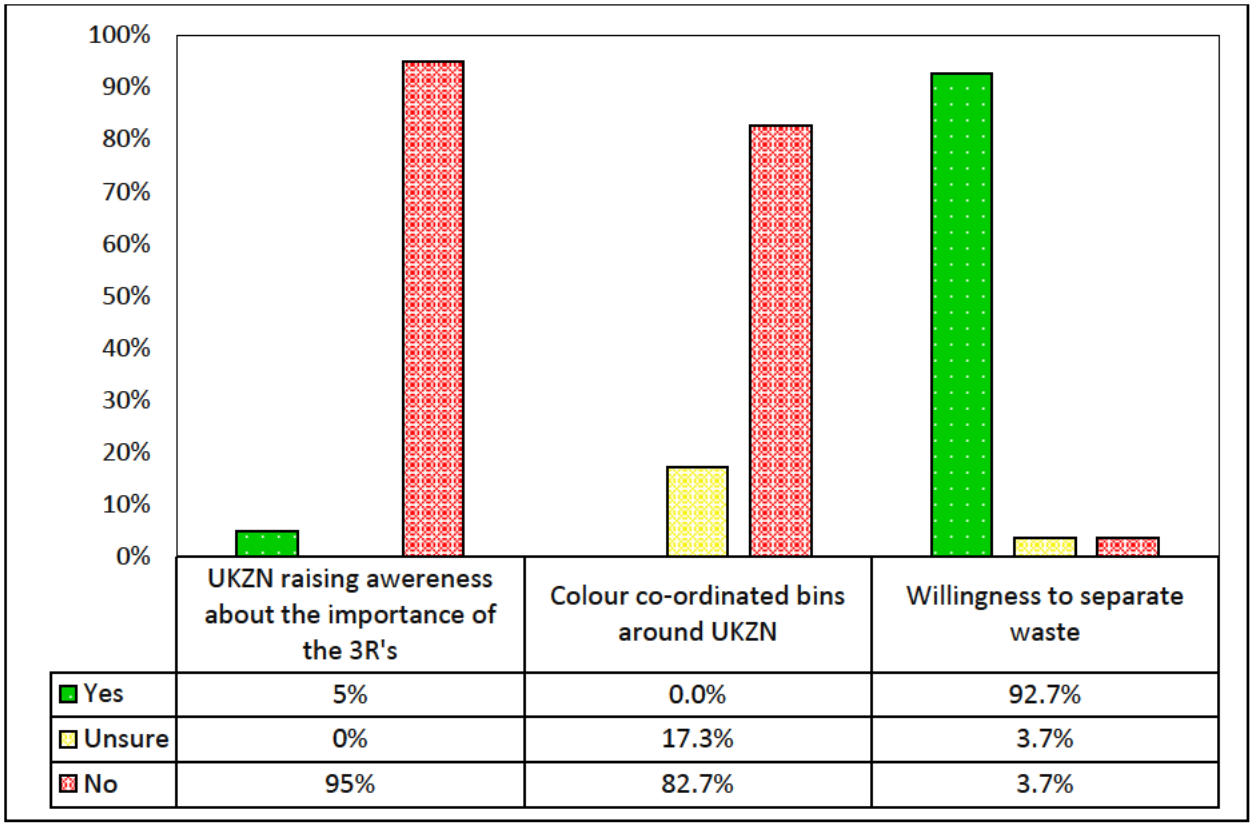


Figure 5.3 Results on the disposal of masks.

5.1.4 Student's observations about the UKZN waste management practices

To determine if the students are observant of the solid waste management practises at UKZN, they were asked if they felt like the university was raising enough awareness about the importance of managing solid waste through the application of the 3Rs either in residences or on campus. The findings in Figure 5.4 below show that 95% of the students responded that the university was not actively advocating for the 3R, while 5% indicated that they were unsure.

Additionally, 82.7% of the students responded that the university needed a colour co-ordinated bin system to encourage waste separation around the campus and residences. In comparison, 17.3% indicated that they were unsure. 92.7% of the students expressed that they were willing to separate their waste, while 3.7% indicated that they needed clarification, and 3.7% indicated that separating their waste would be cumbersome; therefore, they are unwilling to do it.



	UKZN raising awereness about the importance of the 3R's	Colour co-ordinated bins around UKZN	Willingness to separate waste
Yes	5%	0.0%	92.7%
Unsure	0%	17.3%	3.7%
No	95%	82.7%	3.7%

Figure 5.4 Student's observations about the university's waste management practices.

5.1.5 Student's waste management behaviour

Refer to Figure 5.5 below, students were asked how often they carry their shopping bags (plastic) when going to the shop to do groceries, this was to determine the students' behaviour regarding re-using items. 29.4% of the students responded that they always remember to carry a shopping bag, 52,3% responded that they carry plastic bags to the shops only when they remember (sometimes), and 18,3% responded that they never bring plastic with them; they always purchase them.

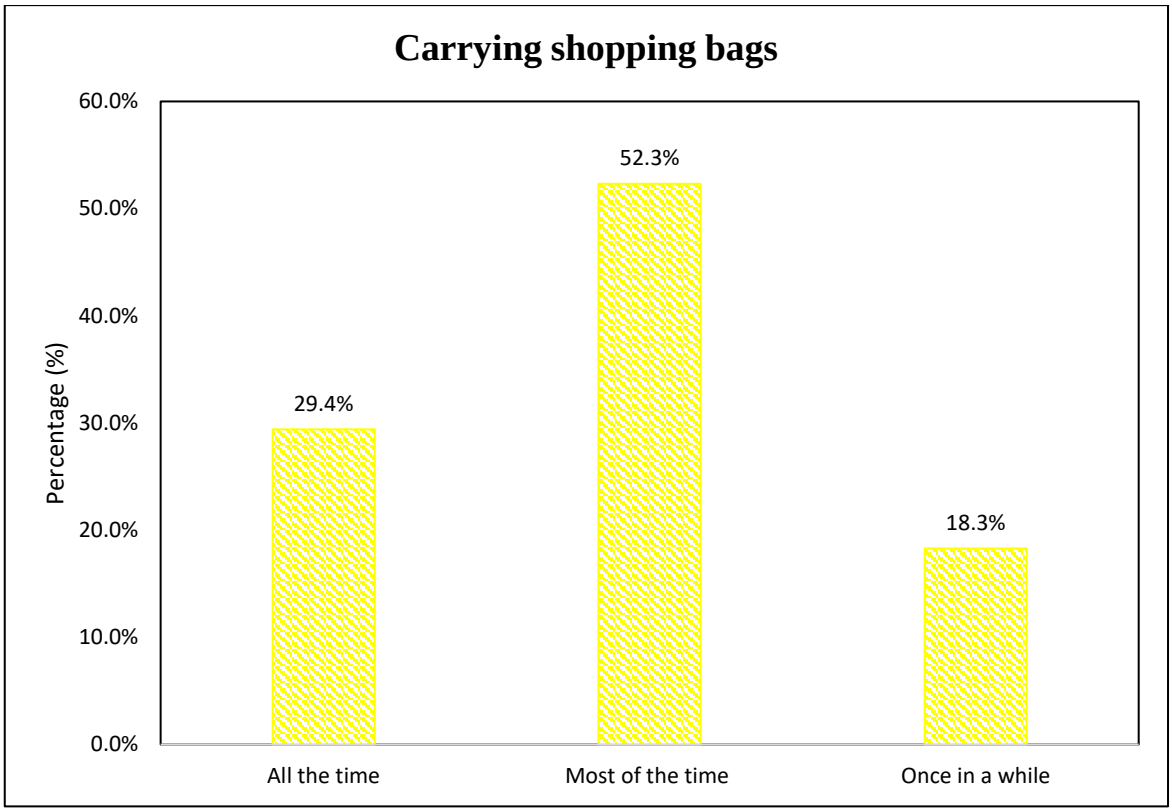


Figure 5.5 Respondents on plastic shopping bags when going to do shopping.

