University of Venda

INSTITUTIONAL SOLID WASTE MANAGEMENT, ITS CHARACTERISATION AND POTENTIAL FOR RECYCLING: A CASE STUDY OF UNIVERSITY OF VENDA, SOUTH AFRICA

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DEDICATION

To

The Alpha and Omega, the faithful Father for starting and completing His good work in me through this degree.

To my parents, Mr. and Mrs. Funmilayo. R. Owojori for their immense love and inspiration.

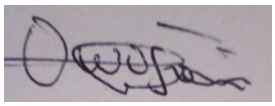
To my siblings for their support.

To my beloved family members.

To my supervisors for making it possible that this project sees the light of the day.

DECLARATION

I, **Oluwatobi Mary Owojori**, student number 18018874 hereby declare the originality of this dissertation entitled “Institutional Solid Waste Management, its Characterisation and Potential for Recycling” as my own except where sources are otherwise cited and acknowledged in the references. This work has not in any way in whole or part previously been submitted for a degree at any University.



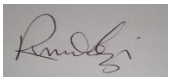
Signature Date 03/08/2020

Oluwatobi Owojori

We, the supervisors, hereby attest that the above declaration is true.

Signature Date 04/08/2020

Supervisor: Dr. J.N. Edokpayi



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ABSTRACT

The generation of waste remains a fundamental aspect of human living and the mismanagement of it manifests as a great plaque in the composite environment. The management of solid waste is highly tedious because it involves inter-disciplinary measures coupled with lots of skills and expertise. The UN 2030 Agenda for Sustainable Development in 2015 flagged the all-inclusive responsibility of world leaders to team up against difficulties that must be collectively addressed if mankind is to get by on this planet. South Africa is focused on the full execution of the UN sustainable development goal (SDG) 2030 which is in harmony with South Africa's national development plan (NDP) with critical focus on sustainable waste management practices. There are challenges in the South African waste management sector, prompting both missed financial chances and superfluous negative environmental effects. This study addresses the problem of solid waste management in a South African tertiary institution with the aim of proposing a sustainable waste management strategy for the University. Through field survey, stakeholders' interview and personal field assessment, the solid waste profile of the institution was established and characterized. The waste generated across selected activity areas was collected from the designated waste bins and hand sorted into categories using the ASTM D5231-92 standard method (ASTM, 2008). The results showed that students generate waste in the halls of residences at an average of 1.7 kg /capita/day. The results also revealed that the average percentage of all recyclables and compostable in the institution's solid waste is 69% and 26%, respectively. A sum of R7,360,847.00 was estimated to be realizable per annum if all recoverable waste from the selected activity areas are harnessed. A solid waste management strategy has been proposed which can be applied to this institution as well as similar institutions in the developing countries for a sustainable environment.

Keywords: Characterisation, recycling, solid waste, tertiary institution, waste-recovery.

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LIST OF ABBREVIATIONS AND ACRONYMS

ASTM	America Society for Testing and Materials
CUC	Central University College
GCI	Green Campus Initiative
HEIs	Higher Educational Institutions
IHE	Institutions of Higher Learning
KAP	Knowledge Attitude and Perception
MSW	Municipal Solid Waste
NDP	National Development Plan
PAYT	Pay as You Throw
PC	Percentage Category
SDGs	Sustainable Development goals
SIS	Step Wise Incentive
SPSS	Statistical Package for Social Sciences
SW	Solid Waste
SWM	Solid Waste Management
SWOT	Strength Weakness Opportunity and Threat
UGO	University Greening Organization
UI	University of Idaho
UIGC	Univen Innovative Growth Company
UNEP	United Nations Environmental Protection Agency
UNIVEN	University of Venda
WG	Waste Generation

CHAPTER ONE

INTRODUCTION

1.1 Background on Waste Management in Tertiary Institutions

Globally, there is rapid recognition concerning the management of waste, the core environmental priority of many colleges and institutions is targeted on the reduction of their environmental impacts through the reduction of waste produced. Educational institutions are taking responsibilities to reduce their waste by diverting the waste to best use (Zhang, 2011).

Waste is an eventual result of human's day-to-day living, which is imminent if mankind engages himself in all forms of activities for existence such as production of goods, packaging and supply, building and mining works (Abera, 2017). Solid waste based on their physical attributes can be subdivided into organic or inorganic waste. Examples of organic wastes are food, garden, paper, textile and rubber waste, on the other hand, inorganic wastes include plastics, metals and glass wastes (Figure 1.1).

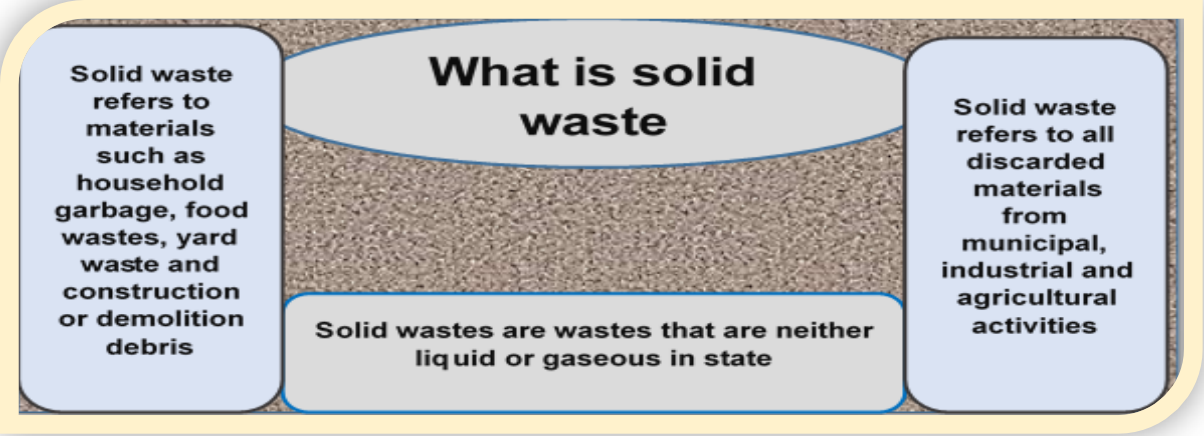

Figure 1.1: Pictorial presentation of solid waste definition (source: Authors field work)

Approximately 108 million tons of waste is generated yearly in South Africa and a great percentage of this amount ends up in the landfill (Dada and Mbowha, 2016). The element and characteristics of these discarded waste is a function of the location, climate and volume of waste generated. In addition, socio-economic characteristics, lifestyle and behavioral characteristics are determinant of the characteristics and amount of waste produced (Burnley, 2007). Khan et.al. (2016) emphasized that the amounts and characteristics of municipal solid wastes vary from nation to nation and even among same locality and this disparity is influenced by social and economic framework, earnings, expenditure and lifestyle of the populace. Revenue and household size are largely mentioned as factors influencing waste generation. Furthermore, waste generation is greatly influenced by elements like size of population, level of education, style of living, geographical attributes, laws, regulations and policies (Kesser et al., 2012). Waste in Africa is commonly discarded without thinking of the possible environmental and human health impacts (Ekere and Mugisha, 2009).

Tertiary institutions of learning generate enormous amount of wastes everyday which give rise to littering, degrading aesthetics of the campus and pollution. Continuous rise in the populations and stress on amenities within universities have resulted in waste generation in all forms which further impact negatively on the environment (Paper and Castrej, 2015). Solid waste in tertiary institutions presents a problem of management which if properly managed could serve as a potential asset. To comprehend the two likelihoods, there is a need to clearly define refuse against waste.

A common constitutional design was developed in Europe. The focus of the constitutional design is that by 2020, waste in European institutions will be harnessed as a resource, a drastic decrease is expected in waste generated per capita in all institutions. Public and private institutions in the union are also expected to make economically enticing and alluring the alternatives of reuse and recycle of waste products (Bailey et al., 2015).

It is important to consider waste management in tertiary institutions because they are synonymous to mini-cities and can design their own effective waste control system. Therefore, when waste management schemes are available in institutions, there can be effective incorporation of recycling and resource recovery measures thereby reducing the impacts on landfill sites (Mbuligwe, 2002).

Managing solid waste is one of the very difficult concern confronting this rapidly-growing world and a major concern in the University of Venda. To achieve sustainability, in respect to the United Nations (UN) sustainable development goal 11, which is to make cities and human settlements inclusive, safe, resilient and sustainable, there is the need to recycle and reuse materials and products to lower the amount of waste produced. The most preferred option for solid waste management is source reduction followed by re-use of whole products, recycling of materials, resource recovery, incineration and finally least preference for landfilling (Nagabooshnam, 2011).

Across academic institutions, huge piles of waste, a lot of which could be recovered, are daily transported to and discarded in landfills. Researchers have indicated about 55–90% of academic institutional waste streams are recyclable (Mason et al., 2004; Vega et al., 2008; Smyth et al., 2010). Towards achieving an efficient solid waste management (SWM), there is a need for a thorough understanding of the constituents of waste flow and how it was generated (Farmer et al., 1997).

Characterisation of waste components depends on their type, constituents and value and the differences in type, constituents and value of solid wastes are associated to several factors which include financial, socio-economic and cultural abilities of residents in that location under study. Furthermore, the most appropriate waste management scheme to embark on will be specified by these distinguishing factors (Coker and Achi, 2016). However, characterisation is the best process through which all forms of wastes generated are investigated and thereby determining opportunities for reducing waste, re-use and recycling (Keniry, 1995).

Decision makers conduct waste characterisation studies to understand the waste flow and makes it possible to design waste management schemes for different regions (Chang and Davila, 2008). At higher institutions, waste characterisation studies detect campus specific and provincially related potentials of waste minimization and recycling and this signifies a fundamental step towards campus sustainability (Keniry,1995; Creighton, 1998).

HEIs can be prudent in sustainable development in two unique manners. To begin with, they can shape linkages between gathering data and its dispersal in the system. This implies that they serve as a bridge between researching and execution of data. Second, they add to community development through exertion and use of the data to serve society (United Nations, 2011). Further data and knowledge on the characteristics of solid waste is crucial in designing a framework that will assess facilities, effectiveness of the system as well as management programs and plans (Kiely, 2007).

Furthermore, knowledge of the amount of waste is important in designing waste management schemes to optimally manage the wastes in the long run (Tchobanaglous, 1977). Therefore, information and data obtained from characterisation studies allow educational institutions to redefine their waste management techniques towards reducing the waste produced and increasing diversion of waste from landfill (Nagawiecki, 2009).

Gebreeyessus et al. (2018) concluded that understanding the composition of solid waste (SW) in Higher Educational Institutions (HEIs) serves as precondition to foster the subsequent sustainable waste management options and even more research. This study focuses on waste management practices at the University of Venda within the Vhembe District Municipality of Limpopo province in view of establishing the potential for recycling through the identification of the composition of waste.

1.2. Statement of the Problem

Waste management ranks topmost among the contemporary problems faced by mankind in this century. Waste management and its improper disposal pose a great environmental problem across all town and country areas (Kenobi, 2015). With regards to higher institutions of learning, not only do wastes detract the visual quality and beauty of the institution but also the health of its residents (Kenobi, 2015). Other than adding to visual contamination, it adds to numerous impeding wellbeing and environmental dangers in the public space (Khan and Ghouri, 2011). Researchers contended that litter is at the same time the most disregarded and most obvious type of environmental degradation. Littering is both a social and environmental problem (Abdul-shukor et al., 2012).

Careless litter of solid waste within the campus community has attained a disturbing rate and, on this note, one begins to wonder what is the reason behind this environmentally unacceptable practice. Is this a function of the orientation or the perception of the community? or absence of required facilities? Or is this a conscious effort to degrade the environment? could the responsible personnel's in the management of waste be struggling with the amount of waste generated?

Evidence reveals that there is a compound effect on the environment when wastes are improperly discarded (Ejaz et al., 2012). This ultimately erodes the beauty of the environment and causes diseases. Although, the grounds and cleaning section of the institution is striving to maintain sanitation, there is still a lot to be done in managing waste on campus.

The provision of waste receptacles is a good move towards curbing the menace, however, these receptacles have not adequately solved the problem of waste and most times there are litters thereby making the environment unsightly. This leads to nuisance coupled with the offensive odors emanating from such litters attracting all forms of rodents such as cockroaches, flies and various disease carrying vectors. The environmental impact is manifesting in form of aesthetic

degradation to environmental pollution and transfer of infectious disease (Al-Khatib, 2007) therefore, serving as a danger to well-being (Ziraba et al., 2016).

It has been noted that higher institutions of learning are capable of exhibiting the theory and practice of sustainable waste management by making the move to know and lower the environmental impacts of their activities. Many institutions are experiencing the littering plaque, and as such researchers are dealing with devising litter decrease methodologies and schemes (Abdul-shukor et al., 2012). For example, to combat littering, the Green Campus Initiative (GCI) at the University of Cape Town runs a waste management venture. The presentation of a two-container framework in 2012, enabled students to isolate "recyclables" from "non-recyclables" (GCI, 2012). Before this GCI presented a four-receptacle framework with canisters shading coded for paper, plastic, tin and other (GCI, 2012). Therefore, there is a need for this study in this institution as a crucial need to re-model waste management strategies and consider potential for recycling, also, to reduce waste generated and educate students on their attitude towards waste generation and management. This study will be useful to develop waste management strategies that may be replicated for this University and other similar institutions.

1.3. Motivation for the study

Waste management and recovery programs are in place in many higher institutions in developed countries over two decades ago. Developing countries are now following suit as the awareness on institutional waste management is increasing, educational institutions of developing nations are taking steps to establish various waste recovery schemes on campuses irrespective of the premises which could be voluntary or mandatory (Vega et al., 2008). Often times, it is said that South Africa is about 20 to 30 years backward to Europe and other advanced countries of the world when it comes to the issue of managing waste and its diversion into reducing, reusing, recycling and recovering (Godfrey and Oelofse, 2017).

Universities play important role in teaching and learning and are saddled with the social responsibility to teach the community on how to overcome the problems of poor solid waste management. Kaplowitz et al. (2009) emphasized that universities are made up of different types of populations hence leading to various activities requiring significant depletion of resources in a vast space. It was debated further that HEIs could be regarded as municipalities that remarkably influence the society at large. Therefore, they are obligated to solve the environmental issues caused through the waste management operations.

Reduction of solid waste (SW) is a major step to design a green and environmentally sustainable University campus (Smyth et al., 2010). Higher institutions of learning are charged with the ethical duty to foster sustainability and create environmental awareness within and outside universities (Lozano et al., 2013; Vega et al., 2008). Waste management practice is a significant step towards greener universities.

It is realized that research studies on the management of waste in developing countries are steered towards municipalities and scarcely discussed waste at universities. Only few researches were conducted on the composition of solid waste generated at universities (Smyth et al., 2010).

About the above background, there is not much studies conducted relating to the amount or compositions of waste produced in most higher institutions within the country and how a proper design pertaining waste management system can be established in those institutions. Most researches conducted have been on large and established universities, considering a rural-based institution of higher learning is peculiar in this study. The indiscriminate littering of waste around the campuses has become a serious environmental problem, causing the depreciating value of aesthetics, pollution amongst others as shown in Figure 1.2. This lack of information and knowledge of the amount and composition of wastes generated within the University of Venda is identified as a shortcoming, which therefore needs to be addressed. However, since the profile, composition and amounts of waste generated in this institution is not well known or understood,

this study represents the first step towards understanding and improving these site-specific waste management practices.

Figure: 1.2 Waste littering on campus

The characterisation of waste and its management is pertinent in universities because there exists a large gap in the knowledge of waste streams in South African educational institutions. Also, these institutions can introduce and embrace innovative solid waste management schemes that can be easily implemented and educate the students about sustainable waste management practices.

The justification for waste characterisation studies is evident for its usefulness in implementing efficient waste management and recycling. The need to characterize and understand the composition of waste stream is often viewed as the critical first step towards the development of effective and sustainable waste management techniques in University campuses (Smyth et al.,

2010; Ezeah et al., 2015). Therefore, the outcome and report of this research will be useful in designing a sustainable waste management strategy that may be reciprocated for this University and other similar institutions.

1.4. Main objective

This research seeks to investigate the institutional solid waste management at the University of Venda, determine its waste generation rate, waste composition, the potential for recycling, and propose a sustainable solid waste management system. To achieve the above goal, the following specific objectives are set:

1.4.1 Specific objectives

The specific objectives are to:

- Assess the existing solid waste management practices in the institution
- Estimate and characterize the amount of waste generated in the institution
- Evaluate the recycling potentials of the solid waste generated in the institution
- Develop a sustainable solid waste management strategy for the institution

1.5 Research Questions

- What are the existing solid waste management practices and the associated challenges?
- What is the amount and characteristics of waste generated in the institution?
- Are there recycling potentials from the compositions of waste generated in the institution?
- What sustainable ways can the institutional solid waste be effectively managed?

1.6. Organization of dissertation

This dissertation is structured into seven parts in which each segment provides a distinct and separate data. Chapter one concisely examines the background to solid waste management in higher educational institutions with the aim of establishing their potential for recycling. It also

presents the statement of problem and the specific objectives of the study. Chapter two discusses extensively the literature review concerning the current body of knowledge relating to the general overview of solid waste management and its characteristics for institutional recycling. Chapter three describes the procedural steps, tools, equipment, employed to characterize the institutional solid waste, determine their generation rate and overall research methodology. Chapter four assesses the perception, knowledge and attitudes of students towards solid waste management in the institution. Chapter 5 presents and discusses the results of the waste characterisation at the selected activity areas and the respective percentages of recoverable waste. Chapter six analyses the current waste management practices in the institution as well as its attendant implications and proposed a sustainable waste management design for the institution. Chapter seven presents a brief review of the results obtained, summary on the results of the specific objectives, and gives concluding and recommendation remarks.

1.7. Output from the study

The contribution of this study to the body of knowledge is being drafted into three distinct articles to be published in accredited journals. The three articles which are listed below are currently drafted at the manuscript stage.

- Perception, knowledge and attitudes of students in tertiary institution towards littering and Solid Waste Management. (Journal of Environment and Behavior).
- Solid waste generation, measurement and characterisation in the University of Venda (Journal of Material Cycles and Waste Management).
- Operative solid waste management practices in the Institution; way forward to sustainable practices. (International Journal of Sustainability in Higher Education).

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CHAPTER TWO
LITERATURE REVIEW

The institutional management of solid waste as well as its potential for recycling demands a comprehensive knowledge of waste and its characteristics. This chapter presents the customary level of knowledge regarding waste and its definitions, summary of literature reviewed on institutional solid waste management. This section conceptualizes and reviews the theories and perceptions on solid waste management broadly.

2.1 Waste and its Definition

The South Africa National Environmental Management: Waste Amendment Act, 2014 (Act No 26 of 2014) defined waste as:

- "any substance, material or object, that is unwanted, rejected, abandoned, discarded or disposed of, by the holder of the substance, material or object, whether such substance, material or object can be re-used, recycled or recovered and includes all wastes as defined in Schedule 3 to this Act or
- any substance, material or object that is not included in Schedule 3 that may be defined as a waste by the Minister by notice in the Gazette,

but any waste or portion of waste, referred to in paragraph (a) and (b) ceases to be a waste -

- once an application for its re-use, recycling or recovery has been approved or, after such approval, once it is, or has been re-used, recycled or recovered;
- where approval is not required, once a waste is or has been re-used, recycled or recovered;
- where the Minister has, in terms of section 74, exempted any waste or a portion of waste generated by a process from the definition of waste; or
- where the Minister has, in the prescribed manner, excluded any waste stream or a portion of a waste stream from the definition of waste".

Thus, the concept of waste is construed in two basic respects. First, a material is termed waste where the user has lost its prime use, therefore, one man's waste becomes another man's raw material for production. Secondly, waste is a function of the technological state of the art as well as its location of generation. Therefore, the concept of waste is highly dynamic.

Table 2.1 shows the type of waste and their sources.

Table 2.1: Types of waste and their Sources (Salsabili et. al., 2013)

Waste origin	**common generators**	**Examples of generated waste**
Residences	Single and Multiple family settings	Food leftovers, paper and cardboard, plastics, textiles, garden wastes, wooden and glass-waste, metals, special wastes like electronics, batteries, tyres and house-hold hazardous wastes.
Industries, Stores and recreational centers,	Small and large scale manufacturing,	Power and chemical plants packaging, food wastes, construction and demolition materials, hazardous wastes, ashes, special wastes
Marketing	Stores, hotels, restaurants, markets	Paper, cardboard, plastics, wood, food wastes, glass, special wastes, metals, hazardous wastes
Institutions	Educational centers, clinics, prisons and government centers	Same as marketing waste
Construction	Infrastructure construction Sites, renovation sites	Wood, steel, concrete, dirt, etc. and demolition road repair,
Agriculture	Farms, yards, poultries, dairies, feedlots, farms, slaughter houses	Spoiled food wastes, agricultural wastes, hazardous wastes (e.g., pesticides).