5.2 Waste Analysis

The experiment was conducted for 11 days, however, during the first two days of sample collection, the waste was mixed and complex to sort. This was to investigate the challenges associated with handling mixed waste, and also, during that time, the students were still struggling to adhere to separate their waste. Therefore, the analysis of the results in this section is based on the data collected amongst the five buildings at the Denison Residence over nine days (Day one is technically the third day of collection). Table 5.4 below is the data that was collected.

Table 5.3 Amount of waste that was collected from five Denison buildings

Waste Collection Days	Organic Waste (Mass kg)	Solid Waste (Mass kg)
1	35	12,4
2	30	10,5
3	41,5	13
4	68	10
5	43,5	9,5
6	36	10,2
7	41	13
8	37	12,5
9	39,5	11
Sum	371,5	102,1
Total	473,6	

5.2.1 Waste generated per building

Figure 5.6 below shows the amount of waste generated by each building. Block 3 generated 117,2 kg of waste, the most significant amount compared to the rest of the buildings, followed by Blocks 2 and 1. The Men and Women's Towers generated 78.9 kg and 71.3 kg of waste, respectively. In buildings, organic waste was the most significant waste stream generated in all buildings, and on average, the students produced 20,38 kg of solid waste.

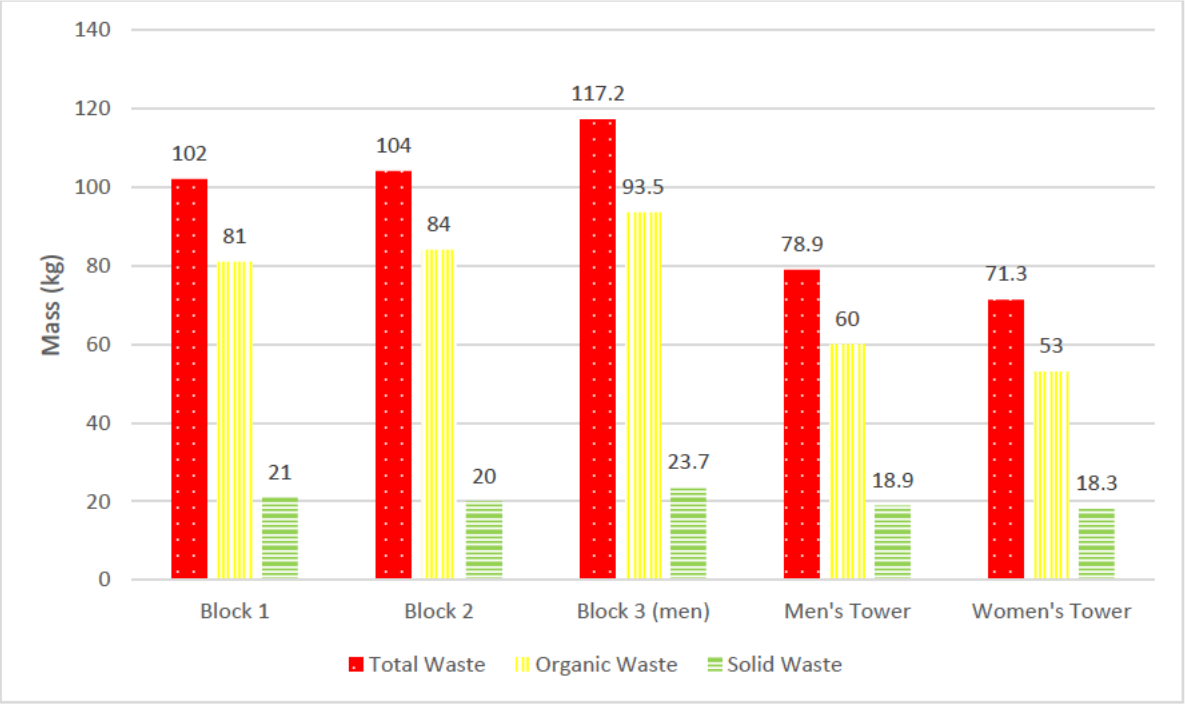


Figure 5.6 Waste generated by each residence building.

5.2.2 Waste generation rate

Over the 9-day duration, students generated a total of 473.6kg of waste (dry and wet waste). On average, 52,62 kg of waste was generated daily, and each student produced approximately 0.168 kg daily. Denison Residence houses 1151 students in total, therefore, it can be estimated that 193.37 kg of waste is generated daily.

Table 5.5 below tabulates the waste generation rate results obtained in three of the Howard College residences. UKZN students produce roughly between 0.047 and 0.322 kg of waste daily.

Table 5.4 Waste generation rates per student per day at Howard Collage residences

Howard College Residences	Waste Generation Rate	Authors
Ansel May	0.322 kg/day	Sihle Langa (2019)
Francis Stoke Building	0.047 kg/day	Sihle Langa (2019)
Sphiwe Langa	0.305 kg/day	Jateen Vallabh (2020)

5.2.3 Waste generation based on gender

Waste generation based on gender was investigated to determine if gender had a significant role in the amount generated. Results are represented in the box and whisker in Figure 5.7 below, and female students generated the minimum waste of 18.5 kg and males generated 10.5 kg. On average 30 kg and 23 kg were generated by females and males respectively. Most females produced 37.5 kg, and males produced 28.9 kg of waste. The females have an outlier of 50 kg, and the contributing factor may be the day on which waste was collected; it was on a Sunday when the female students were cleaning their rooms, discarding old foods and cooking in preparation for the new week. Based on the results, it can be seen that female students generate more waste than male students.