2.2 Classification of wastes

Municipal solid waste is being generated from different sources such as industrial, commercial, institutional, residential, construction and demolition and agricultural activities (Table 2.1). There is the need to categorize waste correctly to determine its correct method of disposal. With regards to the National Waste Classification and Management Regulations of South Africa, waste is

categorized into General waste or Hazardous waste according to the risk it poses (Department of Environmental Affairs and Tourism, 2017).

2.3 Waste Management Concept

Waste management is the overall process of collecting, transporting, processing, and managing waste materials. It involves all processes in handling wastes after they were generated (Vega et al., 2008). The life cycle of waste comprises of a series of steps, whereby the first step starts with the generation of waste. After the generation of waste, there is a need to manage it accordingly. The Department of Environmental Affairs and Tourism (2014) has declared that waste management should involve “measures to reduce waste” and the “avoidance of generating waste”. Waste management is a critical environmental aspect to be considered within educational institutions (Sankoh, 2012). For every institution that generates wastes, it is expected to also have an effective waste management system which is sustainable. There are variations in the practices of waste management between developed and developing countries, town and rural places, large and small organizations. Usually, the management of general residential waste in most municipal areas is assigned to the local government authorities, while the management of general commercial and industrial waste is the obligation of the generating institutions and is dependent on regulations by local, national, or international authorities (Wilson, 2007).

The per capita rate of waste generation differs from one place to another, for instance, waste generation rates in urban areas is much higher than those generated in rural areas because an average rural resident has lower level of affluence, higher rates of recycling and reuse, more composting, and a lower purchasing power. Solid waste poorly managed leads to blockage of drains which is a major cause of flooding; for instance, the flooding in Surat, India 1994, which eventually led to an epidemic of disease (Gupta, 2010) soil, and water pollution (Ferronato et al., 2017). For this study, waste management is within the scope of institutional solid waste and which

exempts liquid, gaseous and hazardous waste materials, it refers specifically to the waste which is produced by the University of Venda. Figure 2.1 shows the solid waste management process.

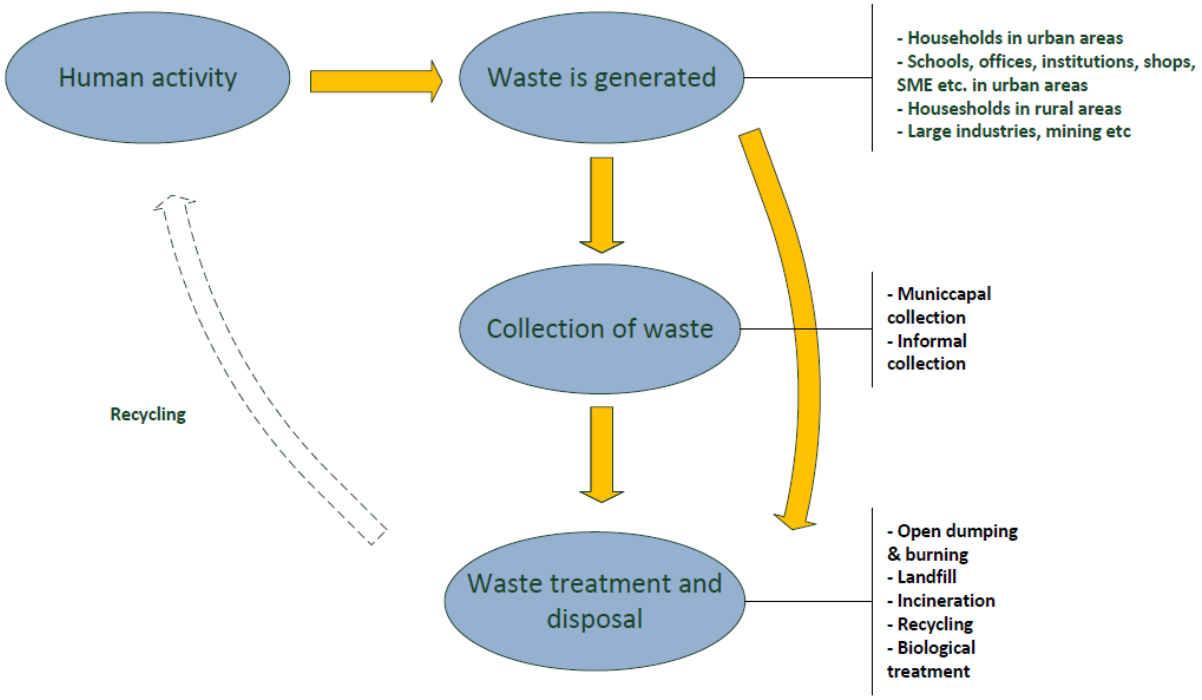

Figure 2.1: The solid waste management process (DEA, 2016).

2.4 The components of solid waste management

2.4.1 Waste generation

This comprises of all activities whereby items which have lost their value and significance are discarded or accumulated to be disposed. Municipal solid waste (MSW) generation rates are generally a function of economic development, level of modernization, attitudes, cultural beliefs and geographical climate (Gichamo and Gokcekus, 2019). Broadly, the higher the rate of modernization and industrial development, the higher the rate of waste generation. This is because the degree of income and urban development are positively correlated, therefore an

increase in income leads to a rise in standard of living, this also increases the consumption of goods and services as well as the by-product which is waste generation (Oribe et al., 2015). The amount of waste generated in urban residence is usually twice that of the rural residents (World Bank, 2012).

2.4.2 Waste storage

Waste generated at the point and time of generation is not instantly collected, therefore the storage of waste is a very important aspect of waste management. The storage of waste on site is significant because of aesthetic, public health and economic impact. Wastes are stored in containers like plastic containers, traditional dustbins, used oil barrels, spacious storage bins for institutions and commercial purposes. Apparently, these options vary largely in their size, shape and material (Ramachandra and Bachamanda, 2007).

2.4.3 Waste collection

Waste generated from various sources such as institutions, commercial industries and residences are collected for the purpose of recovery or final disposal. The collection of municipal solid waste takes several procedures as shown below:

Public Bins: Residents bring their wastes to public bins which are provided by the government and fixed at designated points within the residential community. This is then collected by the municipality, or the responsible authorities, depending on the agreed schedule. (Ramachandra and Bachamanda, 2007).

Door to Door: This requires waste collectors to directly collect waste from each individual house based on an agreed timing. This is usually associated with a service charge (El-Hamouz, 2007).

Curbside Pick-Up: Waste generated by residents are dropped directly outside their homes to be picked up by the local authorities (this is secondary to house to house collection) (World Bank, 2012).

Self-Delivered: This requires individual waste generators to transport their waste directly to disposal sites or transfer stations (UN-Habitat, 2010).

Contracted Services: Waste agency firms are contracted and the mode of collection and associated charges are established with the users. Most times, municipalities authorize private firms and may set up collection points to motivate efficiency in collection (Ramachandra and Bachamanda, 2007).

2.4.4 Transfer and transport

Waste generated needs to be transported from the smaller trucks to bigger ones at the transfer stations, this makes transferring and transporting a key element of managing waste. It requires the transporting of waste periodically and most times over long distances to the disposal sites. There are several factors that influence the structure of a transfer station which include the form of operation, magnitude, facilities and environmental specifications (UN-Habitat, 2010).

2.4.5 Processing of wastes

Processing involves the alteration of the physico-chemical properties of wastes for the purpose of recovery, recycling and energy. The major processing techniques are manual separation of waste components, compaction, thermal volume reduction, composting and incineration (World Bank, 2012).

2.4.6 Recovery and recycling

This involves the several methods, instruments and facilities engaged in recovering usable materials and energy as well as the efficiency of waste disposal systems. When mixed solid waste at transfer sites or processing plants are separated to extract valuable resources, this act is referred to as recovery. Economics is an important factor to consider in selecting any recovery process, which includes the costs of separating versus the cost of recovered material. Some recovered items such as glass, paper and plastics because of their economic value can further be recycled (Oldenziel and Heike, 2013).

2.4.7 Waste disposal

This is the final stage of waste management where activities are targeted at the methodical disposal of waste items in such destinations as landfill sites or waste-to-energy plants. According to Pichtel (2005), unrecyclable or untreatable waste needs to be disposed of in the most environmentally harmless way and in adherence to all relevant regulations. Due to financial barriers and lack of technical knowledge most institutions, provinces and states in African countries have resorted to open dumping as opposed to sanitary land filling (World Bank, 2012).

2.5 Waste management legislation in South Africa

Prior to 1979, there was no priority for waste management both at the national and provincial level in South Africa and the major step in controlling waste was through land fill disposal and issues regarding to waste reduction were not given recognition (Godfrey and Oelofse, 2017). This continued up to 1997 when recognition was given to the need for proper management of waste as a prime concern (Godfrey and Oelofse, 2017). The first legal definition of waste was provided by the Environmental-Conservation-Act (Act 73 of 1989) which stipulates the specifications for

the managing of waste focusing on areas of permission, control and management of waste disposal sites. Ferrari et al. (2016) pin-pointed from his study among countries in Africa that, the prime weakness in the conducts of managing waste are poorly legislative design, unavailable institutional structures and the lack of effective and well-coordinated initiatives of the international stakeholders.

Currently, all affairs of waste management are governed by the NEMWA 2008 (Act No 59 of 2008). Succeeding the establishment of the Waste Act, the National-Waste-Management-Strategy (NWMS) was established by the then Minister of Environmental Affairs in accordance to Section 6(1) to achieving the objectives of the Act. In November 2011, the NWMS was then approved for administration by the committee for administrative purposes. The NEMWA 2008 (Act No 59 of 2008) is very much in line with the waste hierarchy in its approach to waste management via the promotion of sustainable production, waste prevention and reduction, reuse, recycling, treatment of waste and disposal as the last option in the waste management process (Waste Act, 2008). This encourages a comprehensive approach in tackling waste which concentrates on the prevention, minimization and responsible waste disposal.

2.6 Sustainable Waste Management in Higher Institutions

Consistent with other sectors, the issue of sustainability in Higher Educational Institutions (HEIs) has become a matter of interest globally among law makers and subject to continuous investigation among environmental bodies, sustainability groups, University representatives, student campus organizations and non-governmental organizations (NGOs) (Alshuwaikhat, 2008). With Stockholm Declaration on Sustainable Environment, came the idea of sustainable development in HEIs which signifies the first promulgation to identify the connection between mankind and his environment (United Nations Educational Scientific and Cultural Organisation (UNESCO), 2005). Over the last years, UNESCO (2005) announced 2005 to 2014 as the era of

Sustainable Development learning and it's been promoted in universities owing to their large space and the diverse exercises which goes on there. Tertiary institutions can be likened to small cities or towns (Alshuwaikhat, 2008). Therefore, concentration on higher institution of learning as a major focus for improved sustainability is increasing (Waheed et al., 2011).

Sustainable focus universities focus on adopting the framework for reducing the environmental, economic and societal concerns via activities like resource conservation and recovery (Vega et al., 2008; Jibril et al., 2012).

The fact that these universities offer different courses in several specialisations targeted at inter-disciplinary research are the best places to equip and train the students concerning the need for sustainable development. A sustainable University focuses on adopting the framework for reducing the environmental, economic and societal concerns via activities like resource conservation and recovery (Vega et al., 2008; Jibril et al., 2012). In a study at University of Southampton, Zhang, (2011) illustrated why sustainable waste management is necessary in tertiary higher institutions. The work proposed that by improving provision of services and behavioral change, improvement of infrastructure, putting into consideration the socio-economic, technical, legal, political and environmental factors sustainable waste management could be attained.

Emmanuel and Adams (2011) in their study among college campuses of Alabama and Hawaii indicated that students were concerned about pollution and conserving resources and as such willing to take part in such sustainable practices. In a study carried out amongst tertiary institutions in London, Dahle and Neumayer (2001) also stated that the key to overcome obstacles to a green campus is environmental sensitisation and awareness within the campus communities.

Espinosa et al., (2008) recommended that separation of wastes as recyclable and compostable is advantageous in aspects of waste minimisation and economic benefits as discussed in the

results of an integrated solid waste management plan at the Universidad-Autonomy-Metropolitan, Mexico in a duration of three years. Jibril et al. (2012) highlighted the use of the 3R's (Reduce, Reuse, and Recycle) as a tool to achieve integrated waste management in tertiary institutions of Tanzania. In achieving sustainability in waste management practice, the priority is given to waste reduction, followed by "reuse" and "recycling".

2.7 The Waste Hierarchy

The waste hierarchy can be described as a set of priority for the reduction of wastes through efficient utilisation of resources. Waste hierarchy is an instrument used in the appraisal of processes to preserve the environment in addition to resources and energy consumption from most preferable to least preferable actions. It is aimed at deriving the best possible benefits from materials while generating the smallest amount of waste. When the waste hierarchy is properly applied, it produces visible benefits such as energy saving, preventing the release of greenhouse gases, reduction in pollution, job creation, conservation of resources and stimulation of development of green technologies (DEA, 2012). Figure 2.2 shows the diagram of a waste hierarchy.

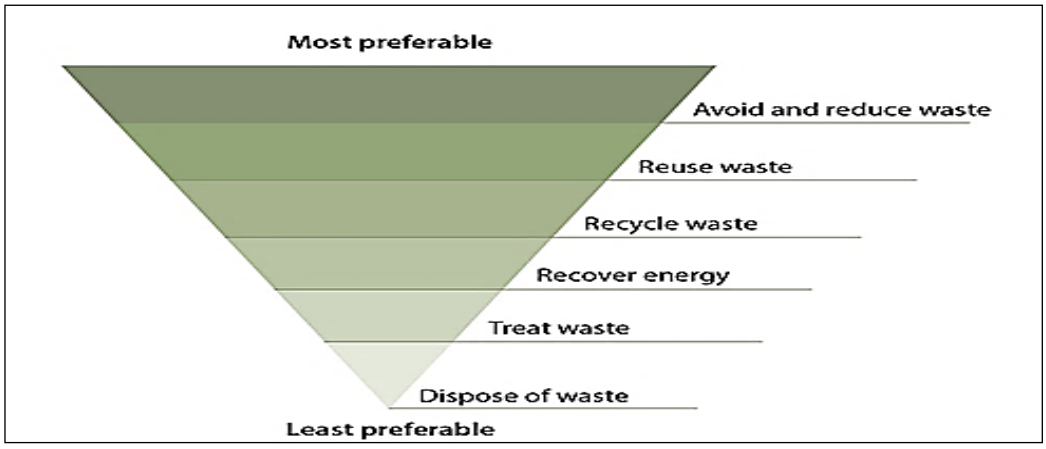

Figure 2.2: The waste management hierarchy (Source: DEA, 2012).

The three priorities of the waste hierarchy are as below:

Avoidance: this refers to all activities taken to lower the quantity of waste produced in all households, industries and institutions.

Resource recovery: this includes all activities taken to re-use, recycle, reprocess and recover energy, in consonant with the best use of the resources recovered.

Disposal: this is the directing and channeling of all possible disposal measures in a way that is environmentally acceptable

Today, the 4R's Reduce, Re-use, Recycle and Recover can be used to achieve the waste management objectives in many higher educational institutions.

2.7.1 Reduction of waste

The reduction of waste implies that all necessary measures to decrease the level of waste generated at the source right from the beginning. This is obtainable by eradicating the use of materials that are not necessary. For example, paper ranks one of the major sources of waste generated in HEIs. There has been the push to reduce paper waste across some universities in the USA. A case in point is using a double-sided printer, reusing of papers and brown envelopes as this will decrease the use of paper and its wastage. The use of electronic media is a good way of reducing the amount of waste paper generated in HEIs (Vega et al., 2008).

2.7.2 Re-use of waste materials

Re-use implies repeating the use of a product, this could be the same initial use or a different one. Referring to the study at Autonomous University of Baja California (UABC), Vega et al. (2008)

pointed out that the re-use of white paper will cut down the rate at which waste paper is generated by half.

2.7.3 Recycle of waste materials

One of the widest spread initiatives of HEIs concerning the management of waste is recycling programs and has proven to be highly productive and rewarding (Vega et al., 2008). 80% of the institutions across USA have institutionalised various waste reduction schemes. As an example, Brown University in USA started a waste management plan in 1972 up to date and currently recycles 31% of its wastes. Also, in China, the University of Shenyang recycles both their solid waste and waste water (Geng et al., 2013).

2.7.4 Recovery of waste materials

The idea of waste recovery is to reduce the amount of waste generated by using waste as an input for production to produce a more valuable product. Few studies evaluated the characteristics of solid waste in HEIs in generating alternative forms of energy (Mason et al., 2004; Vega et al., 2008).

2.8 Waste Recycling at Higher Educational Institutions

Recycling is often adopted to kick start sustainability waste management and sustainable actions in most HEIs (Tangwanichagapong, 2017). Recycling schemes are most feasible and generally non-controversial. They can potentially save money for HEIs because recycling schemes are often highly feasible and generally rewarding (UN HABITAT, 2010). Nevertheless, establishing recycling programs requires hard-work. Generally, the following conditions are essentials to achieve an effective waste management schemes at HEIs (Zhang, 2011):

- Deep knowledge of how HEIs operate
- Devoting strong display towards sustainable initiatives

- Adequate finance
- Campus cohesion
- Extensive interaction and learning
- Organised framework
- Dependable workers (Jibril et al., 2012)

The ability to communicate effectively is an important key to attain an efficient waste management system in higher institutions. There is the need for high publicity when introducing recycling schemes in higher institutions. According to past studies, there is a knowledge deficit among institutions of learning on what to recycle, where to recycle it and how (Flanagan, 2017).

2.9 Selected studies on waste recovery in some institutions of higher learning

2.9.1 Study 1: Waste recycling at the Burdock Hall, Bristol, UK.

Aim: To illustrate that waste disposed at landfill can be reduced if universities improve on their recycling facilities. To improve the rate of recycling at the Burdock Hall of the University of Bristol. Recycling bins were given to each respective room. Also, awareness programs such as posters, presentations and notes were adopted.

Results

Within the school calendar year 2002 -2003, the percentage recycling rate was increased by 30 percent in the University's hall of residences. The recycling program was a success as it brought about reduced workload for the workers and increased general aesthetics of the environment. The municipal also volunteered in collecting from the schools recycling station as it also aided their own municipal recycling target. Therefore, it was a win-win scenario for all (Zhang, 2011).

Limitations

The major limitation to this study is the lack of base line data, monitoring and assessment systems for the program.

2.9.2 Study 2: CRISP Recycling project at South-Wark

Objective: The main objective was to promote waste reduce, re-use and recycle among students' residences in London.

Project Description

From October 2004 to march 2006, a total of 21 universities consisting of 185 halls took part in the project. Questionnaires to determine the existing waste management practices and the attitudes and perception of students towards recycling waste management was distributed. (Zhang, 2011).

Results

The existing recycling facilities at the students' residences were inadequate and inefficient. Also, students underutilized the existing facilities because of lack of awareness and promotion, as well as inconsistent collection. It was also found that the managers and students lack the understanding of what recycling is. It was discovered that large quantities of items could be diverted from the landfill by reusing and recycling. Many universities are eager to take the challenge; meanwhile, additional studies are required.

Limitations

The fund for the project was financed by an external recycling fund in London, and this is a major challenge that could be faced by HEIs when embarking on such recycling schemes, considering the huge cost involved and the limited budget of most institutions. There is also the lack of assessment and monitoring of data just like the case of the University of Bristol.

2.9.3 study 3: Waste management at the Southampton University

The University has 20 halls of residence covering 5000 students. The students are responsible for taking their recyclable waste to the existing recyclable facilities. These facilities are however limited, inadequate and inconveniently located. These factors led to poor participation and low recycling rate. The environmental manager of the University, clarified that under the landfill tax rate, the University spends £60 to dispose every ton of waste generated (Zhang, 2011).

2.10 Determining factors of recycling for students

Many researches on recycling behavior have been focused on the public rather than on smaller groups or organizations like University populations (Amutenya et al., 2009; Williams and Gunton, 2007). William and Gunton's (2007) Model is used to explain college students' environmental behavior. The determinant of students recycling rate and their environmental behavior comprises perception of being capable to create a significant change; conditional barriers; attitudinal inclination; degree of awareness or sensitization; interest in the environment and parental effect and habitual behavior. Convenience in accessing recycling facility is a significant factor determining the participation in recycling.

The desire of the North American University students to recycle provided the facilities are available for them was established through an investigation on their recycling attitude by Pike et al. (2003). An efficient provision of service is fundamental to a successful recycling scheme and this comprises: reliability, convenience in collection, correct tagging and provision of bins. An essential component of recycling is having a dependable recycling agent in charge of the supplying and collection of bins as well as sourcing recyclers for separated and mixed recyclables. HEIs' must therefore work together with their contractors to give assistance and assess them, ensuring that they adhere to the recycling rules and regulations (Evangelinos et al., 2009; Waheed

et al., 2011). Admitting the wide acknowledgement of this, monitoring services provided by waste agents is still a problem for many HEIs because they lack the know-how (Zhang, 2011).