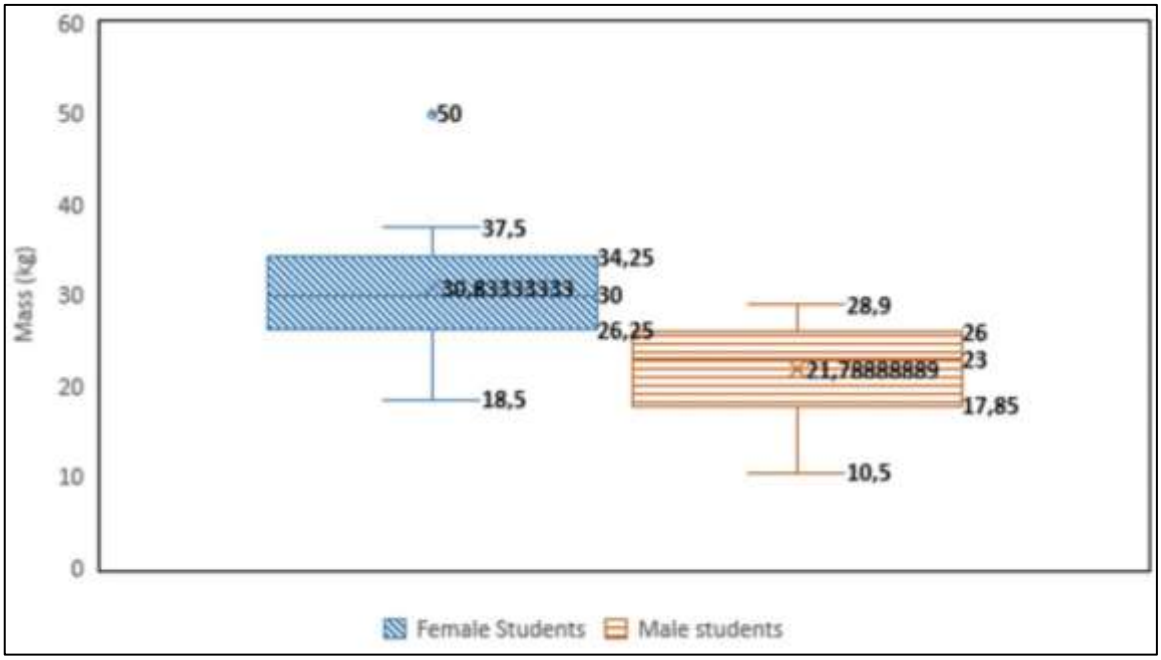


Figure 5.7 Student waste generation based on gender.

5.2.4 wet and dry waste composition

Students were asked to separate their waste into the dry (solid waste) and wet (organic waste) waste streams, as explained in Chapter 3, Sub-Section 3.4. Referring to Table 5.3 above, students generated an organic waste of 371,5 kg and 102,1 kg of solid waste, and in percentage composition, these streams are 78% and 22%, respectively. See Figure 5.8 below.

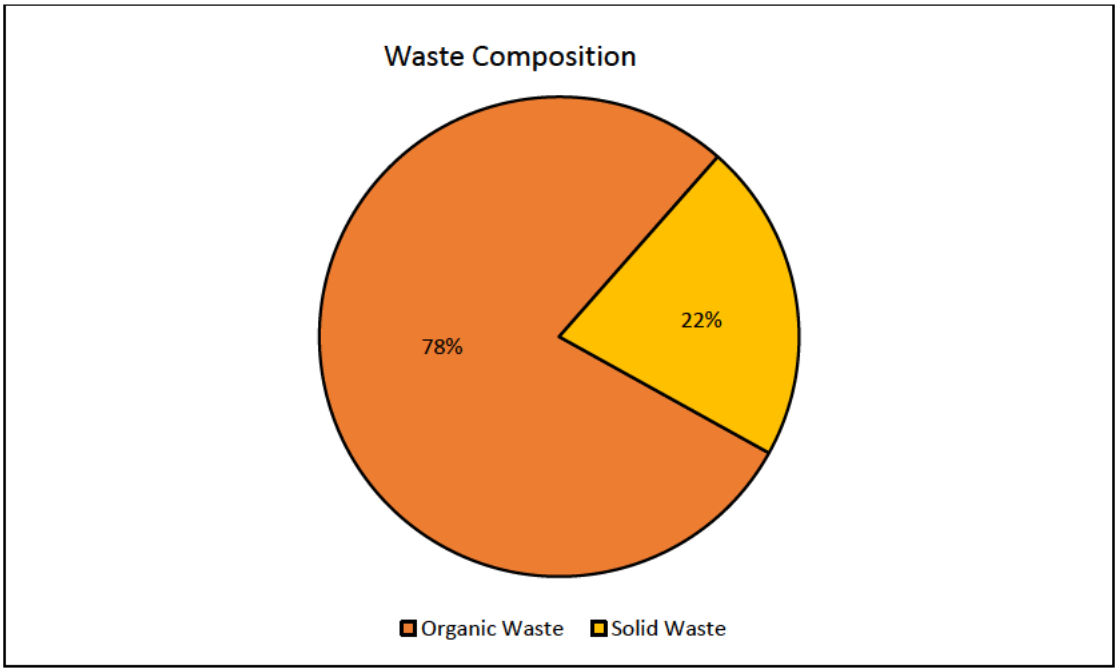


Figure 5.8 Dry and wet waste composition

5.2.5 Waste stream analysis

The dry waste was further analyzed for different waste fractions that the students produced, and the waste was manually separated and grouped into the waste streams for weighing. During the separation process, the plastic bags were first disinfected to kill COVID-19, however, the effectiveness of this process could not be measured as the waste was characterized the same day instead of waiting for nine days after disinfection as recommended.

The dry waste was weighed and analyzed every day, during the analysis it was found that 40% of the total 102.1 kg of dry waste was paper and cardboard, 30% was metal, 9% glass and dense plastic, 5% of soft plastic, 2% polystyrene and 2% of the "other waste" which included COVID-19 waste as represented in Figure 5.9.

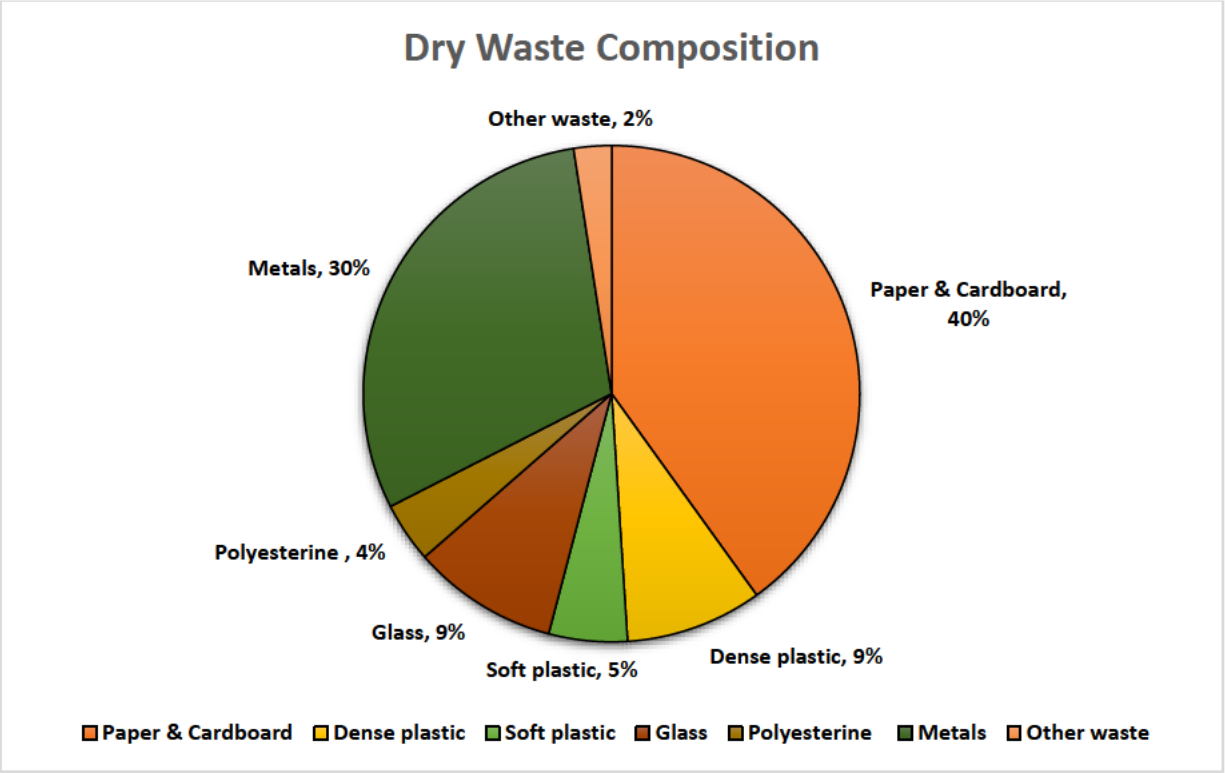


Figure 5.9 Dry waste composition.

5.2.6 Total waste composition

Figure 5.10 below shows that organic/food waste was the most significant waste stream generated; it constitutes 371,5 kgs of the total waste of 476,6 kg. It is followed by paper and cardboard, metals (cans), dense plastic, glass, soft plastic, polyester and other waste (sweet papers, COVID-19, condoms wraps, etc.), which is the lowest.

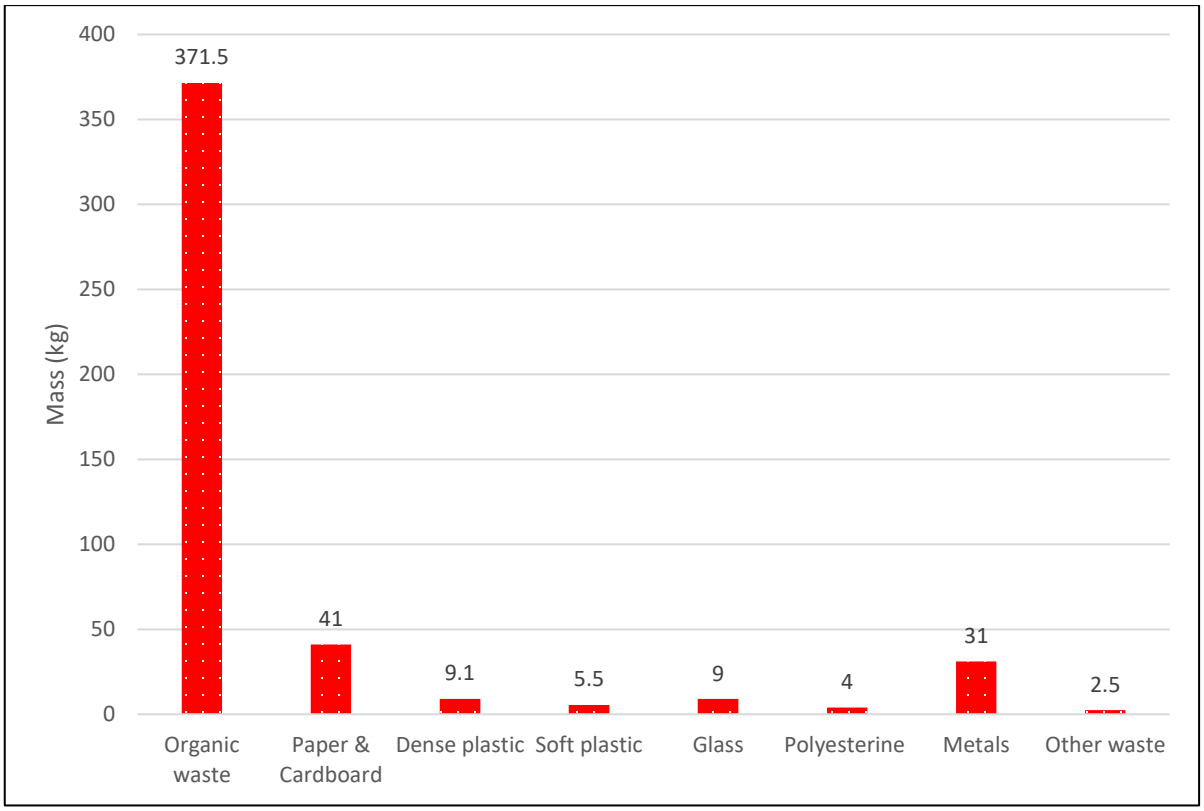


Figure 5.10 Total waste composition.

5.2.7 Recycling potential of the university residence solid waste

Referring to Figure 5.11, to determine the recycling potential of the residence, the waste was divided into three categories: compostable, recyclable and non-recyclable. 78% of the waste was considered compostable because it was an organic waste (food waste), and this is the most significant waste stream produced by the students; 18% of the waste was classified as recyclables, and 4% of the waste was non-recyclable. Therefore, Denison has a potential recycling rate of 96%.

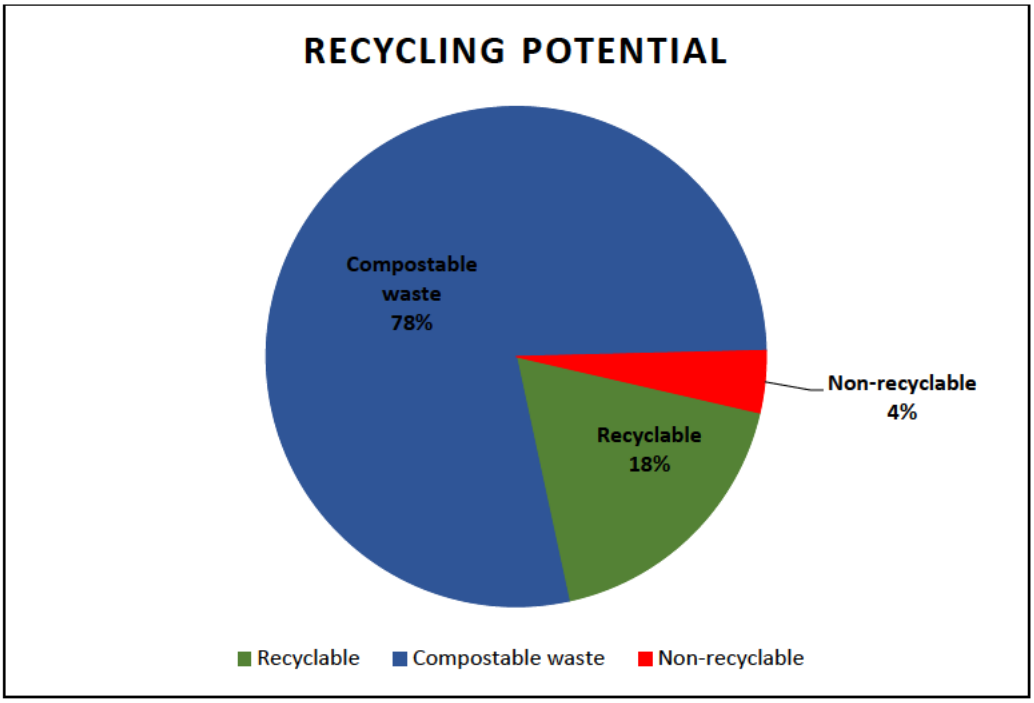


Figure 5.11 Recycling potential at Denison Residence.

The results for recycling potential were compared to those from the studies conducted in UKZN-Howard College residences. See Table 5.5 below.

Table 5.5 Comparison of waste recycling potential analysis of this study with the Howard research

Residence and year	**Francis Stoke Building (2019)**	**Ansel May (2019)**	**Sphiwe Langa (2020)**	**This study (2022)**
Compostable	21%	48%	60%	78%
Recyclable	75%	48%	36%	18%
Non-recyclable	4%	4%	4%	4%

5.3 Discussion

5.3.1 Current waste management strategy in PMB Campus

The current solid waste management strategy practiced by the University of KwaZulu-Natal PMB Campus of sending waste to the landfill site is not sustainable. With the current state of the New England landfill site, the university is adding to the problems of waste management faced by the uMsunduzi Municipality. Although the University has tried to reduce its paper usage by discouraging the printing of course outlines and notes by the lecturers to give to students and by having course material uploaded to the University's Moodle site, the effectiveness of that intervention has not been publicized.