Knowledge of recyclable materials is another factor that is likely to influence recycling behavior. Many lacks the understanding of what, where, how and why to recycle. Evidence revealed that a sound knowledge of what recyclables are and where it can be recycled largely informs a person's probability to recycle (McDonald and Oates, 2003; Bailey et al., 2015). The study of a survey conducted at the North American University revealed that the institution was to an extent aware of the environmental advantage of recycling but deficient in the understanding of how recycling programs operate. Hence, it was recommended that the personnel in charge of implementing the recycling program are required to have communication strategies that goes beyond the explanation of the reasons for recycling (Zhang, 2011).

The role of education in sharpening the behavioral attitude and impacting the environmental knowledge of members has been highlighted by several studies (Duvall and Zint, 2007). Habit is found to also be a major influence on recycling, taking part in new recycling initiatives should do with the formation of new habits. An act which is done consistently with a person having no pre-thought of the act is called a habitual act. Some previous studies linked behavior to be a function of both reasoned and unreasoned influences, for example, attitudes and habits (Knussen and Yule, 2008). Children are more likely to recycle when they grow old if the habit is instilled in them by the parents in their formative years, as Timlett and Williams (2009) illustrated that the habit of recycling when formed becomes very hard to cut off. Recycling however involves two major processes, namely waste characterisation and waste-collection (Keniry, 1995; Creighton, 1998; Zhang, 2011). Waste characterisation is an act of examining the composition of waste generated in a place. Some studies at various institutions targeted at examining opportunities for waste reduction and recycling on campus signifying a crucial step in achieving sustainable waste management on campus are reviewed.

2.11 Waste Characterisation Studies in tertiary institution

Characterisation involves knowing the compositions of the waste stream which helps in developing a suitable method of disposal. Moreover, with information gathered on the composition of waste, various options on sustainable waste management can be explored for example, the amount of waste that is sent to landfill by institutions can be drastically reduced through diversion into schemes like recycling, composting and generation of energy, this ultimately leads to job creation (Vega et al., 2008).

At the University campus of Kebangsaan, a waste composition study was conducted to determine the potential for recycling of the generated waste (Tiew et al., 2010). The waste stream comprises mostly of organics and plastics which could be a useful resource if source separation is done. Therefore for a standard solid waste management system, it is required that a study of the composition of waste be considered as this is what indicates the best method for management and disposal (Jonas et al., 2014).

In the circle of higher educational sectors, the degree of complexity and scope of a campus waste characterisation study is dependent on the motivation for conducting the study and the availability of resources. For example, if the research objective is to ascertain the quantity of recyclable materials that can be found in the waste stream before searching for markets, a representative waste sample must be collected and classification categories should correspond to a full range of recyclable materials. Alternatively, provided the sole objective of the study is to create awareness and raise level of education about waste reduction, a basic audit of a high-profile campus location would be adequate (Von-Kolnitz and Kaplan, 2004).

Gebreyessus et al. (2018) conducted a solid waste characterisation study at the Kotebe Metropolitan University. Following this, majority of waste generated are in the order of food

(84.41%), organics (8.99%), paper (3.65%), plastic (1.83%) and others (1.12%.). This implies that above 90% of generated waste could be channeled as compost.

Majority of the waste were generated from the cafeteria, the photocopying center, laboratories, offices and workshop. The estimated rate of waste generation per day is 0.093 kg /cap /day. There was no significant difference in the generation of waste between seasons. The result revealed that waste characterisation study is a useful tool for academic institutions for waste reduction policies and waste management.

Thagizadeh (2012) also did a study at the University of Tabriz, Iran to determine the characteristics of waste generated in all functional areas of the campus to initiate the most suitable waste management system. Samples were collected every day, for seven days in a one-month period in 2010. The results indicated that the University generates a 2.5 metric tons of waste daily which can be recovered through reduce, recycling and composting. Organic waste that are compostable represent the most significant portion of the waste. Other waste generated are paper, plastics, which can also be channeled towards recycling. Several waste management strategies that can be useful in improving waste management and recycling behavior were also discussed (Thagizadeh, 2012).

This is consistent with another research carried out by Chee et al. (2012) in the waste characterisation study conducted at the University of Malaya. The University generates 1.5 ton of waste per day which clearly reveals a great potential for recovery of waste at the University of Malaya. The most significant portion of waste comes from organic food waste (33%), mixed papers (14%), plastic bags (10%) other plastics (10%) and this agrees with similar studies from universities in the locality. When this is also compared to the currently existing recycling market, a great amount of MSW fell in the recyclable and potentially recyclable categories.

A waste characterisation research was performed within a three-semester period of Fall 2007 to Fall 2008 by an activist group (SUNY-ESF') of the State University of New York. A waste

characterisation study was carried out on three separate days by sorting them into recyclables and non-recyclables. The study revealed that only 40% of generated waste in the campus was recycled while 24% of the waste sent to the land fill have the potential for recycling and recovery.

In Mexico, the Universidad Iberoamericana (IBERO) conducted a waste characterisation and quantification study from 2008 to 2009 for a proposal presentation towards enhancing their waste management system. It was found that the University has a per capita waste generation rate of 0.3 per-capita/day. It was also found that of the total waste produced, 52% has the potential for composting, 27% can be recycled while 21% can be finally disposed (Ruiz, 2012).

In the academic year of 2007 to 2008, a research on waste generation and composition was conducted in Prince George campus of the British Columbia University Canada. The daily waste generation rate was estimated to be 0.05 per-capita/day. The largest waste generated was the paper and cardboard waste, and then plastics and organic waste respectively. Furthermore, it was shown that more than 70% of the waste could have been diverted from landfill through recycling or composting (Smyth et al., 2010).

In a research work conducted at Universität Jaume to investigate the waste generation and characteristics of the Spanish University, in a school year by Gallardo (2016). The waste generation rate was estimated at 0.04 per-capita/day. Estimated generation rate of selectively collected waste is 0.04 per-capita/worker/day. Therefore, data from the study was used to develop suitable measures for enhancing the University waste management system (UWMS) waste by cutting down the amount of waste generated. It was found that If waste were correctly disposed, then generation of waste will be lowered by 92.39 tons per year (Gallardo, 2016).

The study by Mbuligwe (2002) on three different Tanzanian institutions to improve their solid waste management system showed that there is a variation in the rate of per capita daily waste generation rates of staff and students in each institution and also across the three institutions. The daily generation of waste per-capita is said to be 0.190, 0.193 and 0.083 kg/ cap/per day, for

"The University college of lands and Architectural studies" UCLAS, "University of Dar es Salaam" (UDSM), and "Water Resources Institute" (WRI) students accordingly. Majority of the waste generated was organic in form and this shows that there is a great resource to recover this by channeling it to produce animal feeds or biogas production. The research clearly showed that extraction and recovery of waste materials could largely improve the management of solid waste at the institutions.

Coker and Achi (2016) assessed the existing solid waste system at a University in Nigeria. The findings revealed that various student hostels with an estimated population of 762 to 848 students per hostel generate daily around 0.3 to 0.4 kg/capita/day per each hostel. The significant waste material which is organic (29%) shows a promising potential for the extraction of biogas and energy.

The consumption pattern of students was also revealed through the high fraction of plastics, paper and metals generated showing that they consume lots of snacks canned and plastic-bottled drinks. The trade of the non-biodegradables in the secondary market was valued at a daily lump sum of 639,900 naira (2908.6USD). Given that price, a lump sum of N230 million (1,045,454.5 USD) is feasible annually as revenue generated from waste. It showed that if all organic waste generated from all functional areas in the University were recovered, it will be a great source of added revenue for the institution.

In a research to study the practices of two different institutions regarding their solid waste management system in Ghana, (Deryl, 2014) confirmed that in the 2012/2013 school-year, 488.3 tons of solid waste were produced from the University of Ghana at the academic and administrative units, in which 46% were paper. The Central University College (CUC) produced 27.2 tons of solid waste in academic and administrative units and the most significant of this was found to be paper (46%). Also, for the Central University College, the most significant portion of waste produced were paper (52%). Although papers used for examination were being recycled in

the two institutions, the daily generated paper waste are not being recycled. It was estimated that a recyclable waste valued at GH¢29,298 (5320 USD) cost GH¢193,440 (35128.2 USD) to be disposed, meaning that per year a sum of GH¢142,776 (25927.76 USD) is used to dispose GH¢1,632 (296.37 USD) recyclable papers.

2.11.1 Factors influencing inefficient solid waste management in higher Educational institutions

Some factors have been identified to influence the effectiveness of solid waste management in higher institutions such as having a good knowledge of how institutions work, making decisions and their level of interest in environmental affairs (Evangelinos et al., 2009; Kaplowitz et al., 2009). Higher institutions are known for their prolong formalities, inadequate financing among others, un-coordination as a result of improper management, lack of distinction in responsibilities of staff and high population (Velazquez et al., 2006). Past research recommends that for an environmental scheme to be effective, elements such as an active management, assistance of head personnels and the adoption of a workable environmental framework must be present (Velazquez et al., 2006).

Regardless of the prospective advantages, unavailability of finance is still a bottleneck for everyone involved in sustainability schemes (Dahle and Neumayer, 2001), this is in most time a major setback. In addition, it is significance to know the harmfulness associated with failure to embark on environmental sustainability projects (Carpenter and Meehan, 2002).

The direction and supervision of waste management in institutions like colleges and universities is highly cumbersome owing to its large estate departments and population. A proven method to guarantee sound performance is assigning someone to be in charge and oversee the

environmental affairs and performance of the University. Routine management areas include supervision and direction of the waste management of a University strategically, maintaining conformity to legal standards, formulating laws in alignment with sustainability, communicating with relevant members and bodies and writing environmental reports (Aseto, 2016).

Consistent, purposeful and adequate communication is also an essential item for an efficient waste management at HEIs. Recycling facilities must be established and accompanied with creation of relevant campaigns. Based on the organizational structure of HEIs and its large population, access to information is cumbersome and difficult to access. To overcome this, it is suggested that dedicated workers in the departments should be assigned the task of developing how to easily access information (Thompson and Green, 2005).

Furthermore, the importance of employing a trustworthy waste management contractor cannot be over emphasized. Many recycling schemes were fruitless when contractors decide without notice to quit or modify collection methods and charges (Starovoytova, 2018). The appropriateness of a contractor should be thoroughly evaluated by taking into consideration the objective, qualities such as dependability; technology know-how; practices and ethics, years of experience, adherence to environmental and health laws. The lack of environmental awareness is another factor influencing inefficient solid waste system. People in charge of making decisions must acquaint themselves with the advantages of greening, enact sustainable laws and spend on green facilities (Aseto, 2016).

In order to motivate, past achievements should be emphasized concerning benefits and successes achieved through a greening process. For example, there is a website and monthly bulletin which solely provide information to students and staff about the benefits and gains of preserving the environment and suggest room for improvement (Mason et al., 2004).

2.12 South African Cases

There are few published papers concerning waste management in higher institutions across South Africa A research was conducted by the students of computer science at Rhodes University in order to recognize where and what to concentrate on to lower their paper waste generation. For a period of five months, the quantity of paper utilized and the use to which it was put to was strictly monitored by 50 academic staff. Also, an interview was conducted for all procurement officers in academic departments concerning the quantity and usage of paper in various departments. It was found that reducing their paper use by 10% will result to a cut in cost of about US$7000 annually (Amutenya et al., 2009). It was recommended that the culture of reuse, double-sided printing will lead to a great reduction in the use of paper. It was further estimated that 40% reduction will result in a saving of about US$20,000 per year in overall costs, and reduction of waste, and also enhance the environmental standard of the institution (Amutenya et al., 2009).

A study was also conducted on reducing waste through education focusing on the awareness levels and practices at the University of South Africa, Pretoria. The current level of awareness and participation in waste recycling of staff at Unisa was evaluated to give an outlook of their waste management practices. In achieving this, questionnaire sampling was adopted. Simultaneously, an awareness campaign was initiated by the greening of a notable Unisa event. The outcome of the questionnaire showed that even though most respondents (86,6%) identified what waste recycling is, and many are involved in home recycling (74,7%), those who recycle at offices (43,7%), this calls for more awareness on recycling. Support was also confirmed for establishing composting facilities at garden refuse sites (71,8%). Greening of the Unisa Fun Day was remarkably a success as shown by increased and sustained involvement in recycling. The study illustrated that waste recycling at a higher education institution is a necessary platform to kick-start waste minimisation programmes (Joubert and Plessis, 2008).

In January 2015, the North-West University, Potchefstroom Campus admitted ten prospective students who registered for the BSc. Hons. Environmental Sciences with specialization in waste management being the first degree of its kind in South Africa. The research papers of the students centered on analyzing and characterizing the waste stream and the existing behavioral practices in managing waste at the Potchefstroom Campus. Little understanding of the characteristics and quantity of waste generated in the campus was a burden of concern as expressed by the Green Campus Committee of the North-West University. Very little research was done before the year 2015 to maximize waste management practices on the Campus (Roos, 2016).

The perception and attitudes of students and staff regarding waste management were also lacking and little was done in understanding and improving the waste management practices of the institution. The Green Campus initiative of the North-West University had recognized this unavailability of information and understanding as a major set-back that needs urgent attention. The research showed that approximately 60 – 85% (weight) of the residences waste had the opportunity of being recycled and it was determined that 74% of waste disposed of in the normal waste bins on the general campus has the potential to be recycled (Roos, 2016).

2.13 Environmental and Health impacts of improper waste management

The unfavorable result of poorly managed waste on the environment cannot be over emphasized and has been revealed in various studies. Solid waste is capable of polluting the air, water and soil and consequently leading to various environmental impacts and health hazard due to poor handling and transportation (Al-khatib, 2007). For example, in the study of the developing countries and their waste management challenges, poor waste management was found to result in adverse problems health-wisely and environmentally such as air pollution, the attraction and breeding of all sorts of disease carrying vectors, which often transmit different forms of diseases like gastroenteritis and malaria in the institutions. A common sight is also the leaching of leachates from uncollected waste bins (Al-khatib, 2007).

Environment, health and poverty are interwoven significantly in Africa because lots of these pandemic and infectious diseases, especially those that affect the poor usually originate from poor environmental conditions (Hope and Kempe, 2007). Environmental effects like deteriorating aesthetics and nasty odor are increasingly becoming phenomenal in many places of developing countries including higher institutions. Epidemiological effects such as transfer of diseases, obstruction of sewers, blockage of drains and release of harmful gases are taking their toll also as a major threat on human health (World Bank, 2012).

Solid waste left without collection also hinders the flow of storm water runoff, leading to stagnant water bodies that form the breeding home of all sorts of insects. Wastes discarded near a water source can contaminate water bodies and groundwater through leaching. Waste untreated and out-rightly disposed into water bodies accumulates as harmful substances in the food chain as a result of aquatic lives which feed on them as food (Medina, 2002). Ejaz and Janjua (2012) also emphasized that a poor system of managing solid is breeding adverse environmental impacts in form of pollution (air, water and land), contagious illness, obstruction of drains, pipes, little canals and eroding biological diversity.

The management of waste from collection to final disposal is directly or indirectly linked to health (Giusti, 2009). A major cause of air and water pollution amongst other health problems is the issue of open burning and unauthorized dumping of hazardous waste on dump-sites (Kathiravale, and Yunus, 2008). Rushton (2003) conducted a research to determine if poor health is linked to hazardous waste. The findings revealed that agricultural and industrial waste are capable of impacting health negatively. Besides that, not separating hazardous waste from general waste can expose people to harmful substances. According to United Nations Environment Programme (UNEP, 2013), poor management of waste can lead to a serious health risk hence, leading to transmission of diseases. It is further stated that uncollected wastes pull insects and disease

transmitting rodents to itself. Also, when moist waste breaks down due to microbial activities it gives off a bad stench.

2.14 Conclusion

This chapter has reviewed the solid waste cycle from the generation process to final disposal. The institutional responsibility of higher educational institutions towards sustainable waste management was also reviewed with specific case studies locally and internationally. In the light of the above, there are several gaps existing in the current waste management system of the University. The University has no designed layout for the separation of waste from generation to its final disposal, facilities for segregation are lacking. There is a need for resource extraction and waste recovery which is obtainable via the design of a suitable waste management system.

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CHAPTER THREE

RESEARCH METHODOLOGY

This research investigates the institutional solid waste management at the University of Venda. It was initiated on the rationale that HEIs are “controlled” bodies whose characteristics and composition of wastes can be readily measured and investigated with the prospects of proposing a sustainable waste management system. The institution was chosen because it is the largest educational institution in Venda. As it is within an institutional framework, this research was methodically approached by weighing and characterizing the waste generated in the selected areas to determine the potential for recycling and diversion. Underlying factors responsible for the current state of waste management was explored through questionnaires and interviews to know the perception of students and personnel involved in waste management in the institution. The findings were used to design a sustainable waste management system which can be applicable and useful in similar institutional settings. This chapter presents the materials and methods used for this study as presented in Table 3.1.

3.1 Description of the study area

The University of Venda is situated in Thohoyandou, Limpopo province as a South African Comprehensive rural based University. The study area is located in longitude 22.9761° S and latitude 30.4465° E (Figure 3.1). It was founded in 1982 under the then Republic of Venda government (University of Venda, 2020). Thohoyandou is one of the fastest growing towns in Limpopo region with variations in temperature ranging from 12 to 22 °C during winter, and about 20 to 40 °C in summer season. Precipitation also ranges between 340 to 2000 mm, having an average rainfall of 800 mm. The region is classified as a humid subtropical dry forest biozone.

The University has one Campus in Thohoyandou which houses seven schools namely: The School of Agriculture, School of Education, School of Environmental Science, School of Health Sciences, School of Human and Social Sciences, School of Management Sciences, School of Mathematical and Natural Sciences and the School of Law.

Table 3.1: Overview of research methodology

Objectives	Types of Data	Objectively Verifiable Indicators	Methods of Data Analysis
1. Assess the existing solid waste management practices in the institution	Data on current waste management plan and practices Sources: Relevant waste management personnel - Field survey, (Visual investigation and observation, interview, questionnaires)	Existing management strategies - Challenges of existing management practices - Gap identification compared to best practices - Attitudes and perception of waste generators towards existing management strategy	Swot analysis, Narrative analysis
2. Estimate and Characterize the amount of waste generated in the institution	Amount and types of Waste generated and collected for disposal Sources: From personal Field survey Characterisation by ASTM (2008)	Weight of waste generated per source/per day	Micro soft Excel, SPSS, Descriptive statistics
3. Evaluate the recycling potentials of the solid waste generated in the institution	Percentages of different types of waste generated at the selected sources	Percentage weight of recyclable waste	SPSS and Descriptive-Statistics
4. Develop a sustainable solid waste management strategy	Action-plans for successful-implementation of sustainable strategies for SWM.		Content analysis, Descriptive statistics

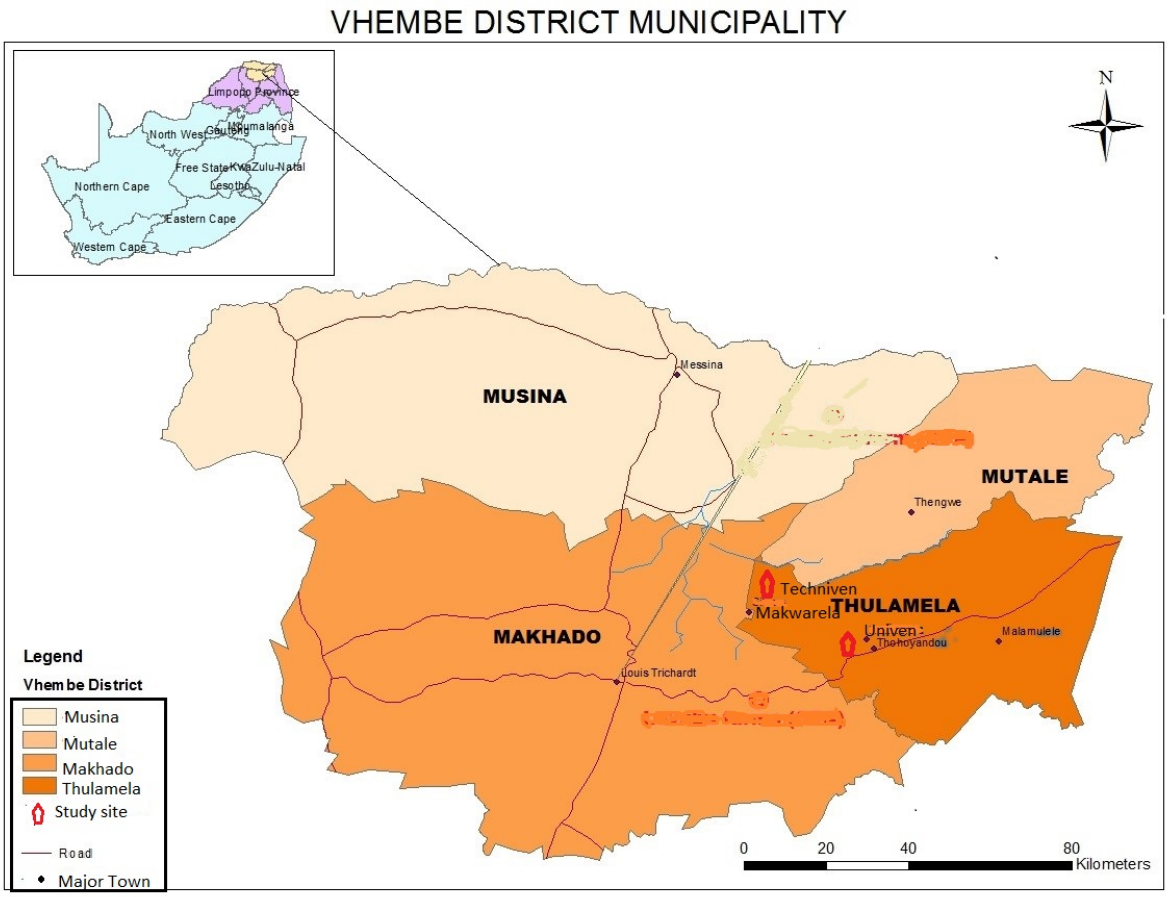

Figure 3.1: Location of the study area (source: Field work)

3.2 Waste management department

The University of Venda has a structured master plan for academic areas, residential, administrative and recreational areas with good road networks. The waste management arm of the institution is being controlled by the Department of Ground and Cleaning under the Maintenance Department. The institution under the auspices of a University owned body known as Univen Innovative Growth Company (UIGC) contracts cleaners as part of the cleaning and

sanitation of the institution. They are responsible for maintaining cleanliness and sanitation in the University.