Based on the studies that have been conducted at UKZN-HC not only PMB Campus has an insufficient waste management strategy, Howard Collage also send its solid municipal waste to the Marian-hill landfill site. It is stated in the 2017-2021 UKZN Strategic plan that by the year 2021 UKZN needs to be "acknowledged as a leader in embedding sustainability and good governance in all aspects of the University's operations" and waste management forms part of the university's operations. Shriram (2018), Langa (2019), and Vallabh (2020b) argued that the main hindrance to the implementation of sustainable waste management strategies at UKZN is the lack of financial investment as the management has no interest in setting aside a budget. It is evident that UKZN leaders do not view waste as a resource.

Apart from the UKZN PMB not having colour-coordinated bins that encourage waste separation at the source, the condition of some of the current bins is in a dilapidated state and needs to be replaced (see Chapter 4, Section 4.1). Furthermore, COVID-19 did not change the way UKZN handles its waste.

5.3.2 Student participation

It has been established in this paper that students play a significant role should the university decide to implement sustainable waste management strategies; their participation is vital. The role of students especially those that stay in university residences is to separate their waste at source. In the survey conducted 92.7% of the students indicated that they were willing to separate their waste, thus the waste separation at the source experiment was to correlate with the survey results.

During the experiment it was observed that students indeed separated their waste according to the organic and solid waste stream, however, for the first two days of the experiment student were still mixing their waste and throwing it in one bin, although an addition bin for the solid waste had been provided. A gradual increase in the rate of waste separation started being witnessed on day three of the experiment, by the end of the experiment most students were participating. The eagerness of students to separate their waste can be attributed to them being constantly reminded and encouraged. Therefore, by UKZN presenting itself as a "green university" and advocating for sustainable waste management strategies, then the students will be in full participation.

Also, when two plastic bin bags were placed together it was observed that students were less interested in separating their waste if the colour of the bin bag was the same, this highlighted the importance of colour coordination. And currently, there are no colour-coordinated bins at Denison residence.

5.3.3 Waste generated

To develop a sound waste management plan that is effective and sustainable for the university, the first step is to conduct waste characterization. On average 52,6 kg of waste per day was generated amongst the five buildings at Denison residence, it is estimated that per day an average student generates approximately 0,168 kg of waste. Given that Denison provides accommodation to approximately 1151 students, thus the daily waste generation rate at Denison may be estimated to be 193,7 kg, which is 5811 kg (5.811 tons) a month, only from the buildings excluding the garden refuse. This is a relatively high amount of waste that the university sends to the landfill site, of which 96% of it may be handled by recycling, reusing and composting.

The largest amount of waste stream that the students produce was food/organic waste, which constituted about 78% of the total waste. Amongst the three residences that have been investigated at UKZN-HCC organic waste was estimated to be 21% for Francis Stoke Building, 48% for Ansel May and 60% for the Sphiwe Langa building in 2020 (see Table 5.5). It can be seen that the was an increase in the amount of organic waste between 2019 and 2020 at Howard College and Vallabh (2020b) accredits the changes to COVID-19, as students had indicated that they spent more time in their rooms and cook more as compared to pre-pandemic. The same may be true for the students at Denison that

COVID-19 contributed to the students cooking more, also it is important to note that Denison residence is 2.2kms away from the nearest shopping complex, which makes the students cook more because it is more convenient. Thus, composting would strive if implemented.

The recyclables mostly plastics, metals (tins), glass, paper and cardboard constituted about 18% of the total waste collected, therefore, it can be estimated that on average Denison generates 1045,98 kg (1.045 tons) of recyclable waste that is sent to the landfill site every month. Compared with the findings at Howard College residences, the recycling potential at Francis Stoke Building and Ansel May was 78% and 48% respectively and 36% at Sphiwe Langa, the recycling potential rate for Denison residence is low, it is half of the Sphiwe Langa residence. Such a significant difference might be due to the time the study was conducted for the Denison residence which was during the examination period.

COVID-19 waste (masks) were found in the waste collection and they were not wrapped, which placed the health of the people handling the waste at risk, although PPEs were worn. At the time this study was complete the South African President had announced that wearing face masks is no longer compulsory. Thus, the university installing a separate COVID-19 bin for the face mask might be unnecessary. However, COVID-19 is still among us, thus integrating interventions such as disinfecting bins is still necessary.

Referring to Figure 5.7 it was found that female students produced more waste than male students, however, these findings have no significance to the study since waste generation is considered for the whole residence. The interesting observation was that both male and female students were keen to separate their waste.

5.3.4 Conceptual integrated waste management plan

UKZN leaders need to have a mental shift and take environmental sustainability seriously, not only will it reflect well on the image of the university but, it will allow for collaborations and attract more sponsorships. The leaders need to be the ones to initiate projects that drive UKZN towards sustainability, for example, the "Khusela Ikamva" which means “secure the future” sustainable campus project that UCT has initiated, which commits to making UCT sustainable by 2030.

Figure 5.12 below is the summary of the integrated solid waste management plan that is proposed to the University of KwaZulu-Natal, it incorporates solid waste generated from the residences and campus buildings.

For the University of KwaZulu-Natal to be sustainable it needs to sign the Talloires Declaration (TD), U7+ Alliance of World Universities and align with sustainable development goals (SDGs), focusing on becoming a “green university” through solid waste management by application of sustainable waste management strategies instead of sending waste to the landfill site.

The university must establish its culture as a sustainable university by creating awareness and sharing with the students and staff that it is a "green university" and that it encourages the 3Rs (reduce, re-use and recycling). This can be done during the orientation week for the first-year students, every residence has an induction day and such information can be shared because the student's participation is vital for the success of the IWMP.

Also, UKZN needs to have waste separation bins on campus to foster waste separation at the source. Since residences generate food (organic) and solid waste, it is recommended that every kitchen to fitted with two bins for ease of waste separation. The cleaning staff then removes the separated waste from the residential buildings to the colour-coordinated bins at the designated waste collection points.

From the collection point, the UKZN waste management collects the organic waste and send it to the composting area and the solid waste to the resource recovery centre where it will be characterized into various waste streams, sending the recyclable to the buy-back facility for revenue and the non-recyclables to the landfill site. The compost can be used by the university, especially the Agriculture Campus and it can be sold to the nearby farmers. Also, the university will have records of the amount of solid waste generated and recovered and the revenue that was generated.