3.3 Materials and Methods

This study is qualitative and quantitative in nature with the use of primary and secondary sources of data.

3.3.1 Primary Data

Primary data was collected through field observations and interviews. Field observations are all assessments made by the researcher concerning the state of cleanliness of the institution, methods of waste management from generation to disposal, availability of waste recycling facilities. Field survey was conducted by administering questionnaires to the students of Univen. The questionnaires focused on the existing waste management practices, perception and awareness on recycling in the University, the challenges of waste management and recycling in the University as well as suggestions for improvement (Appendix C).

3.3.2 Secondary Data

For this study, the required data was gathered from published and unpublished sources such as government gazettes, internets, waste management reports, statistical abstracts, development plans and Univen policy documents among others.

3.4 Sample population and sample size for questionnaire

The total population of students in Univen was considered as the sample population of this study. According to the Department of Quality Assurance and Control, the University of Venda has a population of 490 members of staff (teaching and non-teaching) and 16,702 students respectively for the year 2019. A cross-sectional design was used to assess the knowledge, attitude and practice of waste management as adopted in similar study (Adeolu et al., 2014).

This study adopted simple random sampling design for the collection of data from questionnaires.

- a random selection of 3 schools in Univen campus
- a record of the number of staffs and students residing in each school was obtained from department of quality assurance and control
- A total of 376 students were randomly selected from the schools.

A total sample size of 376 students was drawn from the school's total population in Univen using both combination of simple random and stratified method of sampling, a confidence level of 95% was adopted. The Cronbach's Alpha computed was given as 0.792 and this was found acceptable based on a standard scale (George and Mallery, 2003).

3.4.1 Pilot-test of questionnaire

There was a pre-test of 30 questionnaires among students of School of Agriculture and Law. The respondents were randomly selected, and all the questionnaires were filled and collected. Some responded choices were not well understood and this therefore called for a restructuring of the questions. The response collected from the pilot test was carefully analyzed.

3.5 Waste audit sampling

Waste samples were collected from designated waste bins of key activity areas, selected schools and residences, which are: School of Social Sciences, School of Environmental Sciences and School of Education. Riverside residence, cafeteria, and new administrative building. These areas were chosen as representative of the entire University considering that covering the entire school was not feasible. There was a 2-day trial audit conducted at the School of Law for the purpose of knowing the likely challenges and what to expect from the waste stream.

3.6 Waste characterisation process

The direct waste analysis method (DWA), also commonly known as 'sample and sort' which is a scientifically and broadly accepted approach to solid waste characterisation was utilized in this study. This requires the hand-sorting of waste materials into selected material components and taking their measurements in weight (Yu and Maclaren, 1995). The statistical measurement on

waste characterisation is usually by weight (Williams, 2005). Waste characterisation in all selected activity areas for this study was performed using the ASTM (American Society for Testing and Materials) D5231-92 standard method (ASTM, 2008). The

procedures for characterisation and sampling methodology was adopted from the Standard Test Method of Determining the Composition of Unprocessed Municipal Solid Waste (ASTM D 5231-92). Other methodologies consulted are; the characterisation methodology designed for developing countries such as: (Smyth et al., 2010; Smuts, 2014). The reduction of sample was done using the Quartering with a sampling cross approach. This method has been widely adopted by similar studies in other universities (Vega et al., 2008). Waste from designated bins were collected every morning for each activity area and assembled or gathered, then transported to a designated point in the University premises for characterisation (Figure 3.2).

Figure 3.2: Weighing scale used for measuring

This was performed three days in a week to get an average of the daily waste generation rate. A black plastic sheets was spread on the sorting site to allow for the sorting of the waste collected. The waste was poured on the plastic sheet and hand-sorted into different categories by the waste team into a labeled bucket in order to derive their respective percentage categories (Figure 3.3 and 3.4). The different categories were put in a labeled bucket and weighed with the aid of a platform scale and the weights were recorded in an excel spread sheet. This was carried out on three different days. Segregation was carried out six hours a day for three weeks. Waste categories included paper and paper products, plastic bags, plastic bottles, aluminium cans, organic (compostable) materials, glass and others.

Figure 3.3 Waste audit process

The composition of waste found in the different location was determined to know the opportunities present for the diversion and recovery of waste. The option of recycling versus landfilling was also considered by weighing the components of waste prior to sorting and after sorting.

The analysis was carried out to know:

- The percentage category of solid waste generated in the selected activity areas
- The total amount of solid waste generated from the selected activity areas
- The total value of the waste that are recyclable using equations i and ii below

$$percentage\ recyclable = \frac{PC}{PL}\ X\ 100 \qquad (ii)$$

$$per - capita\ waste = total\ waste\ generated\ /\ no.of\ persons\ X\ no.of\ days \qquad (ii)$$

Figure 3.4: Black plastic bags of waste generated and sorted

3.7 Interview

Interview was also conducted as a means of collecting vital data from stakeholders in the school waste management department. The supervisor for grounds and cleaning who is also the head of waste management department in the University was considered suitable for the purpose of the interview (Appendix E). The following questions were asked:

- What types of waste are generated in the key activity areas?
- How are those wastes stored?

- What is the mode of collection?
- Who are responsible for the collection?
- What is the mode of disposal?
- Are there any recycling systems in place for the collected waste?

A paper recycling company was also interviewed to give insight to the recycling of paper. The following questions were asked:

- How do you get raw materials for recycling?
- How much are you willing to pay in exchange for paper waste?

All interviews were conducted at a time conducive for the interviewee and in their offices and confidentiality of the information given were ensured. The results of the interview which is qualitative were analyzed by summarizing the views of the respondents which were supported with relevant citations that explain it, also with data from documented sources as well as from personal field observations of the existing waste conditions in the institution.

3.8 Analysis of Data and Presentation

The analysis of data and its presentation obtained from the field was subjected to analysis through the Statistical Package for the Social Sciences (SPSS) software. In analyzing the data, descriptive and inferential statistical tools such as Anova, Cross -tabulations and Swot analysis were utilized. The basic features of the field data are presented using descriptive statistical tools. The data gathered from the questionnaire survey was digitally compiled, coded and edited. The coded items were collated to provide frequencies and percentages of the respective waste categories using SPSS software, Version 25. About data presentation, tables, maps and diagrams from various sources were used in the study.

3.9 Difficulty in data collection

In the quest to acquiring the required data, lots of difficulties were encountered in the process. There were numbers of respondents who chose not to cooperate and were not willing to give out the necessary information. Many times, appointment was fixed but not honored by the respondents and some avoided it because they thought it will waste their time.

3.10 Ethical consideration

Ethical clearance to conduct this study was obtained from the Research Department of the University of Venda (Appendix D). This study considered and abided by all ethical rules and regulations and all data collected during this study were treated as confidential and not to be revealed to anyone outside the research team.

3.11 Conclusion

This chapter discussed the study location and the research methods and materials applicable to the study. The next chapter discusses the perceptions and attitudes of students towards solid waste management in the institution.

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CHAPTER FOUR

Perception, knowledge and attitudes of students in tertiary institution towards littering and Solid Waste Management: Case study, University of Venda

4.1 Abstract

The environmental knowledge, attitude and perspectives of students in academic institutions are instrumental in providing solution to the solid waste menace and other environmental problems in the community. The current study was carried out with the aim of examining the knowledge, attitude and perception (KAP) of students at the University of Venda on source separation and reduction of solid waste, recycling, environmental effects of mismanagement of solid waste. Three hundred and seventy- six students from nine schools of the institution were surveyed in this cross-sectional study. Results from the study showed the knowledge of the students on solid waste management and waste separation was low and inadequate. The environmental education and awareness across all schools is recommended. The relationship between their level of study and perceived environmental state of Univen was also evaluated and found to be statistically significant. The results of this study showed that 54.5% of the students were not satisfied with the environmental state of Univen. However, students are willing to participate in recycling projects and separation of waste at source to improve the current environmental state of the institution. This study also revealed that some of the students require motivation to participate in recycling schemes through economic incentives (N=154; 41%). Based on this study, increasing awareness on environmental education, provision of necessary facilities and materials as well as initiating

participatory environmental programs on recycling for the students can effectively improve their knowledge and solid waste management in the institution.

Keywords: Attitudes, knowledge, perception, student, recycling, solid waste.

4.1.1 Introduction

Attitude refers to a set of beliefs which a person has developed relating to a thing, phenomenon or event (Richard, 2016). Attitudes and perception inform students pro-environmental behavior, and as such, it is crucial to evaluate the environmental awareness level by assessing student's perception, knowledge and attitudes towards solid waste management in academic institutions (Bradley et al.,1999). Our environment suffers from diverse environmental problems that require an individualistic approach and to be addressed at the individual level, requiring each person to develop the right attitudes that will direct them to environmentally sustainable behavior (Al-rabani and Al-mekhlafi, 2009).

To ensure a sustainable environment, there is a need to protect, conserve and manage the environment in a sustainable manner through environmental education and awareness (Boca and Sarah, 2019). Environmental education is a procedure planned for building a total populace that knows and is concerned about the environment's entire condition and its related problems and which has the information and responsibility to work exclusively towards tackling of current issues and the avoidance of new ones (UNESCO, 2011).

Spira (2013) referred to students as change agents and are an important tool for sustainable development and the time has come to harness the student's potential as change agent without hesitation. Levin (2000) suggested that institutions must put students at the focal point of their agenda for environmental education since students are result oriented and their contribution is crucial to environmental development and improvement. One of the institutions capable of promoting awareness on solid waste management in the community is the University. In the same

way that change is a constant phenomenon, and different forms of waste are evolving, so also must the attitude of people towards waste management especially institutions regarded as change agents. Institutions must realize that the solution lies in harnessing and utilising waste as a useful resource rather than an item to be destroyed (Desa et al., 2011).

Researchers on students' perception and analysis on solid waste management have seen an improvement in behavior and waste management practices among students through provision of recycling and environmental awareness (Vega et al., 2008; Kaplowitz et al., 2009). Inferring from literature, it is imperative to develop solid waste management awareness in educational institutions. Present literature in South Africa on perceptions of people towards solid waste has been mostly on household and municipal. Perceptions of students in educational institutions are scarcely discussed and skewed to tertiary institutions in the urban areas, currently, there is no study particularly on the assessment of the knowledge, attitude and perception (KAP) of students in a rural based University like University of Venda, therefore making this study of benefit.

This will help to understand KAP from the perspective of students directly in a different setting, as this might influence their perception of solid waste management. This is because waste generation and perception are a subject to location and climate, and socio-economic conditions (Coker and Achi, 2016). Considering the foregoing, this study aims to assess the knowledge, attitudes and perception of the students of University of Venda concerning solid waste management.

4.1.2 Sample selection

This cross-sectional survey was conducted among the registered students of Univen in 2019 (N= 16,702). A total of 376 students were included in this survey. The sample size for the study was determined using the following (Glenn, 2003):

$$Sample\ size = \frac{Z^2 x\ (P)\ x\ \ (1-P)}{C^2} \qquad 4.1$$

Where: Z = Z value (e.g. 1.96 for 95% confidence level)

p = percentage picking a choice, expressed as decimal

(.5 used for sample size needed)

c = confidence interval, expressed as decimal (e.g., .05 = ±5)

This gives a total of 376 students to represent the school.

4.1.3 Data collection

Data for this study was collected using research tailored questionnaire. The questionnaire utilized both structured and semi-structured questionnaires with a mixture of open and closed ended questions to assess the perception, knowledge and attitude of students to solid waste management at the University of Venda. The reliability of the questionnaire was confirmed by distributing it among 30 students as a pre-test. The content validation method was utilized at the introductory stage as the data collection tool, in which each item in the questionnaire was compiled according to the aim of the investigation. Then the content of the questionnaire was evaluated by the Research and Innovation Committee of the University of Venda and approved for the study.

The questionnaire for the research data comprised of three sections. The first section contained the demographic statistics of respondents (gender, age, student level of education, and school); this was studied to determine their effect on the knowledge, attitude and perception of solid waste in the institution. The second section measures the students' perception and attitude to the environment. The third section sought the perception of students to recycling in the institution,

possible solutions and suggestions to improve waste management in the institution. The knowledge, attitude and perception of the students were rated based on their scores in three levels of low (lower than 50% of the score), average (50-75% of score) and good (above 75% of score).

4.1.4 Statistical analysis

Descriptive and analytical statistics of data collected were done using SPSS software (version 25.0). The data were tested firstly for outliers and normality of distribution using Skewness and kurtosis indices. Results showed that the distributions of all the items did not deviate significantly from normality. The parameters calculated include percentages and frequency. Statistical analysis performed also included One-way Anova and cross-tabulations to test the relationship between level of education and knowledge, attitude and perception of students at 0.05 level of significance. The visualization of data was assisted with tables, pie-charts and histogram.

4.2 Results and discussions

4.2.1 Perception, knowledge and attitudes of students towards Solid Waste Management

A very important aspect of environmental education is the dissemination of information on matters of environmental concern to the academic community as an entity which includes students, staff and other workers. Regarding the question to know the personnel responsible for waste management in Univen, 88% of the students responded that they do not know those responsible for the solid waste management in the institution while only 12% know the responsible personnel. This high percentage of respondents not knowing the responsible personnel is an indication of the need for awareness. It is imperative that students have adequate knowledge of the personnel responsible for solid waste management in the institution. This could encourage effective

communications on feedback and suggestion. Keles (2017) opined that higher institutions of learning have the responsibility to pioneer process of building knowledge, inculcating skills, awareness, values and sustainable attitudes to enable a sustainable environment to make the leaders of future generations innovative and critical thinkers towards a sustainable environment.

4.2.2 Perceived state of environmental cleanliness in the institution

Cleanliness of the environment is often deciphered by the populace as an important measure of the effectiveness of solid waste management in the community. A few questions were asked on the state of cleanliness of the University campus. Responses received are presented in Figure 4.1. Above 50% of the respondents were not satisfied with the current environmental state of the institution (Figure 4.1) because good sanitation and cleanliness of an environment is a vital aspect of the health and general well-being of the users. Campbell and Bigger (2008) reported a positive correlation between environmental cleanliness and increased learning of students at Brigham Young University, Utah. Similarly, Tagor et al. (2018) showed a correlation between healthy school environment and the students' behavioral disposition. The results also indicated that a clean and sanitary school environment is a major determinant of the attitudinal lifestyle and performance of the students in Indonesia. Table 4.1 shows the correlation between the level of study to the response given using one-way Anova shown below.

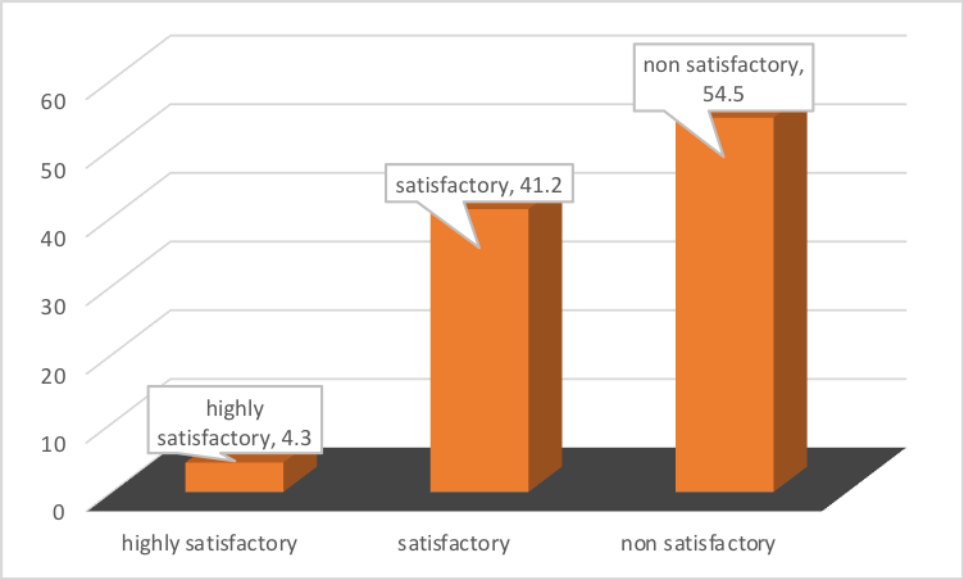

Figure 4.1: State of cleanliness of Univen (Source: Field work)

Table 4.1: One way Anova of level of study and state of Univen

	N	Mean	Std. Deviation
1st year	22	2.50	.512
2nd year	50	2.46	.503
3rd year	87	2.38	.651
4th year	52	2.50	.505
Honors	53	2.58	.633
Masters	56	2.43	.628
Phd	56	2.73	.447
Total	376	2.50	.580

ANOVA

State of Univen

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	5.030	6	.838	2.557	.019
Within Groups	120.967	369	.328		
Total	125.997	375			

The One-Way ANOVA was used to test if there is a significant difference in mean values between level of study and perceived environmental state of UNIVEN at 0.05 significant level. A significant difference was recorded between both variables. This implies the observed differences between the level of study and environmental state of UNIVEN was significant and not by chance. Based on the prior findings on the state of the institution, the perceived areas of concern (as untidy) of the students are presented in Table 4.2.

Table 4.2: Cleanliness state of Univen (Source: Fieldwork 2019)

Unsatisfactory Areas	Frequency	Percent
Student's residences	63	16.8
Lecture halls	6	1.6
Cafeteria	2	.5
Others	5	1.3
Student's residence and lecture rooms	13	3.5
Student's residence and cafeteria	55	14.6
Student's residence, lecture rooms and cafeteria	66	17.6
Not applicable	166	44.1
Total	376	100.0

From the results obtained, the student residence, lecture rooms and cafeteria are the most littered places identified, having the highest percentage (17.6%). This shows that these major activities areas require utmost attention as students spend most of their productive time in these places for receiving classes, reading, sleeping and eating and this could have an impact on their well-being and academic performance. This agrees with a research conducted by Kiplagat et al. (2018) which revealed that students believed that with a cleaner hall of residence and campus they stand to gain a better qualification because a strong positive correlation was established between the state of students' residences and their well-being and performance. To assess the performance of the

current waste management in the institution, the students were asked to rate according to good, excellent or bad as explained in Table 4.3.

Table 4.3: Rating of current waste management

	Frequency	Percent
Excellent	9	2.4
Good	213	56.6
Bad	154	41.0
Total	376	100.0

The result showed that respondents had mixed feelings regarding the current waste practices in the institution. A little above half of the respondents feel the University waste management is ideal, while 41% of the respondents regarded it as bad. However, from physical observation on campus, there is much littering in most places. In a comparative study by Adelaide and Goddey, (2017) at Accra University, although 50% of the students expressed they were impressed with the state of their school, most of the total student respondents had problems with the sanitary conditions of the hostel and its environment.

4.2.3 Littering on campus

Littering refers to an act of indiscriminate discarding or deliberately disposing off items that are no longer of use in an undesignated place which in most cases such items can be recycled (paper, can, aluminum). Students were asked if they perceive littering as an environmental problem, above average of the respondents identified that littering is a problem in Univen (68.4%) and the most commonly littered areas of the University is presented in Figure 4.2. This finding is in congruent with the findings of Tome and Mashiloan (2017) where students identified littering as a

major environmental problem. This result also concurs with the works of Karkkainen et al. (2013) whereby learners identified littering as a national and global problem.

Students reported that the hall of residences, lecture rooms and cafeteria are the most littered

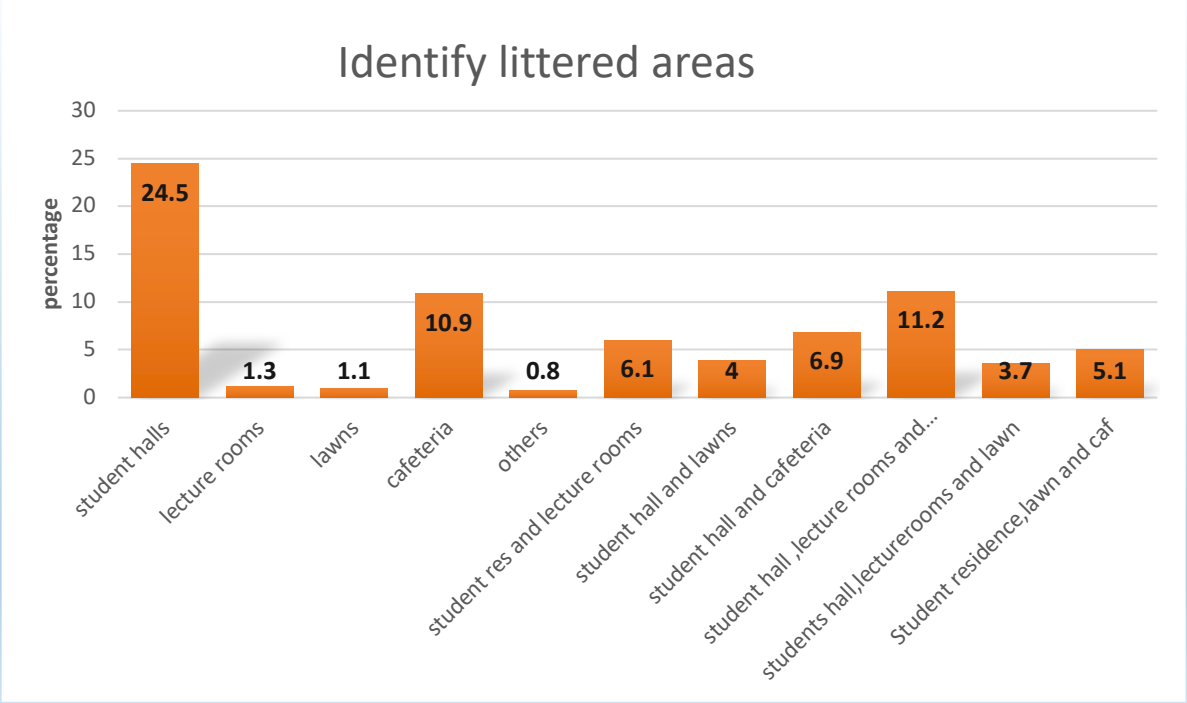

Figure 4.2: Littering problem (Source: Fieldwork 2019)

area on campus. Littering in academic environment speaks about the level of environmental commitment of an institution, such that it encourages bad littering habits of students and projects a negative image of the institution which must be curbed (Makonya, 2004). In a deliberate attempt to combat littering, the Green Campus Initiative (GCI) at the University of Cape Town runs a waste management scheme having a two-container framework in 2012, which enabled students to isolate "recyclables" from "non-recyclables" (GCI, 2012). Good hygienic practices should be encouraged in those hotspots area because they can lead to health risks of the students.

4.3 Practices of students towards solid waste management

4.3.1 Attitudes to waste disposal amongst Univen students

In order to know the culture of waste disposal amongst students, they were asked where they dispose their waste. Majority of them (n=356, 93.6%) claimed that they dispose their waste adequately using the provided waste bins, some of the respondents however complained that the bins are not sufficient (n=176, 46.8%) for efficient solid waste management on campus. This is different from a similar study in Ghana by Ampofo (2018) where above average of the respondents (n=120,83.33%) indicated that waste is discarded in open spaces in senior high schools within the Wa Municipality, while 8.33% indicated that waste is being disposed in dustbin. This suggests that insufficient bin is a vital issue that needs to be addressed. Results are presented in Table 4.4 below.

Table 4.4: Disposal Of waste (Source: Fieldwork,2019)

		Frequency	Percent
	Waste bin	352	93.6
	Road side	24	6.4
	Total	376	100.0

The type of waste bins employed for use in tertiary institutions has been implicated to affect the attitude of students towards waste disposal (Staroyvotova, 2018). Students were asked if they experience difficulties in using the waste bins provided, close to average (4.4%) reported that there are difficulties associated with the provided bins. This shows that some students find the waste bins difficult to use. Figure 4.3 provides the result obtained pertaining to the difficulties associated with the waste bins in Univen.

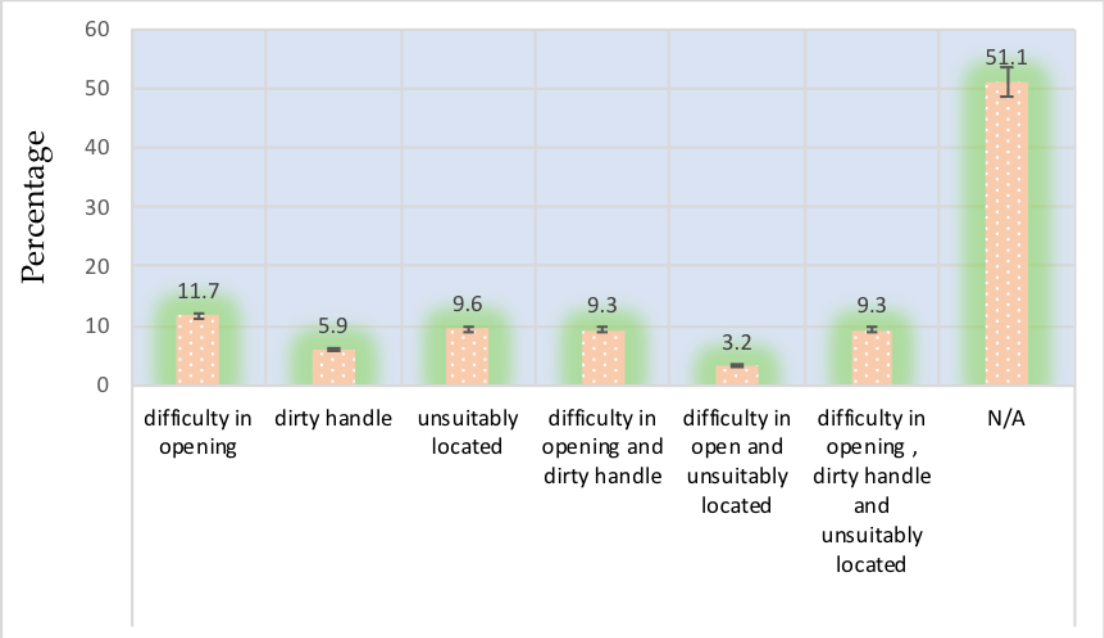

Figure 4.3: Difficulties of the waste bin (Source: Field work)

Respondents reported the difficulties they encounter in the usage of the waste bins. The most commonly reported difficulty is the difficulty in opening the bin lid and dirty handles (11.7% and 9.3%). Physical inspection of the bins as shown in Figure 4.4a and Figure 4.4b below also reveals long heavy iron handle which is heavy to open and most times dirty which is a demotivating factor for effective usage. However, the institution in an interview with relevant personnel stated that the bins provided has heavy lids because of the threats of monkeys who scavenge the bins for food items thereby littering the premises.

A research carried out by Katherine (2012) concluded that to encourage and facilitate students in the efficient use of waste receptacles, reported that waste bins must be unified and aesthetically pleasing to the users so as to increase the usage. Similarly, Duffy and Verges (2009) observed that some lid openings are capable of constituting barriers to effective usage and discouraging users from compliance. Through their study it was shown that some type of lids is capable of promoting the reduction of waste at a rate of 95% and it was therefore concluded that some designated lids can increase the proper utilization of waste bins.

Figure 4.4a: Bin with dirty handle; 4b: heavy long handle

4.3.2 Awareness on waste separation

The importance of waste separation is fundamental for any effective waste management process. In a research on the driving mechanism of waste separation behavior by Feiyu et.al., (2019), it was shown that the extent to which recycling and reduction process can be effectively carried out in any waste reduction scheme is largely dependent upon waste separation at the source.

The respondent's knowledge regarding waste management and separation was tested, majority of them (70.7%) had no idea of what waste separation is all about and this calls for a need for awareness on waste management. When those who claimed to have adequate knowledge on waste separation were further asked about its advantage, more than half (60%) indicated that they don't know (Table 4.5).

Table 4.5: Knowledge on waste separation			
Frequency			Percent
	Yes	110	29.3
	No	266	70.7
	Total	376	100.0

This response is similar to Alam and Ahmade (2013) whose study found that knowledge and attitudes of students on waste management is generally low, and a study by Arora and Argawal, (2011) which showed that practices of students on waste management are less favourable. The cross tabulation between students' level of study and their knowledge on waste separation is presented in Figure 4.5.

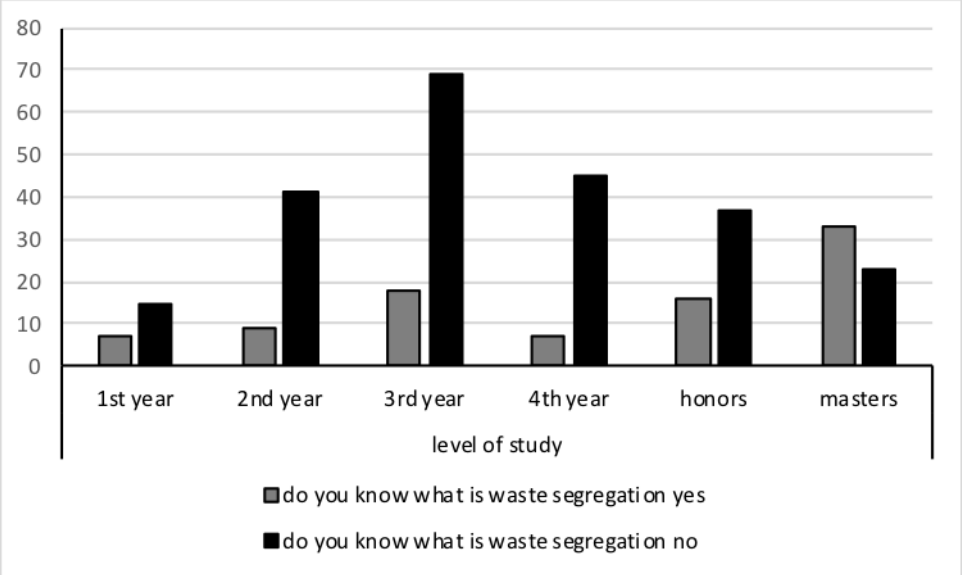

Figure 4.5: Cross tabulation of level of study and knowledge on waste segregation

The cross tabulation shows that higher percentage of students across all level of study do not know what waste segregation is compared to those who know it. Furthermore, there is an exception from the master's level of study, where larger percentage of students reported to know what waste segregation is about. The reason for the low and shallow knowledge could be due to lack of environmental education in the institution. With the foregoing, it is evident that there is a need for a thorough and deliberate waste management education in the institution. To establish whether waste separation is being practiced in the institution, students were asked if there are different waste bins for different types of waste generated. It was revealed (Table 4.6) that such practice does not exist (77%) in the University. The percentage of respondents (22.9%) who indicated that waste separation is being practiced in the institution is unexpected because there is no form of waste segregation in the University. The reason for this (22.9%) could be their lack of understanding on the subject of waste separation. This is similar to the study by Ampofo (2018) which found that among senior school students in Ghana where respondents (N=120) representing 100% respectively each indicated that they do not separate plastic waste, glass waste and organic waste in their schools within the Wa Municipality. Waste separation at source improves the process of sustainable waste management and decreases the amount and cost of disposal. Waste separation is highly fundamental to any waste management scheme and therefore cannot be over emphasized.

Table 4.6: Recycling bins (Source: Field work, 2019)

Are there different bins for different waste in Univen			
Frequency			Percent
	Yes	86	22.9
	No	290	77.1
	Total	376	100.0

The implication of the lack of waste separation bin is a significant hindrance to waste diversion and recovery opportunities such as recycling with its many advantages. The institution has not set in place a major environmental scheme on recycling such as waste separation at the moment and there is a need to know what could be the reason, students were asked what the reason could be and the responses are presented in Figure 4.6 below:

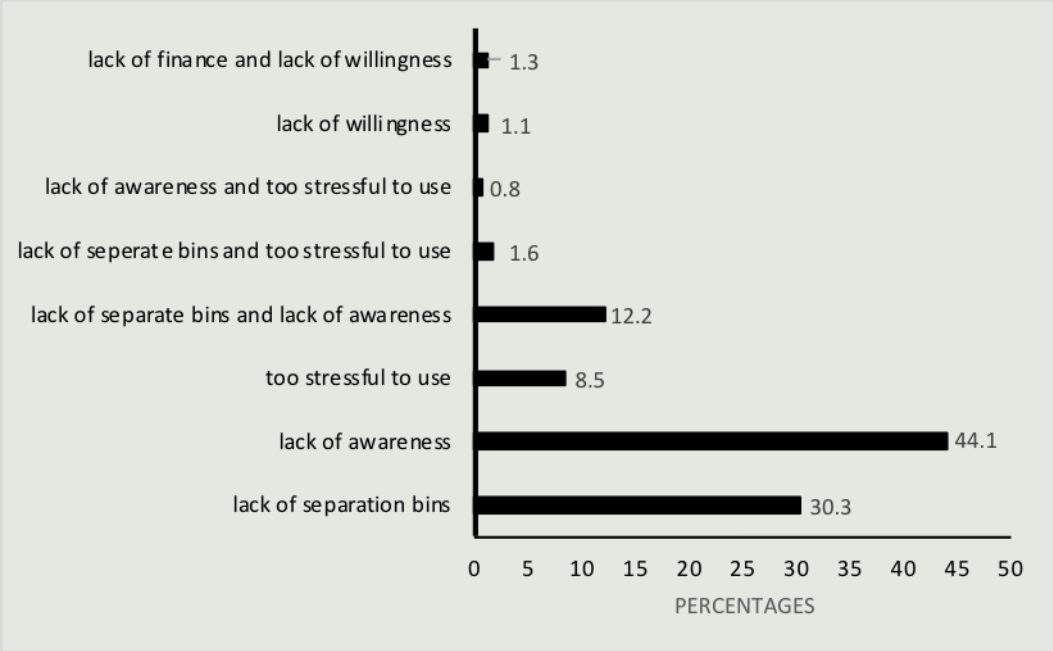

Figure 4.6: Reasons for non-segregation of waste (Source: Field work)

From the above, it can be deduced that the highest percentage why waste is not segregated in the institution is lack of awareness (44.1%) and lack of separate recycling bins (30.3%). Paramount lessons can be learnt on waste management from developed countries, for instance in the US, where all institutions are mandated to provide separate waste bins for waste separation. Therefore, for a meaningful waste management scheme to kick off, waste management education should be included in all curricula in schools, and there should be provision of separate waste bins with awareness programs.

4.4 Respondents perception and attitude towards recycling

As argued by Velaquez et al. (2005), recycling does not only improve campus sustainability, or income generation, it contributes to the sustainability of the immediate community and country by cutting down excessive resources consumption and lowering the negative impacts on the environment. However, there are several factors which contribute to successful recycling and the most important is the motivation to recycle, as well as the fulfillment associated with it. The question was asked to know the mindset of students towards recycling, what will they do if there are provisions of recycling waste bins. The responses are given in Table 4.7.

Table 4.7: Students perception to recycling (Source: Field work 2019)

Segregation of waste adds value to waste resources

	Frequency	Percent
Agree	293	77.9
Undecided	60	16.0
Disagree	23	6.1
Total	376	100.0

From Table 4.7, it can be seen that majority of the students (77.9%) somewhat believe that waste separation adds value to resources even though they may not have experienced it or know how it works. Upendra et al. (2017) observed that in Sweden over half of the respondents (74.16%) attached value to waste segregation. Similarly, Scott (1999) also indicated in his finding that respondents perceive waste separation as valuable to waste management practices. Yasmina (2015) also reported in a study that above half of the (71.1%) students of the University of Twente indicated that waste separation is highly important.

Table 4.8 also shows that 81.4% confirmed that if provided with the necessary materials they are willing to recycle their waste. This is an expression of willingness to recycle provided the institution do their part by providing the needed resources. Emmanuel and Adams (2011) in their study among college campuses of Alabama and Hawaii indicated that students were concerned about their environment and conservation of resources and as such willing to take part in such sustainable practices. Also, students of the North American University expressed their willingness to separate waste and recycle provided the facilities are available, this was established through a study on the students' recycling attitude by Pike et al. (2003). Therefore, the efficient provision of service is critical to a successful recycling scheme.

Table 4.8: Students' willingness to separate waste

If necessary materials provided, I will separate my waste		
Opinion	Frequency	Percent
Agree	306	81.4
Undecided	49	13.0
Disagree	21	5.6
Total	376	100.0

Moreover, a fair percentage of them also believe that incentive should be given as a motivation to recycle. Table 4.9 below shows the respondents opinion.

From Table 4.9, 41% of the respondents are of the opinion there should be an incentive to enable them separate their waste. Several studies have shown that to attain a sustainable waste

management system, there is the possibility of implementing what is called “recycle drivers” like economic incentives that positively influences the recyclers decision and attitude towards recycling. Abila and Kantola (2019) conducted a study on the role of incentives in promoting waste recycling in Finland and results from the study indicated that there is a direct relationship between waste management and financial incentives. Financial incentives should be regarded as a tool to maximize the efficiency of a solid waste management scheme (Wilson, 2014). Thorgesen (2003) explored the effect of financial motivation on waste separation and recycling using two controlled groups, where a group pays a fixed rate on waste collection and the other pays according to the weight of the waste, the results showed that the group which pays according to the weight of the waste recycled more.

Table 4.9: Financial incentives to separate my waste

I believe there must be financial incentives to separate my waste

		Frequency	Percent
	Agree	154	41.0
	Undecided	114	30.3
	Disagree	108	28.7
	Total	376	100

Tam and Tam (2008) adopted a step-wise incentive scheme (SIS) to reduce waste generation in Hong Kong, the study proved that SIS can help reduce wastage generation by up to 23.60%. In a study by Alessandro et al. (2011), it was established that the “pay as you throw” (PAYT) incentive scheme increases the willingness of respondents to recycle by over 12%, thereby supporting financial incentive as a strong tool to improve recycling attitude and waste management. There are environmental and economic benefits to be derived from recycling and

when people are aware of this, it makes it easier to engage in recycling activities, thus the students were asked if there is any benefit associated with it and the responses are presented in Table 4.10 below.

Table 4.10: Environmental benefits of recycling

Knowledge on environmental benefits of recycling		
	Frequency	Percent
Yes	212	56.4
No	164	43.6
Total	376	100.0

An awareness question to ascertain if the students know the benefits associated with recycling. More than 40% of responded no, which is an indication of the need for consecutive awareness programs on environmental issues. Furthermore, when the respondents were asked if they know of any environmental club within the institution, majority responded that they do not know (96%). Even though there is an environmental club named Universal greening organization (UGO), it seems this club has not made so much presence within the University community specifically on the issue of solid waste management.

4.4.1 Potential for recycling

To determine if there are recycling potentials of the solid waste generated in the institution, question was posed and respondents indicated that there is potential for recycling (88.3%) in waste generated in the institution, while only 11.7% noted otherwise. This is an indication that there is opportunity for waste reduction and diversion through recycling in the institution which should be adequately harnessed. To ascertain if the current solid waste management system of

the institution poses any problem, students were asked to indicate, responses revealed majority (64.9%) are of the opinion that the current system is appalling and poses problem as shown in Table 4.11.

Table 4.11: Problem posed by current waste management (Source: Fieldwork 2019)		
Do you think current waste management in the University pose problem		
	Frequency	Percent
Yes	244	64.9
No	132	35.1
Total	376	100.0

4.4.2 Potential solutions to problem of solid waste management in the institution

The solid waste management system in Univen is inefficient, to that end, the following were suggested by the respondents in Table 4.12.

The results show that the knowledge, perceptions and attitudes of students towards solid waste management is generally low, hence it is highly important to invest in instilling positive environmental behaviors as suggested in Table 4.12.

Table 4.12: Suggestions to improve waste management, (Source, Field work, 2019)	
1	The establishment of education and awareness program on Environmental and waste management, this can be in form of orientation or part of their academic curriculum, this will address the challenge of ignorance and motivate towards sustainable management of waste.
2	The provision of modern recycling labeled waste bins to separate waste from source, the conventional old waste bin is a barrier to waste separation.
3	Provision of more sufficient and user-friendly bins that are easier to open.
4	The need to employ more waste management team.
5	Strict monitoring process of waste bins provided, and sanction for any caught erring.
6	Timely collection of waste from residences and within campus, the frequency of collection should be increased.

4.5 Conclusion

The study found that the level of awareness of the students is low. The students do not engage in solid waste management practices of segregation, reduce, reuse, recycling and proper disposal. The low level of awareness on solid waste management practices of the students in terms of segregation, reduce, reuse and recycle had significant impact on their perception of solid waste management.