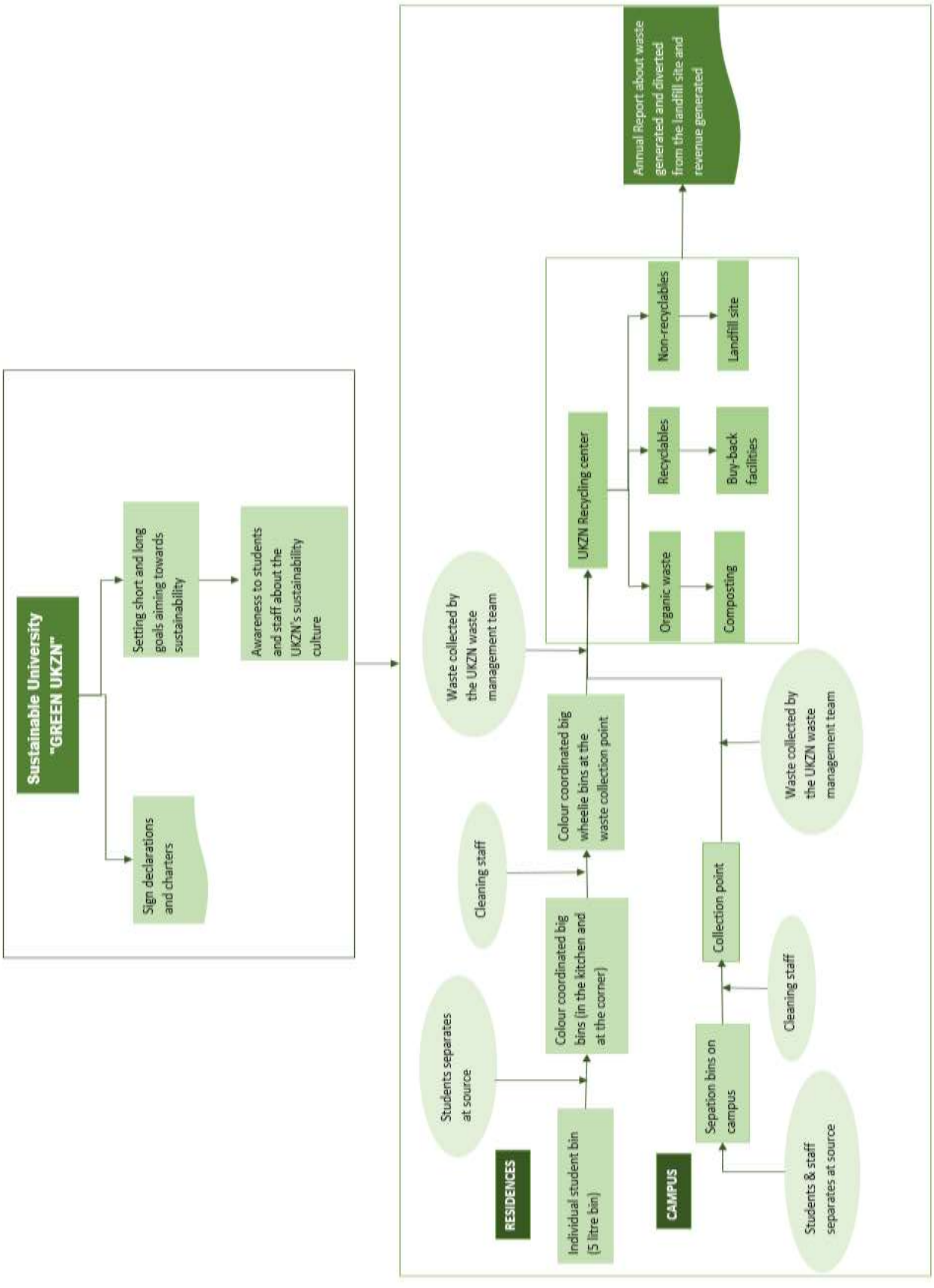


Figure 5.12 Summary of the UKZN conceptual Integrated Waste Management Plan.

6. CHAPTER SIX: CONCLUSSION AND RECOMMENDATION

This project aimed to develop a solid waste management plan that integrated the green strategies to ensure that the University of KwaZulu-Natal is sustainable. This chapter comprises of the review of the fulfilment of research objectives as well as the conclusion and recommendations for the future research.

6.1 Fulfillment of Research Objectives

The objectives of this research were achieved as following.

Objectives	How they were fulfilled
Evaluate the current solid waste management strategies implemented.	This objective was achieved through observations and interviewing the SHE manager.
Determine the amount of solid waste produced and recycled by PMB campus residences	This objective was achieved through conducting the waste characterization experiment.
Propose a solid waste management plan for the UKZN PMB campus.	Chapter 5, Section 5.3 details the conceptual integrated waste management plan that is being proposed to the university.
Develop a waste management awareness program among students.	This objective was not met, however, students' willingness to participate was determined through survey and their participation in the experiment.

6.2 Conclusion

The main objective of this research was to investigate the sustainability of the current waste management strategy at the UKZN-PMB campus and residence and quantify the amount of waste produced. Denison residence was used as a case study. Findings show that Denison students generate approximately 7 tons of waste per month, and its sent to the New England Road landfill site, which is not an engineered landfill. It constantly releases toxic fumes into

the atmosphere, endangering the lives of the community near the site. Thus the way UKZN handles its waste is not sustainable.

As mentioned in Chapter 1, the essence of UKZN is to inspire greatness through excellence, transformation, innovation/entrepreneurship and services culture, with enabler four speaking into the sustainable future of the university. Therefore, the UKZN needs to create a clear and sound integrated waste management plan (IWMP) detailing how enabler 4 (Sustainable future) will be achieved regarding waste management through setting short and long terms goals aiming toward zero waste. If the goals that have been set are achieved, they will positively impact the National Waste Management Strategy and the Sustainable Goals Development.

The university leaders must realize that they are drivers in ensuring that UKZN is sustainable. Therefore, by embracing change, they will attract funding and collaboration from government and private organizations. Finally, students' participation is crucial, so environmental awareness must be made by orienting students.

In conclusion, the University of KwaZulu-Natal has specialists in Environmental Engineering and Science, which needs to be reflected in the framework of the university. It should lead by example when it comes to solving environmental issues. This includes transparency by creating a sustainability tab on the UKZN web page that will have information regarding sustainability projects that the university might be working on and all the necessary documents, such as the IWMP.

6.3 Recommendations

Research on waste generation at UKZN Howard Collage and now PMB Campus has been conducted intensively under the Green UKZN Initiative, where waste has been quantified and characterized. The data collected on both these campuses can be used as the true reflection of municipal solid waste generation on the other three campuses (Medical School, Westville Campus, and Edgewood Campus). Therefore, it is recommended that the university implements the findings from this research, one being transparent about the plans and initiatives contributing to its sustainability. It also recommended that the university installs an anaerobic digester to handle the organic waste produced or establish a composting site. A survey has shown that students are willing to participate, so induction can be facilitated to inform them about waste management and the programmes/clubs initiatives within the university.

This study focused on quantifying solid waste; therefore, the quality of the organic waste was not considered. Future studies need to focus on the quality of the organic matter to determine

the amount of biogas produced during the anaerobic process and the quality of the fertilizer from composting.

REFERENCES

Abu Hajar, HA, Tweissi, A, Abu Hajar, YA, Al-Weshah, R, Shatanawi, KM, Imam, R, Murad, YZ and Abu Hajer, MA. 2020. Assessment of the municipal solid waste management sector development in Jordan towards green growth by sustainability window analysis. *Journal of Cleaner Production* 258 120539.

Adeniran, AE, Nubi, AT and Adelopo, AO. 2017. Solid waste generation and characterization in the University of Lagos for a sustainable waste management. *Waste Management* 67 3-10.

Armijo de Vega, C, Ojeda Benítez, S and Ramírez Barreto, ME. 2008. Solid waste characterization and recycling potential for a university campus. *Waste Management* 28 S21-S26.