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CHAPTER FIVE

Solid waste generation, measurement and characterisation in the University of Venda: The potential for recycling

5.1 Abstract

The waste generation rate in tertiary institutions is on the rise due to increase in population of both staff members and students. However, institutional solid waste management in South Africa is yet to receive the required attention when compared to advanced countries. The measurement of the rate, characteristics and composition of solid waste in institutions is a fundamental pre-requisite towards creating sustainable and viable process of solid waste management systems across institutions as this provides an adequate and reliable information on the waste generated. This study aims to determine the variations of waste components at the University of Venda by characterisation of the waste generated. To this end, solid waste samples were collected from key activity areas (schools, cafeteria, administrative building and hall of residences) and characterised by using the ASTM D5321- 92 method for unprocessed municipal solid waste. The per capita generation of solid waste was high (1.7 kg/person/day) at the students' dormitory (residential) followed by 0.01 kg/person/day at academic buildings. The recyclable, compostable and non-recoverable components of the waste generated was found to be 69%, 26% and 5%, respectively. The result of the waste audit revealed a strong potential for recycling in the institution (69%). This would decrease the measure of waste sent to landfills and the issues emerging on grounds because of improper solid waste management, prompting a zero-waste campus. Other campuses with similar settings can gain from this contextual analysis and work towards a zero-waste campus. This study recognizes a need to actualize a sustainable SWM at the University of Venda.

Keywords: Characterisation, Higher educational institution, recycling, waste generation.

5.1.1 Introduction

A rapidly developing community coupled with increasing economic development and a rise in the standard of living, have quickened the rate of institutional solid waste generation (MSW), making its management difficult and challenging (Seo et al., 2004). To make solid waste management decisions that are sustainable requires the understanding of the composition of wastes and how they were generated, since the components of a waste differ from source to source (Tchobanoglous, 1977). Decision makers conduct waste characterisation studies to understand the waste flow to make it possible to design waste management schemes for different regions (Chang and Davila, 2008).

A thorough comprehension of the composition, characteristics and procedures of waste generation is essential for an effective solid waste management. Unique consideration ought to be paid to the source of waste generation since the attributes and generation of the waste vary as per their source (Coker and Achi, 2016). One of the serious issues in solid waste management is to decide the amount and compositions of waste generated in academic institutions. The plan, execution and administration of the solid waste management process require exact data on the amounts and attributes of the solid waste to be managed. Universities play important role in teaching and learning and are saddled with the social responsibility to teach the community on how to overcome the problems of poor solid waste management to set an example to both the students and the community. The significance of universities in propagating sustainable development through various significant declarations, such as the “Talloires Declaration (1990), the Halifax Declaration (1991), the Swansea Declaration (1993), the Kyoto Declaration (1993), the Copernicus Charter (1993), Students for a Sustainable Future (1995)’’, has been reported by Lozano et al. (2011). Waste characterisation studies in higher institutions have been reported to bring viable changes in solid waste Management. Mbuligwe (2002) recorded a recover potential

of 71% in three tertiary institutions of learning in Tanzania. Likewise, the study of Emenike et al. (2013) enabled the UKM Institution in Malaysia considered utilising vermi-composting method to sustainably manage their high generation rate of organic waste. In the Universität Jaume, Malaysia, Gallardo et al. (2016) conducted a waste generation and characterisation study and the results obtained were useful in designing strategies to enhance and upgrade their University's waste management system, this led to increased waste separation at source to minimize the amount of waste generated. Kassaye (2018) in the study at Hamaraya University, Ethiopia, reported that the waste characterisation study conducted has been advantageous in the designing and implementation of an integrated solid waste management system for the institution. Characterisation studies are lacking in many South African Universities and this suggests the need to know the compositions of waste and devise appropriate means of handling those waste. Hence, this study presents the waste characterisation and generation at the University of Venda with a potential of recycling and recovery.

5.1.2 Methodology

5.1.3 Sampling area and activity grouping of buildings

The University of Venda is located in Limpopo, South Africa. It is one of the major University campuses in Venda hosting 9 schools, 11 students' hostels, two staff members and student administrative buildings. It has 16,702 registered students for the 2019/2020 academic year and 490 members of staff for the 2019/2020 academic year. Buildings within the University were grouped into structures (a structure refers to a group of buildings designed for a for specific utility). The structures were further classified into four zones (activity areas) namely: (i) academic and research, (ii) cafeteria (iii) residential area (iv) administrative buildings. The structures in each respective zone were grouped together based on the nature of activity. Characterisation study was carried out at the selected key activity areas, which are: School of Human and Social

Sciences, School of Environmental Sciences, School of Education, Students Residences, cafeteria and new administrative building.

5.1.4 Sampling for characterisation

Sampling was conducted using the ASTM D5231-92 (2008) standard test method for unprocessed municipal solid waste. The ASTM specifies that: 1) the number of samples should be determined according to statistical criteria; 2) the sub-sample to be sorted should be approximately 4 times in weight than the initial sample; 3) sample selection should be at random and performed over a period of 5 to 7 days (AbdAlqader and Hamad, 2012). The samples were manually hand-sorted into categories of six namely: paper, aluminum, glass, plastic, organic waste and others and the average weights of each component is determined. Samples were collected between May 2019 and August 2019.

5.1.5 Estimation of daily waste generation rate

The daily waste generation rate on campus was determined by direct measurement at source from each activity area. Waste from designated bins were collected every morning for each activity area and assembled or gathered and then transported to a designated point in the University premises for weighing and sorting. The measurement for each activity area was conducted for three weeks. The measurement was carried out utilizing a standard platform weighing scale of 300 kg capacity. The weight of the waste bins is subtracted from the weight of the waste.

5.1.6 Analysis of waste composition

All the recorded information was imputed in a standard spreadsheet for further analysis. The percentage category of waste in each activity area was determined using equation 5.1 while the per-capita waste was computed using the relation in equation 5.2 (Vega et al., 2008).

$$percentage\ recyclable = \frac{PC}{PL} X100 \quad 5.1$$

$$Per - capita\ waste = total\ waste\ generated\ /no.of\ persons\ X\ no.of\ days \quad 5.2$$

5.2 Results and discussions

5.2.1 waste measurement at halls of residences

Tables 5.1 & 5.2 show the waste generated in the male and female halls of residence, respectively which are allocated to basic degree students (Figure 5.1). Riverside residence is the only postgraduate hall of residence which accommodates both male and female students. From Tables 5.1 & 5.2, F4, girls residence records the highest amount of waste generated per day (339.8 kg). This could be attributed to the population of those residing in the hall, and it is important to note that during field observation, it was observed that the F4 residence has a lot of squatters and residents above the ideal capacity which is in an unusual rate than the other residences. However, the new residence female recorded the least daily waste generation rate (212.3 kg). This could be attributed to the fact that the residence is relatively new and only one third of the room was allocated. The F3, boys' residence also recorded the highest daily waste generation rate (349.3 kg). This in similar fashion with the girls due to squatters, thereby generating waste and utilizing resources above the ideal the residence could cater for.

Table 5.1: Waste generation at female residences													
Residence	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**	**Day 8**	**Day 9**	**Day 10**	**Sum**	**Average**	**Standard deviation**
Lost City	332	351	387	384	379	251	276	312	294	302	3268	326.8	47.6
New Residence	219	196	228	187	198	232	247	216	188	212	2123	212.3	19.9
F4 residence	321	297	351	389	401	287	345	332	376	299	3398	339.8	39.8
F5 residence	283	348	356	323	298	312	349	332	296	331	3228	322.8	24.9
Bernard Ncube	226	294	321	346	284	291	349	290	329	347	3077	307.7	38.5
Mango Groove	183	288	189	290	312	284	307	285	196	289	2623	262.3	51.2

Table 5.2: Waste generation at male residences													
Residence	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**	**Day 8**	**Day 9**	**Day 10**	**Sum**	**Average**	**Standard deviation**
Lost City Boys	247	288	324	298	279	354	331	285	302	298	3006	300.6	29.9
New Residence	187	178	198	234	189	221	237	232	199	182	2057	205.7	23
F3	348	376	421	287	265	345	321	399	347	384	3493	349.3	48.6
Carousel	189	162	245	223	287	294	187	207	221	232	2247	224.7	42.3
Riverside	200	205	203	214	226	208	211	206	213	219	2105	210.5	7.8

Figure 5.1: Waste weighing process at residences (Source: Field work)

From Table 5.3, the population represents the ideal capacity that each hall was designed to accommodate, however, the situation on the ground is far from the ideal whereby the number of students residing in each hall are far beyond the capacity because of squatters. It is apparent that the number of residences and their capacity is not enough to cater for the entire student population. This results in crowded residences and the over-stretch of utilities such as water, waste-bins with their resultant environmental implications. According to Mr. Mbatha, who is the supervisor for housing, the challenges being faced by the residences have to do with the number of people living there, which the available infrastructures cannot cater for. Waste generation differs as a result of affluence. However, there are significant differences between regions and countries. The average per-capita waste generated in the residences was found to be 1.7 kg/capita/day. This is high, in comparison with the study of Coker and Achi (2016), where students generate waste in the range of 0.3 to 0.4 kg /capita/day. One of the possible reasons for the high generation rate could be attributed to the fact that each residence accommodates twice as much

its designed capacity. However, the generation rate falls within the per capita waste generation rate in sub-Sahara Africa which spans between 0.09 to 3.0 kg/ person/day (World Bank, 2012). The results of waste generated in both male and female residences revealed that the F4 and the F5 residences in male and female halls are the highest generator of waste, while the least generator of waste are the new residence male and new residence female. Reason for this could be attributed to the fact that the F4 and F5 residences have the highest population and the new residences have the least population.

Table 5.3: Per-capita waste generation rate at residences

Residence	Population	Waste generated per day	per capita /day
Lost city boys	180	300.6	1.6
Lost city girls	180	326.8	1.7
New residence boys	328	205.7	0.6
New residence girls	328	212.3	0.6
F3 boys	405	349.3	0.8
F4 girls	405	339.8	0.8
F5 girls	134	322.8	2.4
Bernard Ncube	58	307.7	5.3
Carousel	123	224.7	1.8
Mango groove	124	262.3	2.1
Riverside	256	203	0.7
Average	285.2	226.5	1.7
Total	3055	2521	

5.2.2 Waste audit/ Characterisation

A waste characterisation study is important to inform effective planning and sustainable waste management techniques. Opportunities for waste diversion from landfill are being assessed. For the residences, Riverside waste was selected for the characterisation study since it accommodates both male and female students. Composition of waste generation rate at Riverside residence over a period of three weeks (Appendix 1a -1c) is presented in Figure 5.2 below.

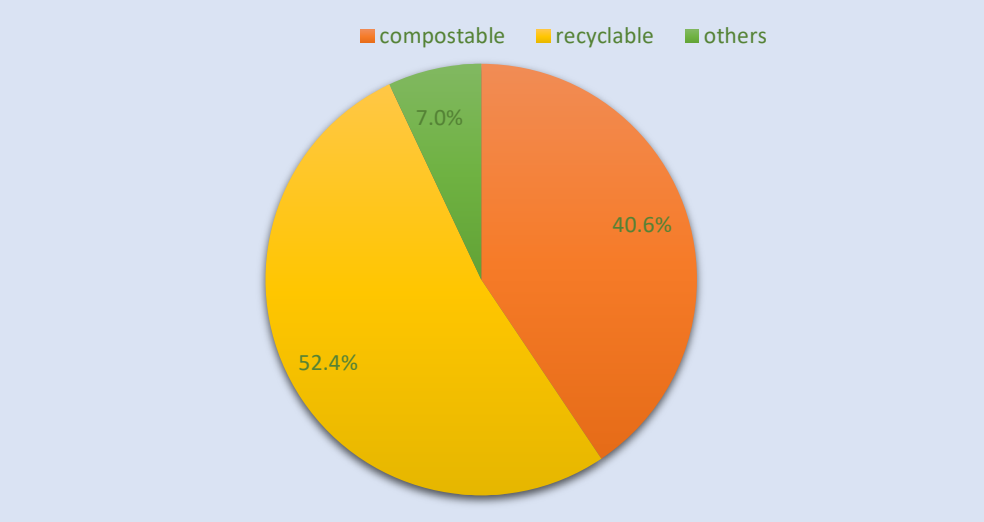

Figure 5.2: Composition by percentage in Riverside (Source: Field work, 2019)

As illustrated in Figure 5.2, recyclable waste (52.4%) represents the highest percentage of waste generated followed by compostable (40.6%). Aragaw et al. (2016) reported 38.9% recyclable waste and 57.4% compostable waste in their study in Bahir Dar Institute of Technology. The composition of waste generated is usually influenced by several drivers such as affluence, knowledge and climatic conditions amongst others (Coker and Achi, 2016). Vega et al. (2008) indicated that about 65% of solid waste generated in academic institutions can be recycled. The

characteristics of waste (kg) over 3 weeks at Riverside are presented in Table 5.4 below. A closer look at the material breakdown in Table 5.4 reveals food accounts for the highest in kilogram (82.5 kg), and the least is other wastes (14.1 kg). It is not surprising that food waste constitutes the largest percentage of waste generated in the residence because students usually cook in their residence. It can be seen from the waste audit outcome that recyclable waste accounts for over 50% of the waste stream and this signifies that there will be a remarkable reduction in waste sent to landfills if the potential to recycle these recyclables is optimized.

Table 5.4: Waste audit at Riverside per kg (Source, Field work 2019)

Materials	Category	1st week	2nd week	3rd week	Mean	Percentage	Standard deviation
Recyclables	Paper	25.7	25.4	23.7	24.9	12.3	1.07
	Plastic bags	18.1	20.3	19.4	19.2	9.5	1.10
	Plastic bottles	26.9	25.3	29.4	27.2	13.4	2.06
	Aluminum cans	20.2	17.8	22.6	20.2	9.9	2.4
	Glass bottles	15.2	14.8	14.3	14.7	7.3	0.45
Compostable	Organic materials, food leftovers,	80.2	87.5	79.8	82.5	40.7	4.33
Others	Non-recoverable	13.9	14.6	13.8	14.1	6.9	0.43
Total		200.2	205.7	203	203	100	2.75

This finding is consistent with another research carried out by Chee (2012) in Malaya University where the waste audit reported include: organic food waste (33%), mixed papers (14%), plastic bags (10%) and other plastics (10%). Findings of similar study at the University of Washington resonate with the results of this study highlighting that the three major components of waste generated from halls of residences are organics, plastics and paper. Figure 5.3 shows the characterisation at Riverside residence.

Figure 5.3: Waste characterization process (Source: Field work)

A research conducted at the North-West University (Potchefstroom Campus) in South Africa found that about 60% to 85% of the waste generated at the residences had the potential to be recycled (Roos, 2016). An estimation of per capita waste generation rate in Riverside residence gives an average of 0.7 kg/capita/day which is at the threshold of the South African solid waste generation per capita per day (Emenike et al., 2013). The result of the waste audit is used in extrapolating the annual waste generation rate which gives an estimate annual rate of 44.4 tons per year (see equation 5.3, Coker and Achi, 2016) as given in the Table 5.5 below. This is further used to derive the annual recyclable and compostable waste in Riverside which is given as 17.1 (recyclable) and 23.4 tons (compostable) respectively as shown in Table 5.6.

$$\boldsymbol{Daily\ waste\ generation\ rate\ (tons) = \frac{per\ capita\ X\ total\ population}{1000}} \qquad (5.3)$$

$$\boldsymbol{Annual\ waste\ generation\ (tons) = daily\ waste\ generation\ (tons)\ X\ 247\ days} \qquad (5.4)$$

Note: {247 days = No. of days in a year (365) – public holidays (14 days) - weekends (104 days)}

Table 5.5: Annual recyclable and compostable waste in Riverside				
Activity area	Daily rate per persons (kg)	Total population	Daily waste generation per Ton	Annual waste generation rate X 247 (tons)
Riverside residence	0.7	256	0.18 (179kg)	44.3
	Annual waste generation rate in ton		Percentage daily generation rate	Fraction recyclable per year
Compostable	17.9		40.6%	17.9
Recyclable	23.2		52.4%	23.2
Non-recoverable	3.1 ton		7%	3.1

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5.2.3 Waste audit at the cafeteria dining section

The characteristics of waste per kg at the cafeteria over 3 weeks (see appendix 2a-2c) is presented in the Table 5.6 below. The result of the waste audit conducted at the students dining section of the school cafeteria reveals that 55.7% of the waste are recyclables, which include food packages, plastic bottles and cold drink cans. The compostable waste accounts for 44.3% which includes food remnants, bones of fish and meat. Zotesso et al., (2015) reported that organic waste represents 82.6 % of the total waste generated in the cafeteria of which school?? Which is higher than that of this study (44.3%). Similarly, Sales (2009) reported 93.2% of waste generated from three popular public cafeterias in Rio de Janeiro were categorised as organic. The reason for this lower value could be attributed to the fact that Univen cafeteria is not as large as those universities and it is still a developing institution compared to other established institutions. However, this shows that almost all waste produced here is resourceful. Organic waste shows

the highest waste generated as per kilogram and lots of food packaging waste as shown in Figures 5.4 a and b).

Figure 5.4: Percentage waste at dining (Source: Field work)

5.2.4 Average daily waste generation rate at the dining cafeteria.

Table 5.6: Average daily generated waste at dining cafeteria

Cafeteria Dining							
Material	**Category**	**1st week**	**2nd week**	**3rd week**	**Average**	**Standard deviation**	**Percentage**
Recyclables	Paper	1.3	1.4	1.8	1.5	0.3	1.7%
	Plastic bags	3.5	2.1	3.8	3.13	0.9	4%
	Plastic bottles	20.2	18.7	24.8	21.2	3.2	24%
	Aluminum cans	18.5	21.1	16.4	18.6	2.4	21%
	Glass bottles	5.5	3.2	3.8	4.16	1.2	5%
Compostable	Food leftover	45.3	38.2	31.5	38.3	6.9	44%
Others	Non-recoverable	0.2	0.4	0.2	0.26	0.1	0.3%
Total		**94.5**	**85.1**	**82.3**	**87.3**	**6.3**	**100%**

Table 5.7: Waste generated at kitchen (Source: Fieldwork 2019)						
Material	Category	1st week	2nd week	3rd week	Average	Percentage
Recyclables	Paper	30	38	41	36.3	18.5
	Plastic bags	12.8	17.4	19.3	16.5	8.4
	Plastic bottles	29.5	34.4	39	34.3	17.5
	Aluminum cans	20.4	21.9	23.7	22	11.2
	Glass bottles	2.2	2.7	3.1	2.7	1.3
Compostable	Food leftover	70.8	78.7	89	79.5	40.5
Others	Non-recoverable	5.0	4.7	5.2	4.9	2.6
Total		170.7	197.7	220.1	196.2	100

5.2.5 Waste audit at the Kitchen Section

The material composition of the waste characterisation at the kitchen over the period of three weeks (Appendix 3a-3c) is as presented in Table 5.7. The result in Table 5.7 presents the waste from the kitchen audit which shows that 41% of the kitchen waste are compostable, this ranges from all pre-consumer organic food waste such as spinach, cabbage, tomatoes, also recyclable waste accounts for 56%, this is made up of papers, card board, boxes, food packaging box and plastic bottles. Clearly, there is a great potential for recycling and re-use of compostable materials as fertilizers in the cafeteria kitchen waste. Unfortunately, this goes to the landfill and occasionally, some outsiders come to collect these food waste to use on their farm according to the kitchen manager.

Majority of institutions across USA utilise organic waste from their dining room and kitchen areas to produce compost. The Appalachian State University utilises food waste through a composting system that converts about 105 tons of waste per year to compost (Sullivan, 2010). Araujo et al.

(2012) in their study, conducted at University of São Paulo reported that per day, 233 kg of waste were generated in the restaurant established in the school, of which 84% represented organic matter. A similar study at the University of Tabriz, Iran could reduce waste on campus by 80% by producing compost and the recycling of recyclables within their University campus (Thagizadeh et al., 2012). The study by some students in an India campus, Calicut, went further to generate bio-gas from the organic waste on campus, they reported that a daily generation of 200 kg organic waste produces 50 kg of biogas (1.29 cylinder/day). This is highly resourceful as an alternative clean source of energy (Mani et al., 2013).

5.2.6 Waste audit result of selected schools and administrative building

From the outcome of the waste audit process in the administration and academic buildings, the larger proportion is represented by paper of which 45% of paper waste is potentially recyclable (Tables 5.8 & 5.9). The School of Management Sciences (Appendix 5a-5c) recorded the highest generation of paper waste at a percentage of 54.6% which is followed by plastic bottles at 12.2% (see Table 5.8). This result is in line with the study of Vega et al. (2008) at the Universidad Autonomous Baja California (UABC) Mexicali campus, who found that waste generated in school and administrative buildings constituted mostly paper of which 33% is potentially recyclable. The high record of paper waste in the schools reflects the activities which go on in a typical academic area with lots of students and staff using paper in their offices and classrooms. Also, paper from cardboard, boxes and packages also add to the figure.

Currently, there is no separation from other types of waste, hence, the contamination of papers. The School of Environmental Science recorded the lowest generation of paper waste (35.3%). The possible reasons for this could be due to the fact that the staff and students of the School of Environmental Science are more conservative towards the use of resources due to their environmental knowledge, and this has reflected in their paper usage. Also, the population of staff

and students that contributed to the waste generation vary from school to school and this is also a determinant factor of the amount of waste generated. There is an established link between population and waste generation rates, reporting that the higher the population, the higher the waste generation rate scholars (Senzige and Makinde, 2015). However, the School of Environmental Science recorded the highest amount of plastic bottle waste (22.2%). This could be implicated as a result of the mini food mart that operates within the School of Environmental Science, as this attracts students from other schools who contribute to the quantity of waste generated.

The percentage recyclable waste from the audit in the schools is over 70%. The research carried out by Mbuligwe (2002) on solid waste management within three campuses in Tanzania, bears similarity to the result in this study; a waste recovery potential of 71.6% to 86.8% was recorded from the schools. This shows there is high potential for recovery. Gakungu et al. (2012) in their research have proven that there is high potential for waste to be diverted to profitable use to a high degree in school faculties through recycling and composting activities. The School of Education and Environmental Science were found to generate highest portion of plastic bags and plastic bottle respectively. These plastic bags are contaminated from source, a local waste picker stated that the contamination makes sorting difficult and requires extra cleaning process after sorting. The volume of plastic bags in the waste generated at the University Tecknologi Malaysia was also high (plastic 17.2% and plastic bags 31.8%), which prompted an establishment of the Green office initiatives in the University (Zen et al., 2016). This indicates the importance of source separation in solid waste management which reduces the rate of contamination of recoverable waste components as examined earlier in this study.

Table 5.8: Mean waste generated at Schools							
Characterisation of waste across schools							
Material	Composition	Mean and standard Deviation			Percentage waste		
		Management	Education	Environmental science	Management	Education	Environmental science
Recyclables	Paper	15.2 ± 1.7	12.2 ± 4.7	8.2 ± 1.2	54.6	37.3	35.3
	Plastic bags	3.1 ± 1.3	5.3 ± 1.1	3.3 ± 0.8	11.1	16.3	14.2
	Plastic bottles	3.4 ± 1.2	5.8 ± 0.6	5.3 ± 1.1	12.2	17.7	22.2
	Aluminum	1.6 ± 0.2	1.5 ± 0.9	1.1 ± 0.8	5.7	4.5	4.7
	Glass	0.4 ± 0.2	0.8 ± 0.2	0.4 ± 0.1	1.43	2.5	1.7
Compostable		3.2 ± 1.0	5.9 ± 0.9	3.8 ± 0.7	11.5	18	16.3
Other		0.9 ± 0.8	1.2 ± 0	1.1 ± 0.2	3.2	3.7	4.7
Total		27.8 ± 2.0	32.7 ± 4.9	23.2 ± 1.7	100	100	100

5.2.7 Waste audit at the main administrative building

The waste audit result at the main administrative building (Appendix 7a-7c) is presented in Table 5.9, paper waste was found as the highest percentage of the waste stream at a percentage of 55.6%, followed by plastic bottles at 19.2%, while food waste was only 6.5. Table 5.9 gives an overview of the recyclable, compostable and non-recoverable components in the administrative building and schools.

Table 5.9: Mean waste generated at Administrative Building

		Administrative Building		
Material	Composition	Mean Weight/kg/day	Std. Dev	Percentage waste generation
Recyclables	Paper	15.3	0.9	55.6
	Plastic bags	2.1	0.3	7.6
	Plastic bottles	5.3	1.1	19.2
	Aluminum	1.9	0.2	6.9
Compostable	Organic waste	1.8	0.2	6.5
Other		1.1	0.3	4
Total		27.5	1.7	100

The per capita SW generation at the selected schools was calculated from the total generation rate and the number of registered students and staff in 2019/2020 academic year as in Table 5.10, which gives a value of 0.01 kg to 0.012 kg/capita/day. The School of Environmental Sciences recorded the least annual waste generation rate (5.7 tons) per year and the School of Education has the highest rate of waste generated (8.1 tons) annually. The reason for this could be due to the fact that the School of Education has the highest number of staff and students compared to the other schools. The mean of daily waste and extrapolated annual waste generation is presented in Table 5.10.

Table 5.10: Annual waste generated at schools											
Daily rate per persons (kg)			**Total population (staffs and students)**			**Daily waste generation per tons per kg/person x total population/1000**			**Annual waste generation rate X 247 (tons)**		
Management	Edu-Cation	Environ-Mental science	Management	Edu-Cation	Environ-Mental science	Management	Edu-Cation	Environ-Mental science	Management	Edu-cation	Environ-Mental science
0.01kg	0.01kg	0.012kg	2795	3377	1950	0.0278 ton	0.033 ton	0.0232 ton	6.9	8.1	5.7

Table 5.11 below gives the summary of the average daily waste generated in all selected activity areas. The University of Venda on average generates about 3,397kg (3.39 tons) per day (Table 5.12), the volume of daily waste generated in Univen was found 3 times higher than the daily waste generation on Autonomous University of Baja California (UABC) with 1 tons/day (Vega et al., 2008).

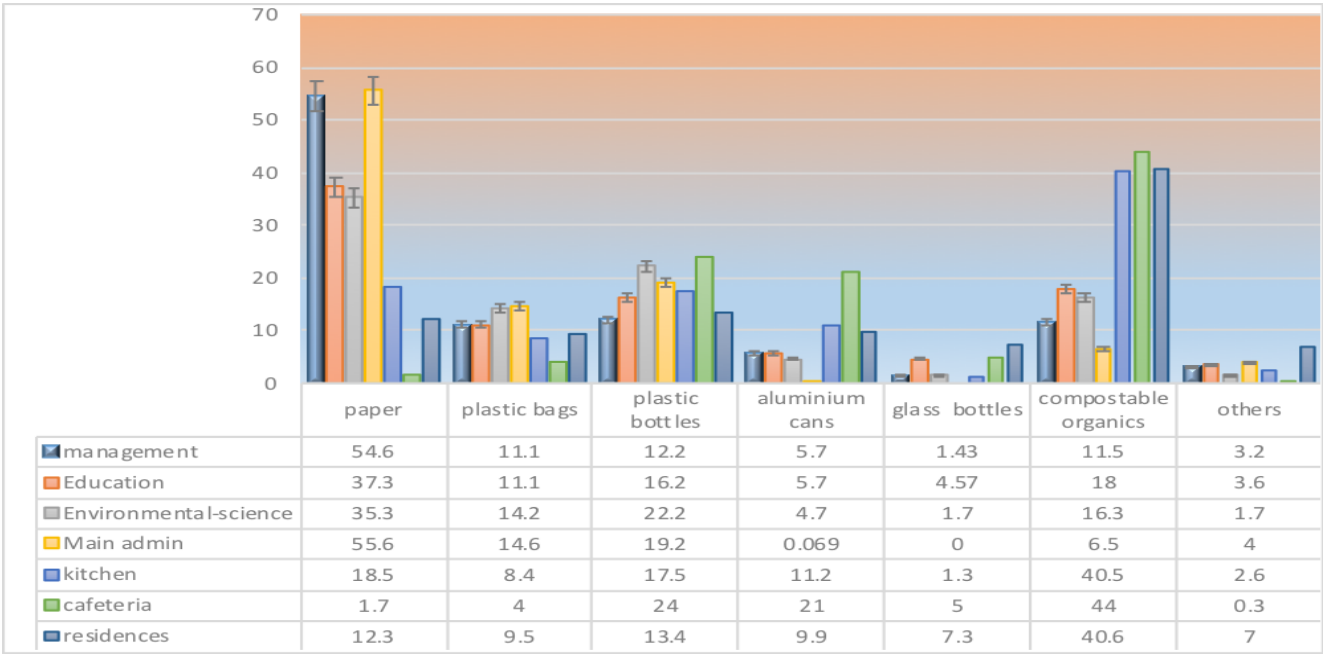
Table 5.11: Average daily waste generated in all activity areas

Activity area	**waste generated per day/kg**
Residences	3062 ± 56.4
Management	27.8 ± 2
Education	32.7 ± 4.9
Environmental Science	23.2 ± 1.7
Cafeteria	27.9 ± 6.3
Kitchen	196.2 ± 24.7
Admin	27.5 ± 1.7
Total	3397 ±133

5.2.8 Percentage composition across all activity areas

From the overall waste composition as presented in Figure 5.5, all the activities area has a recycling potential of above 50% and this is a good indication that waste generated across the campus will be significantly reduced if recyclables are targeted for recovery. Also, the generation of waste varies between different schools and the main administration building. Paper waste is most recorded kind of waste across the schools, this is owing to the fact that this is an academic activity area and the bulk of the paper comes from examination and test scripts, cardboards, A4 paper and calendars. The main administrative records, the highest generation of papers at 55.6%. This is largely due to the nature of the administrative work. Furthermore, the compostable waste

also records a high proportion showing that if the institution can target both recycling and compostable waste, the institutional waste could be reduced by 96%. There appears to be a trend in types of waste generated across the activity areas, the residences, kitchen and cafeteria generates the highest amount of organic waste (pre-consumer and post-consumer food waste), therefore strategies to harness the organic waste is much more optimal in those areas, researchers on solid waste in China have suggested that source separation of food waste is a key solution to the problem of solid waste (Tai et al., 2011; Zhang et al., 2016). Moreover, paper waste trends are higher in the schools and administrative buildings, therefore, strategies on reduction of paper waste should be intensified in these areas for optimum results.



	paper	plastic bags	plastic bottles	aluminium cans	glass bottles	compostable organics	others
management	54.6	11.1	12.2	5.7	1.43	11.5	3.2
Education	37.3	11.1	16.2	5.7	4.57	18	3.6
Environmental-science	35.3	14.2	22.2	4.7	1.7	16.3	1.7
Main admin	55.6	14.6	19.2	0.069	0	6.5	4
kitchen	18.5	8.4	17.5	11.2	1.3	40.5	2.6
cafeteria	1.7	4	24	21	5	44	0.3
residences	12.3	9.5	13.4	9.9	7.3	40.6	7

Figure 5.5: Waste composition across activity areas

One-way Anova was used to test if there are significant differences in waste generated across activity areas (see Table 5.12).

Table 5.12: One-way ANOVA across activity areas

Groups	*Count*	*Sum*	*Average*	*Variance*
Riverside	8	402.1785	50.27231	4175.539
Cafeteria	8	392.3546	49.04432	4118.666
Kitchen	8	174.672	21.834	872.5332
Education	8	65.65675	8.207094	112.7016
Environmental	8	46.53047	5.816309	56.37555
Management	8	55.6397	6.954962	93.30472
Administrative building	8	55.07374	6.884217	93.27154

Source of Variation	SS	Df	MS	F	P-value	F crit
Between Groups	19473.52	6	3245.587	2.385861	0.042188	2.290432
Within Groups	66656.75	49	1360.342			
Total	86130.27	55				

A Significant difference ($P<0.05$) in the mean values of the waste generated at different activity place across the University was profound (Table 5.12). This implies that there are differences in amount of waste generated at different activity areas within the University.

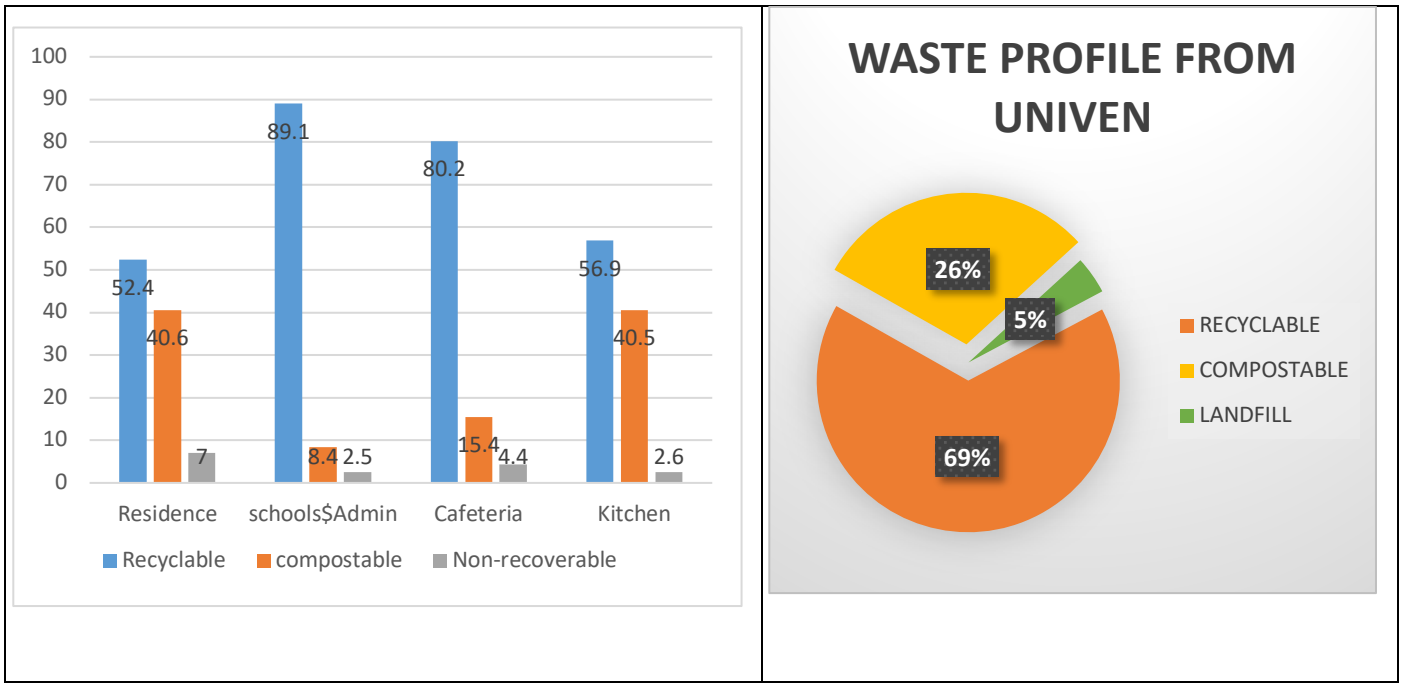


Figure 5.6: Waste profile of Univen

5.3 Conclusion

The average daily generation of solid waste in the selected area of Univen under study is 3.4 tons. The waste from Univen indicates a high recovery potential from waste generated in the residences, cafeterias, kitchen, school and administrative buildings. The highest portion of waste lies within the potentially recyclable categories which as an aggregate, represents 52.4% in the case of residence, 80.2% in the cafeteria, 56.9% in the kitchen and 89.1% in the schools and administrative building. Also, the compostable organic waste from the activity areas accounted for 26%. The following studies bear similarity, waste audits in three universities in Canada revealed, that compostable organic waste accounted for 17-29% of the entire campus waste-stream (Van Adrichem, 2007; Thompson, 2005).

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CHAPTER SIX

Operative solid waste management practices in the Institution: Way forward to sustainable practices

6.1 Abstract

The sustainable Management of solid waste is a global concern and a phenomenal problem in institutions of learning due to the diverse activities that take place in them. The study aims to examine the existing waste management practices at the University of Venda, with the goal of proposing sustainable waste management strategy. Research method included a mixed approach of personal field observation and structured interviews with different stakeholders to gather data on the operative waste management system in the institution. The institution's current waste management system was assessed against legal standards (Waste Management Act 2014). The SWOT analysis was utilized to analyse the strength, weaknesses, opportunities and threats in the present waste management system in the institution, and a sustainable waste management system was designed. The findings from the study revealed that the existing solid waste management practices at the University of Venda is inefficient and inadequate due to lack of awareness and improper collection, lack of segregation, lack of campus storage facility for recycling, lack of recycling and recovery of recoverable waste. A sustainable waste management framework was designed for the institution through an integrated waste management approach, as this will serve as a way forward from the current solid waste management practices to sustainability.

Keywords: Solid waste management, waste-recovery, reduce, reuse, recycle, higher education

6.1.1 INTRODUCTION

Solid waste management is associated with the process of controlled generation, proper storage, sustainable collection, transportation, processing and disposal of solid waste with careful consideration of public health, resource conservation, economics and environmental conditions (World Bank, 2012). However, the solid waste management system is often inefficient and weak as a result of scientific methods and new initiatives, population and poor standard of living (Sorme et al, 2019). There is a need to develop sound practices in waste management by incorporating an integrated waste management approach to remediate the inefficient waste management practices. The sound practices of the waste management refer to policies and waste management initiatives which balance effectively between the environment and the people. Higher institutions of learning are often a representation of mini-cities because of various departments and diverse activities that take place (Vega et al., 2008). They are regarded as role models in their respective communities, as well as frontiers in issues of environmental responsibility (Velazquez et al., 2005). Solid waste management practices, initiated by higher institutions of learning have greater chance of being-absorbed by the community at large, because higher institutions generally are placed in-high-esteem by the community (Vega et al., 2008). The results of integrated solid waste management programme implemented at Universidad Autónoma Metropolitana, Mexico over a period of 3 years were highlighted by Espinosa et al. (2008). The findings indicated that waste segregation into recyclable and non-recoverable have yielded tremendous benefits like reduction of waste and financial benefits as a result of recycling aluminum cans, plastic bottles and glass. Similarly, the positive benefits of integrated waste management through the adoption of Triple R: reduce, reuse and recycle in HEIS was discussed by Jibril et al. (2012). The present study proposes a sustainable waste management system in the institution, through the analysis of the strength, weakness, opportunities and threats of the existing waste management system for determining the best options for a sustainable waste management system.

6.1.2 Methodology

6.1.3 Study area

The University of Venda is a multi-cultural educational institution of about 20,000 persons from different countries including students, staff members and visitors. The waste management practices of the institution are guided by the South Africa's law and regulations. The institution is saddled with direct responsibility for the collection and transportation of waste generated on campus for final disposal. The existing solid waste management in the institution is waste generation, collection, transportation and disposal.

6.1.4 Data collection

The study utilized a descriptive method using a mixed approach of interview, questionnaires and personal field observation for the collection of data. Primary field survey was conducted by the researcher over a period of three months (August to October, 2019). The field survey was used to gather data through personal observations, interview with the unit heads of ground and cleaning department, facility manager, transport officer and unit head of sweepers. The survey enquired about the current waste management practices in the institution on the types of waste generated, quantity of waste, challenges and shortcomings of solid waste management in the institution.

6.1.5 Data analysis

The existing solid waste management practices in the institution was compared against legal standards. The assessment of the current waste management practices at Univen were performed using the SWOT framework to give a better understanding of the weaknesses and threats to solid waste management in the institution and highlight the strength and opportunities internally. Major emphasis was laid on ways to harness the opportunities and strength for a sustainable solid waste system in the institution. Visual interpretation of data was presented using tables and charts.

6.1.6 Overview of waste management system in Univen

Solid waste management initiatives and intervention are pivotal to a sustainable campus (Smyth et al., 2010; Tu et al, 2015). The institution has an existing lay-out practices and routine about waste management. The existing waste management routines practiced at the institution are waste generation, ground cleaning, waste storage prior to collection, waste collection, waste transportation and final disposal at landfill as shown in Figure 6.1. Currently, Univen has no formal waste management plan, current practices at the institution indicate some form of commitment to a safe learning environment. However, little had been done to optimize sustainable waste management practices in the institution. The perception and behavior of students and staff, with regards to solid waste management is yet to be explored, the amount and composition of waste was yet to be known, and not much has been attempted to upgrade the institution's waste management practices sustainably. These have been identified as shortcomings, which needed interventions.

6.2 Results and discussions

6.2.1 Existing waste management process in Univen

The current institutional waste management process (Figure 6.1) does not include any form of waste segregation, recycling and recovery or treatment process incorporated. Waste generated and litters are taken care of by the sweepers apportioned to different activity areas. According to the head of cleaning department, sweeping is to be done twice daily, early in the morning and late in the afternoon, but it is of doubt if this is the practice. Field observation revealed that sweeping is done mostly once daily and takes place in the morning at about 9.30 am in the residences and about 8 am in the schools. When some of the sweepers were asked if they sweep twice daily, some responded that sometimes it is still clean so there was no need for them to sweep again. Some of them however, noted that the students intentionally litter the ground to make sure they

are frustrated, because they have the mindset that the cleaners are paid to make the campus tidy. It is worthy of note that they didn't deny that the practice of sweeping twice daily is dysfunctional.