Awasthi, SK, Sarsaiya, S, Awasthi, MK, Liu, T, Zhao, J, Kumar, S and Zhang, Z. 2020. Changes in global trends in food waste composting: Research challenges and opportunities. *Bioresource Technology* 299 122555.

Ayeleru, OO, Okonta, FN and Ntuli, F. 2018. Municipal solid waste generation and characterization in the City of Johannesburg: A pathway for the implementation of zero waste. *Waste Management* 79 87-97.

Bahçelioğlu, E, Buğdaycı, ES, Doğan, NB, Şimşek, N, Kaya, SÖ and Alp, E. 2020. Integrated solid waste management strategy of a large campus: A comprehensive study on METU campus, Turkey. *Journal of Cleaner Production* 265 121715.

Bui, T-D, Tseng, J-W, Tseng, M-L and Lim, MK. 2022. Opportunities and challenges for solid waste reuse and recycling in emerging economies: A hybrid analysis. *Resources, Conservation and Recycling* 177 105968.

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

Das, AK, Islam, MN, Billah, MM and Sarker, A. 2021a. COVID-19 and municipal solid waste (MSW) management: a review. *Environmental Science and Pollution Research* 28 (23): 28993-29008.

Das, AK, Islam, MN, Billah, MM and Sarker, A. 2021b. COVID-19 pandemic and healthcare solid waste management strategy - A mini-review. *Sci Total Environ* 778 146220.

DEA. 2012. Waste Management [Internet]. Available from: www.environmental.gov.za. [Accessed: 21/08/2020].

Dehkordi, SMMN, Jahromi, ART, Ferdowsi, A, Shumal, M and Dehnavi, A. 2020. Investigation of biogas production potential from mechanical separated municipal solid waste as an approach for developing countries (case study: Isfahan-Iran). *Renewable and Sustainable Energy Reviews* 119 109586.

Demirbas, A. 2011. Waste management, waste resource facilities and waste conversion processes. *Energy Conversion and Management* 52 (2): 1280-1287.

Evode, N, Qamar, SA, Bilal, M, Barceló, D and Iqbal, HMN. 2021. Plastic waste and its management strategies for environmental sustainability. *Case Studies in Chemical and Environmental Engineering* 4 100142.

Fissi, S, Romolini, A, Gori, E and Contri, M. 2021. The path toward a sustainable green university: The case of the University of Florence. *Journal of Cleaner Production* 279 123655.

Gallardo, A, Edo-Alcón, N, Carlos, M and Renau, M. 2016. The determination of waste generation and composition as an essential tool to improve the waste management plan of a university. *Waste Management* 53 3-11.

Gardiner, B. 2020. Pollution made COVID-19 worse. Now, lockdowns are clearing the air.

National Geographic. . [Internet]. Available from: https://www.nationalgeographic.com/science/2020/04/pollution. [Accessed: 22/08/2020].
Jiang, J, Li, L, Cui, M, Zhang, F, Liu, Y, Liu, Y, Long, J and Guo, Y. 2018. Anaerobic digestion of kitchen waste: The effects of source, concentration, and temperature. *Biochemical Engineering Journal* 135 91-97.
Jibril, JDa, Sipan, IB, Sapri, M, Shika, SA, Isa, M and Abdullah, S. 2012. 3R s Critical Success Factor in Solid Waste Management System for Higher Educational Institutions. *Procedia - Social and Behavioral Sciences* 65 626-631.
Kulkarni, BN and Anantharama, V. 2020. Repercussions of COVID-19 pandemic on municipal solid waste management: Challenges and opportunities. *Science of The Total Environment* 743 140693.
Langa, S. 2019. INTEGRATED ZERO WASTE MANAGEMENT: GREEN UKZN. 90.
Lozano, R, Lukman, R, Lozano, FJ, Huisingh, D and Lambrechts, W. 2013. Declarations for sustainability in higher education: becoming better leaders, through addressing the university system. *Journal of Cleaner Production* 48 10-19.
Magubane, T. 2021. KZN Landfill sites in a sorry state report. [Internet]. Available from: https://www.iol.co.za/mercury/news/news/kzn-landfill-sites-in-a-state-report-48e01260-a468-4fce-ab7f-38b4755235. [Accessed: 14/02/2021].
Matete, N and Trois, C. 2008. Towards Zero Waste in emerging countries – A South African experience. *Waste Management* 28 (8): 1480-1492.
Mbuligwe, SE. 2002. Institutional solid waste management practices in developing countries: a case study of three academic institutions in Tanzania. *Resources, Conservation and Recycling* 35 (3): 131-146.
Moqbel, S. 2018. Solid Waste Management in Educational Institutions: The Case of The University of Jordan. *Environmental Research, Engineering and Management* 74
NEMA. 2014. National Environmental Management Act. [Internet]. Available from: http://cer.org>2014/02PDFWEBresultsNATIONENVIRONMENTALACT107OF1998. [Accessed: 23/08/2020].
NWMS. 2020. National Waste Management Strategy. [Internet]. Available from: [Accessed:
Okeniyi, JO and Anwan, EU. 2012. Solid wastes generation in Covenant University, Ota, Nigeria: characterisation and implication for sustainable waste management. *Environ. Sci* 3(2) 419-425.
Ragazzi, M, Maniscalco, M, Torretta, V, Ferronato, N and Rada, EC. 2017. Anaerobic digestion as sustainable source of energy: A dynamic approach for improving the recovery of organic waste. *Energy Procedia* 119 602-614.
Ramos, TB, Caeiro, S, van Hoof, B, Lozano, R, Huisingh, D and Ceulemans, K. 2015. Experiences from the implementation of sustainable development in higher education institutions: Environmental Management for Sustainable Universities. *Journal of Cleaner Production* 106 3-10.
RU. 2020. Waste Sustainability. [Internet]. Available from: https://www.ru.ac.za/facilitiesmanagement/sustainability/waste/. [Accessed: 28/08/2020].
Sharma, HB, Vanapalli, KR, Cheela, VRS, Ranjan, VP, Jaglan, AK, Dubey, B, Goel, S and Bhattacharya, J. 2020. Challenges, opportunities, and innovations for effective solid waste management during and post COVID-19 pandemic. *Resources, Conservation and Recycling* 162 105052.
Shriram, N. 2018. Sustainable Development for Green UKZN: Waste Management. 77.
Silpa, K, Lisa, Y, and, B-TP and Frank, VW. 2018. What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050. [Internet]. Available from:

http://olc.worldbank.org>filePDFWebresultsWhatawaste2.0-OpenLearningCampus-WorldBankGroup [Accessed: 14/08/2020].
Srivastava, RK, Shetti, NP, Reddy, KR and Aminabhavi, TM. 2020. Sustainable energy from waste organic matters via efficient microbial processes. *Science of The Total Environment* 722 137927.
StatsSA. 2011. Only 10% of Waste Recycled in South Africa. [Internet]. Available from: www.statssa.gov.za/?p=11527. [Accessed: 20/08/2020].
Surendra, K, Takara, D, Hashimoto, AG and Khanal, SK. 2014. Biogas as a sustainable energy source for developing countries: Opportunities and challenges. *Renewable and Sustainable Energy Reviews* 31 846-859.
Taghizadeh, S, Ghassemzadeh, H, Vahed, M and Fellegari, R. 2012. Solid waste characterization and management within university campuses case study: university of Tabriz. *Elixir Pollution* 43 6650-6654.
UCT. 2011. Sustainable Campus Charter [Internet]. Available from: www.egs.uct.ac.za. [Accessed: 20/08/2020].
UCT. 2021. UCT Environmental Sustainability Strategy. [Internet]. Available from: https://www.uct.ac.za/sites/default/files/image_tool/images/328/explore/sustainability/UCT_Environmental_Sustainability_Strategy_2021.pdf. [Accessed: 20/03/].
Ugwu, CO, Ozoegwu, CG and Ozor, PA. 2020. Solid waste quantification and characterization in university of Nigeria, Nsukka campus, and recommendations for sustainable management. *Heliyon* 6 (6): e04255.
UKZN. 2020. University of KwaZulu Natal Webpage. [Internet]. Available from: www.ukzn.ac.za. [Accessed: 08/04/2020].
UN. 2022a. THE 17 GOALS| Sustainable Development Goals. [Internet]. Available from: sdgs.un.org/goals. [Accessed: 11/04/2022].
UN. 2022b. MAKE THE SDGS A REALITY. [Internet]. Available from: https://sdgs.un.org/. [Accessed: 15/04/].
vallabh, J. 2020a. Integrated Waste Management for Student Residences During a Global Pandemic - As Part of the Green UKZN Initiative. 124.
van Doremalen, N, Bushmaker, T, Morris, DH, Holbrook, MG, Gamble, A, Williamson, BN, Tamin, A, Harcourt, JL, Thornburg, NJ, Gerber, SI, Lloyd-Smith, JO, de Wit, E and Munster, VJ. 2020. Aerosol and Surface Stability of SARS-CoV-2 as Compared with SARS-CoV-1. *N Engl J Med* 382 (16): 1564-1567.
WHO. 2020. Coronavirus disease (COVID-19) pandemic. [Internet]. Available from: https://www.who.int/emergencies/diseases/novel-coronavirus-2019. [Accessed: 15/09/].
Worldometer. 2020. Countries where COVID-19 has spread. [Internet]. Available from: http://www.worldometer.info/coronavirus/countries-where-coronavirus-has-spread/. [Accessed: 24/08/2020].
Zaman, AU. 2015. A comprehensive review of the development of zero waste management: lessons learned and guidelines. *Journal of Cleaner Production* 91 12-25.
Zand, AD and Heir, AV. 2020. Emerging challenges in urban waste management in Tehran, Iran during the COVID-19 pandemic. *Resources, Conservation and Recycling* 162 105051.
ZWIA. 2004. Zero Waste Definition Adopted by Zero Waste Planning Group. [Internet]. Available from: http://www.zwia.org/main/index.php?option.com_content&view=article&id=49&Itemid=7 [Accessed: 19/08/2020].

APPENDICES

APPENDIX A – Sample size calculations

Cochran's Formula

Variables	value
P	50%
E	0.05
Z	1.96

$$n = \frac{P(1-P)Z^2}{E^2}$$

$$= \frac{0.5(1-0.5)(1.96)^2}{(0.05)^2}$$

$$= 384.16$$

$$s = \frac{n}{1 + \frac{(n-1)}{N}}$$

$$S = \frac{384.16}{1 + \left(\frac{384.16 - 1}{312}\right)}$$

$$= 172{,}424$$

$\approx$ 172 respondents

Slovin's Formula

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

$$= \frac{312}{1 + (312)(0.05^2)}$$

$$= 175{,}28$$

$$\approx 175 \text{ respondents}$$

$$\text{Average} = \frac{175 + 172}{2} = 173{,}5 \approx 174 \text{ respondents}$$

SURVEY QUESTIONS

- Which year of study are you currently doing?
- What is your gender?
- What does the 3R's stand for?
- Is the University of KwaZulu-Natal PMB Campus raising enough awareness about the importance of reducing, re-using, and recycling waste?
- How often do you purchase plastic shopping bag when going to the shops?
- How often do you Reuse the plastic shopping bag?
- How often do you discard food?
- Do you think that having a compulsory waste management module will spread enough awareness?
- Do you consider littering a nuisance?
- Do you understand the different purpose of the colour coordinated bins?
- Does the UKZN have enough colour coordinated bins around the campus and residences?
- Are you willing to separate waste at point of generation (discard it in different bins)?
- Are you aware that waste can be a transmission vehicle for COVID-19?
- How do you discard your facemask (cloth and disposal facemasks)?

APPENDIX B – Separation at source experiment

APPENDIX C – Raw data collected

Table C.1: Raw data

Collection dates 8 June to 17 June			
Collection Days	**Buildings**	**Waste streams**	
		Organic (kg)	**Solid waste (kg)**
Day 1 (Thursday)	Block 1	5	1
	Block 2	3	1
	Block 3 (men)	11	4
	Men's Tower	10	3,9
	Women's Tower	6	2,5
	Total	**35**	**12,4**
		Organic	Solid waste
Day 2 (Friday)	Block 1	11	2
	Block 2	6	2
	Block 3 (men)	5	2,5
	Men's Tower	2	1
	Women's Tower	6	3
	Total	**30**	**10,5**
		Organic	**Solid waste**
Day 3 (Sartuday)	Block 1	11,5	2
	Block 2	8	1,5
	Block 3 (men)	10,5	3
	Men's Tower	7,5	3
	Women's Tower	4	3,5
	Total	**41,5**	**13**
		Organic	**Solid waste**
Day 4 (Sunday)	Block 1	16,5	1
	Block 2	14	4,5
	Block 3 (men)	13,5	1
	Men's Tower	11,5	2
	Women's Tower	12,5	1,5
	Total	**68**	**10**
		Organic	**Solid waste**
Day 5 (Monday)	Block 1	7	4,5
	Block 2	18,5	1
	Block 3 (men)	11,5	0,5

	Men's Tower	1,5	2
	Women's Tower	5	1,5
	Total	**43,5**	**9,5**
		Organic	**Solid waste**
Day 6 (Tuesday)	Block 1	7,5	2
	Block 2	8	4
	Block 3 (men)	10	1,2
	Men's Tower	7	2
	Women's Tower	3,5	1
	Total	**36**	**10,2**
		Organic	**Solid waste**
Day 7 (Wednesday)	Block 1	8	3
	Block 2	10	2,5
	Block 3 (men)	11	4
	Men's Tower	6,5	1,5
	Women's Tower	5,5	2
	Total	**41**	**13**
		Organic	**Solid waste**
Day 8 (Thursday)	Block 1	7	2,5
	Block 2	7,5	1,5
	Block 3 (men)	11	4
	Men's Tower	6	2
	Women's Tower	5,5	2,5
	Total	**37**	**12,5**
Day 9 (Friday)	Block 1	7,5	3
	Block 2	9	2
	Block 3 (men)	10	3,5
	Men's Tower	8	1,5
	Women's Tower	5	1
	Total	**39,5**	**11**

Table C.2 Raw data based on gender

Female Students (mass kg)	Male students (mass kg)
10	28,9
21	10,5
23	24
36	28
31	15,5
21,5	20,2
23,5	23
18,5	23
21,5	23

Table C.3 Solid waste stream data

CATEGORY	Mass(kg)	%Percentage
Paper & Cardboard	41	40%
Dense plastic	9,1	9%
Soft plastic	5,5	5%
Glass	9	9%
Polyesterine	4	4%
Metals	31	30%
Other waste	2,5	2%
TOTAL	**102,1**	**100%**