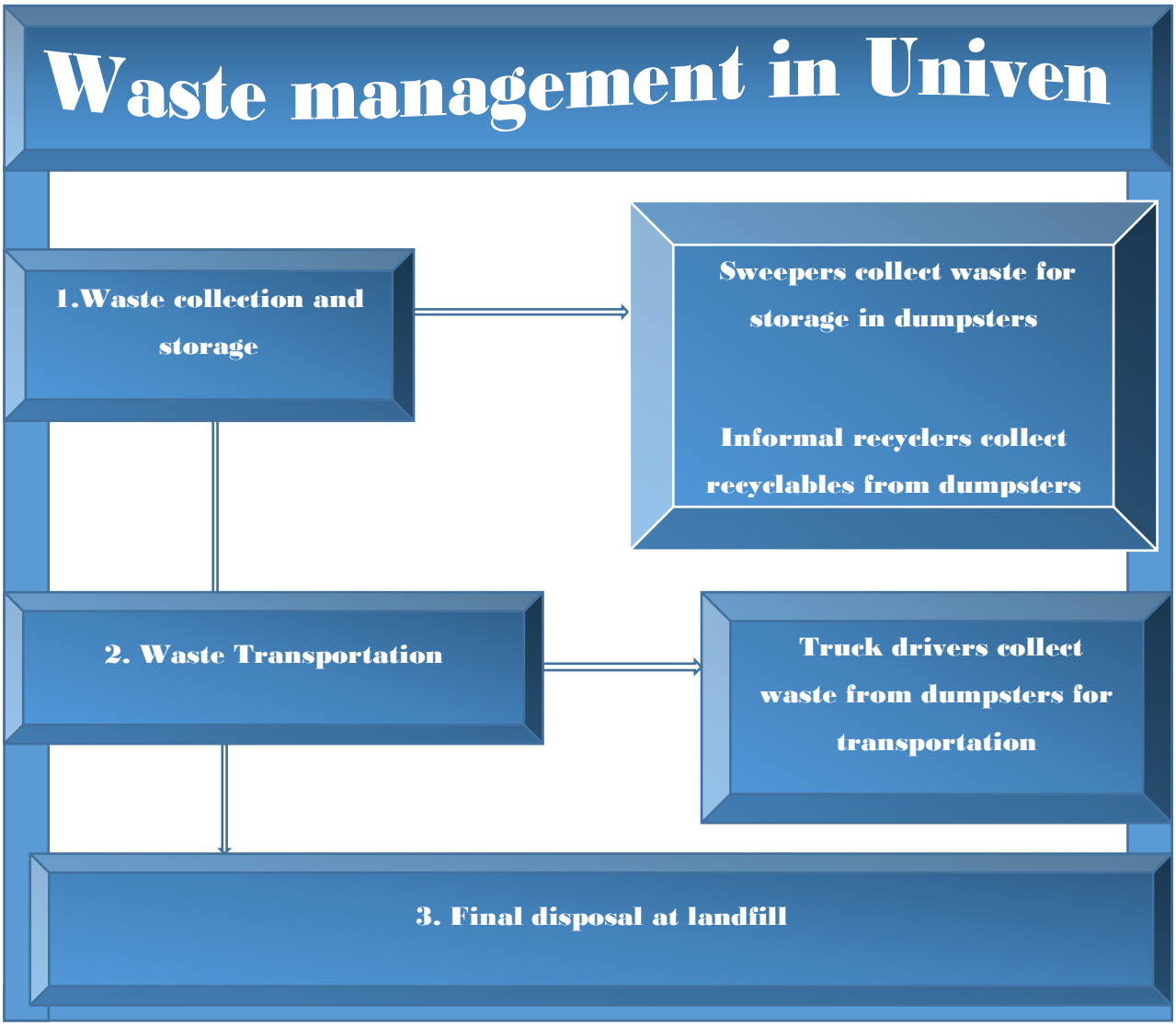

Figure 6.1: Current waste management system in Univen (Source: Field work, 2019)

As observed, the residences on campus are not clean, this is also supplemented with responses from the questionnaires, where majority of respondents mentioned that the student hall of (there

are nine) residence are one of the untidiest areas, meanwhile other areas like the library, administrative buildings and clinic are relatively clean. The Head of the cleaners lamented that they have limited numbers of staff due to financial constraints and this greatly impact their work. Additionally, it is of great concern the recent infestation of the campus with animal feces and this is because of dogs coming into the institution and constituting nuisance together with the indiscriminate feces everywhere in an academic environment. They also scatter the content of the bins on the floor in search of what to eat, this is not a pleasing sight and unacceptable for an academic institution.

6.2.2 Waste storage and collection

A very crucial aspect of waste management is the method in which waste is stored and collected before disposal. It is an indication or a good assessment of how well the institution is concerned with the issue of waste management and their quest for a healthy environment. In a means to appraise the waste collection and storage practices of the institution, the relevant personnel in respect of this was contacted to know the method of storage and frequency of collection system. In the residences, it was observed that the students drop their waste into designated waste bins provided on each level of the building. This is ideally to be collected by the cleaners twice daily and stored in the big dumpster (Figure 6.2) of about 4 cubic meter capacity.

Figure 6.2: 4 cubic meter dumpster on-site storage

Waste is firstly stored in waste bins of 85 L capacity and later collected by the cleaners to a bigger dumpster prior to disposal in the landfill. Likewise, the bins at other locations in the institution such as the street bins are collected and stored in the bigger dumpster. Also, there are also bins in respective offices which are collected every morning and emptied to bigger designated bins. According to the supervisor for grounds and cleaning, there are hundred 85 L bins and 32 dumpsters serving the whole institution. These bins are distributed and stationed throughout the entire institution (interval of 30 m) along walkways, outside lecture rooms, administrative buildings, schools and residences. It is observed that some of the bins do not have lids and some do overflow and attracts monkeys and other rodent and disease carrying vectors which is a serious risk to health of the cleaners.

The supervisor however raised concern about the indiscriminate littering around the institution even though there are empty waste bins at accessible intervals, and based it on the fact that the students have an attitude of littering which must be dealt with. The attributes of waste bins need to be carefully planned to meet the needs of the users and be effectively utilized, however, it seems that the waste bins are under-utilized due to the indiscriminate littering. This is of great concern as there must be a reason for this which could be owing to the attributes of the designated waste bins itself, many are discouraged from using due to heavy and dirty handles as shown in the Figure 6.3 below.

Figure 6.3: Type of bins used on campus (Source, Fieldwork)

6.2.3 Existing logistics, transport and methods of waste disposal in the Institution

The Department of Grounds and Cleaning under the auspices of the Maintenance Department are responsible for the cleanliness and sanitation of the institution which includes the management of solid waste. The unit has two tractors, and two bakkies for transportation and disposal of waste. These trucks are operated by four drivers who transport the waste from the dumpsters to the landfill site at Muledane. These four drivers are not able to transport all waste

generated in the institution in a day. This has resulted in transporting it in batches. Also, inadequate personnel are a challenge because sometimes one driver is not available and this affects the transportation of waste. The trucks as seen in Figure 6.4, have to make several trips about five times daily to landfill site due to the volume of waste generated in the school and it is seen that the transportation of waste in the institution is not efficiently managed.

Figure 6.4: Waste tractor and truck used in the institution (Source, Fieldwork)

Presently, all waste generated at Univen are taken to Thohoyandou landfill site and there is no diversion or other sources of recovery. Figure 6.5 shows Univen truck loaded with waste about to offload at the Thohoyandou landfill in Muledane.

Figure 6.5: Univen Truck at Thohoyandou landfill (Source, Fieldwork)

6.2.4 Waste pickers in the institution

It is noted through field observation and interview that there are some activities of informal waste pickers from nearby communities who apparently make a living by surfing through the waste generated in search of recyclables that can be resold or re-used (Figure 6.6). The major aim of waste pickers is to gather enough waste that can be sold for a living. High rate of unemployment, poverty and hardship have pushed many to seek alternatives and means of survival by picking waste for recyclables. Waste is also collected for their own household use and items such as pots and pans for cooking, clothes and even food are salvaged (Schenck and Blaauw, 2011). According to the interviewee, some workers also engage underground in these activities as a source of additional income to supplement their income. Materials picked usually include plastic bottles, cans, glass bottles, papers and organic waste. These are often cleaned after picking before selling to their customers. However, there are often contamination because the waste is not separated from source and it is being picked from a mixed waste, this thereby reduces the

quality of recyclables and poses a risk to the health of waste pickers as they scramble unhygienically through the mixed waste. This study therefore brings to light the need of the institution to engage in the use of separate waste bins for different types of waste as this reduces contamination and adds value to the recycled material.

Recycling creates opportunities for people to sell used products to buy back centers thereby creating some sort of income and reducing poverty and reducing the quantity of waste disposed in landfills if properly harnessed. Langenhoven and Dysell (2007) cited that there were 37,000 waste pickers in South Africa, while Schenck et al. (2011) suggested that 70,000 waste pickers may be operating in South Africa. These waste pickers often serve as a bridge between the waste generator, buyback centers and recycling firms. In a research conducted on the role of waste pickers in the recycling industry, it was revealed that 73% of respondents agreed that waste pickers contribute positively towards the recycling economy and 86 percent of recycling companies strongly agreed that waste pickers contribute positively to the growth of recycling companies.

Figure 6.6: Waste collected by a waste picker (Source: Field work)

6.3 Current practices in Univen vis- a-vis contemporary practice

Institutions across the world have been contemporarily incorporating the integrated waste management system approach into the conventional waste management system. The concept of the reduce, re-use, recycle and recover is strictly regulated into their waste management plan. The University of Venda is yet to adopt the principle of reduce, re-use, recycle and recover, as currently all waste generated goes to the landfill. Globally, the United States and United Kingdom showed the greatest efforts in sustainable campus initiatives (Leal et al., 2015) and those sustainable campus initiatives were taken up by many other countries like, Australia, Canada and China (Sharp 2002; Fonseca et al., 2011; Yuan and Zuo, 2013).

At the University of Indonesia, there is an integrated solid waste treatment plant located inside their campus that helps in managing solid waste generated within the campus of Universitat Diponegoro (UNDIP) (Utama et al., 2018). At the just concluded UI Green-Metric University ranking for the year 2019, the level of sustainability initiatives in campuses across the world was clearly revealed. The UI Green-Metric World University Ranking was established by Universitas Indonesia to foster sustainability in higher education institutions worldwide. Universities can share knowledge, experiences and practices on sustainability matters. The UI Green Metric (2019) rankings are based on six environmental criteria, namely, “Setting and Infrastructure (15%), Energy and Climate Change (21%), Waste Management (18%), Water Usage (10%), Transportation (18%), and Education and Research (18%)”. In 2019, 780 universities across the globe took part in the UI Green-Metric World Rankings, the top three universities are namely; Wageningen University and research (Netherlands), University of Oxford (United Kingdom) and University of California, Davis (USA). The three African campuses that featured in the ranking were Benhha University in Egypt (222nd), University of Kwazulu-Natal, South-Africa (722nd) and University of Al Akhawayne Infrane Morocco (725th). The only African University ranked among the first half is the Benhha University in Egypt, this implies that campuses in developing countries

still have a long way to go, to be at par with these universities, however, the journey of a thousand mile must begin from somewhere.

6.3.1 Environmental implications of the current waste management practices

The current waste management practices in the institution have far reaching impact on the environmental, economic and health aspects of the institution. The daily amount of waste collected to be transported to the disposal site is a small fraction of daily generated waste in the institution. Students whose rooms are closer to the waste bins complained of odors and stench from the bins which usually interfere with the normal air quality as well as nuisance caused by birds and monkeys attracted to the garbage in the waste bins which are mostly uncovered.

These monkeys thrive on the accessibility of waste foods and organic waste, the more the accessibility of these wastes to feed on, the more their numbers grow. Often these monkeys pose threat to students in the hall of residences by their aggressive behavior and harassing them, snatching items from people and sometimes injuring them. Several studies have shown that monkeys are capable of transmitting diseases to humans which are referred to as 'zoonosis'. They serve as pathogens and disease carriers that pose a risk to human population. These zoonotic diseases according to Jones et al. (2008) now constitute more than 60 percent of emerging infectious diseases. However, it is not only the monkeys but also, dogs and birds. This gives a clear indication that waste is not properly managed and they are attracted because it is accessible. It is therefore very important for this institution to ensure proper solid waste management using standardized waste bins with secure lids (step–open) and monkey proof. There is also a need to raise public awareness on the dangers of monkeys and how to repel them. Furthermore, exposed solid waste bins attract flies which are also capable of settling on food items in the residences or cafeteria leading to food borne diseases. Other rodents and vermins like rats are also present in the study area. It is observed that uncollected waste release gases which are toxic to human health.

6.3.2 Health impacts of existing solid waste management system

The waste workers and the waste pickers are at risk of health hazards of waste because they handle waste directly through personal contact. According to Ziraba et al. (2016), improperly managed waste, most especially solid waste from households and institutions, constitutes a serious health hazard which results to the spread of infectious diseases. Ejaz et al. (2010) also expressed that the next set of people at risk are those staying close to the waste source. Organic waste due to fermentation and breakdown of enzymes lead to favourable conditions for the breeding of pathogens. Some studies showed the potential health risk of waste generation within higher educational institutions (Baldwin and Drips, 2012; Taghizadeh, 2012; Tu et al., 2015; Ramírez, 2017).

According to the two cleaners interviewed, some said they experience irritation of nose, throats and eyes and skin infections when they have contact with the waste. When asked about the use of protective gloves and clothing, they said although they were provided with this safety equipment but they need new ones consistently. Of great concern is also the infestation of most residences with roaches, this is a clear sign of unhealthy sanitary conditions and poor waste management (Zain et al., 2012). Starovoytova, (2018) highlighted that the problems of roaches are associated with a system of poor *storage* of solid waste and are capable of transmitting typhoid, cholera and amoebiasis.

6.3.3 Current practice on paper use

The interview with administrative workers in the institution revealed that they don't practice any form of paper re-use or recycling. The procurement officer however lamented on the current practice of no recycling or re-use of papers. He mentioned that the institution procures an average of 20,000 reams of paper yearly, which costs about R1240 000 (82,667 USD) annually. This is a huge amount on paper and yet there is no provision for reuse and recycling. This study therefore

brings to light the need for the integration of the 3R's through reusing of unused side of papers and recycling of papers. Many papers cannot be recycled because of contamination due to lack of waste separation. This also emphasizes the need for waste separation at source, as it gives the opportunity to recover resources from the waste stream.

6.3.4 Optimizing institutional waste as useful resource

Paper Products

As mentioned earlier, this study found that paper constitutes more than 45% of the generated waste in the school area. Previous studies also supported that paper accounts a significant proportion of waste produced in educational institutions (Atieno, 2016). At the University of Ghana, it was found that paper waste constituted 46% of the entire waste generated (Deryl, 2014). There is a need to cut down on the paper waste generated and a starting point is the campaign against paper waste on-campus and to have a separate recycling bins for paper waste to avoid contamination of paper products. Studies have shown that recycling rates are increased when a campus community is given the opportunity to recycle conveniently by having access to recycling bins and educational program on recycling (Haymes et al., 2014).

When waste is segregated and markets are available, paper recycling therefore generates extra source of income for the institution that can be used to pursue other waste reduction facilities, for example, a bio-gas reactor for converting waste to gas or compost machine. For Univen to achieve a sustainable waste management system, the principle of waste hierarchy must be adhered to by first attempting to reduce waste from source, practice the re-use of products, recycle the recyclable and then recover the other waste through composting or possibly energy recovery. A proposal on paper waste reduction for Univen in this study is the implementation of a paperless system, where all memorandums are electronic and double side printing in cases where

E-mode is not available. Also, students' proposals could be submitted electronically to the relevant persons because students print more than 5 copies of these which usually end up as a waste as found in this study. Therefore, a combination of institutional policies, waste segregation at source and massive education and awareness campaigns will be instrumental to achieving a sustainable waste management in the institution.

6.3.5 Average yearly cost of A4 paper in Univen

Table 6.1 shows that the average yearly paper procurement of about 19,528 reams per year (Appendix E). If this paper wastes can be recycled without contamination and sold to paper recycling companies, then it becomes a useful resource. From the study at the different activity areas over 45% of waste generated is paper, which shows a good potential for recycling. Moreover, 54.7 tons of waste can be diverted from the landfill by targeting only white A4 paper, this is excluding other sources of paper like examination booklets, students photocopying centers, school printing press. If recycling from all other miscellaneous sources of paper are harnessed without contamination, the tons that will be saved from landfill will be much more, even well coupled with other recyclables like plastic bottles and cans, therefore bringing value addition to the institution.

Table 6.1: Average yearly cost of paper

Procurement of A4 paper	2017		2018		Yearly average	
	No. of reams	Cost/R @R62	No of reams	Cost/R @R62	Average no of ream	Average Cost/R

					2017 &2018	
	19.045	1180,790	20,012	1240,744	19,528	2421534
Average ream/year	Amount in kg (/1000)	Amount in ton				
19,528	19528 x2.8/1000	54.7				

Table 6.2 presents the amount of waste disposed by the institution at landfill. From the record of monthly waste disposal obtained from landfill site, the average and annual yearly disposal is extrapolated. It was revealed that the institution disposes an average of 2677 ton per year. The institution revealed that they do not pay any levy for the disposal of waste at the land-fill.

This might be a probable reason for the non-segregation and recovery of waste before disposal. However, institutions such as universities are role models and agents of change to foster environmentally sustainable practices in the society and should incorporate waste segregation into their waste management framework with its attended advantages (Velazquez et.al., 2005). Furthermore, if paper waste were to be recycled and subtracted from the 2677 ton/year, then 54.5ton is reduced from the annual waste disposal

Table 6.2: Average yearly waste disposal at landfill (Source: Thohoyandou landfill 2019)

Month	Amount disposed in tons at landfill
April	197.4
May	287.4
July	204.3
August	196.8
Total	893
Average monthly	223
Average yearly	2677 ton/year

A recycling firm was consulted to know the price of recyclable items from the waste stream, an interview with the manager revealed that non-contamination is very crucial to recycling as it adds value to the recyclable resources. Table 6.3 shows the prices of which recyclables can be sold currently in the market. The available market for the recyclables reflects that the proper management of waste will bring benefit to the institution by the resale of those reclaimed resources. Table 6.4 shows the potential economic benefits that can be derived per annum from the sale of recyclables.

Table 6.3: Market price of recyclables	
Material	**Cost per kg**
White paper A4	R120
Pet clear bottle	R150
Card-box	50cent
Aluminum cans	R10
HD plastics	R120
Plastic bags	R1
Cold drink lids	50cent
Metals	R1.50
Steel	R1

Table 6.4: Potential Price of recyclables in the University of Venda			
Material	Recycling Cost per kg	Kg/year	Amount recyclable in Rand
Paper	R120	13,620	3,364,140
Plastic bags	R1	52	12,844
Plastic bottles	R150	100	3,816,150
Aluminum	R10	68	167,713
			Total =7,360,847

The total Figure of R7, 360,847 gives the waste to wealth equivalent of recyclables in the major activity area of the institution, if all recovered and sold. This signifies a strong recovery potential of recyclables in the institution.

6.4 SWOT analysis of the existing waste management practices

SWOT analysis serves as a perfect tool for analyzing possible ways of implementing a sustainable waste management system by evaluating the strength, weakness, opportunities and threats of the existing system. These findings were derived through the analysis of responses obtained from waste generators, assessment of the solid waste management practices, interview session with concerned stakeholders, personal field observations and the comparison of existing legal standards with the existing waste management practices. SWOT analysis aimed at assisting institutions to make appropriate decisions by bringing to light or awareness of internal or external factor that contributes to decision making.

- ✓ **Strength**: this signifies all positive factors that can contribute to achieving a sustainable waste management system
- ✓ **Weaknesses**: this signifies all negative factors that serves as barrier to achieving the objective of a sustainable waste management system
- ✓ **Opportunities**: this refers to all external factors that can contribute positively to achieving a sustainable waste system.
- ✓ **Threats**: this refers to all external factors that could jeopardize the institutions success of sustainable waste management.

The table 4.41 below gives the SWOT for the institutions solid waste management.

6.4.1 Compliance to waste management act

The Waste Management Act (2008 amended in 2014) established the general requirements for the handling of waste management process from storage to final disposal. The act stipulated that "Any person who stores waste must at least take steps, unless otherwise provided by this Act, to ensure that-

(a) the containers in which any waste is stored, are intact and not corroded or in any other way rendered unfit for the safe storage of waste; (b) adequate measures are taken to prevent accidental spillage or leaking; (c) the waste cannot be blown away; (d) nuisances such as odour, visual impacts and breeding of vectors do not arise; and (e) pollution of the environment and harm to health are prevented".

In the light of the afore-mentioned act, the University of Venda is commendable to keep par with the stipulations, however, the condition of nuisances such as odour from the waste storage, and breeding of vectors is a shortcoming. There is infestation of cockroaches, mosquitoes and other vectors which emanates from the waste storage and this is an important issue which needs to be considered. Another aspect of the Waste Act that the institution must address is the issue of littering which is a serious environmental problem globally as earlier discussed in this study.

The Waste management Act also established standards of littering, it stated that "An owner of privately owned land to which the general public has access, must ensure that sufficient containers or places are provided to contain litter that is discarded by the public; and no person may throw, drop, deposit, spill or in any other way discard any litter into or onto any public place, land, stream, watercourse, street or road, or on any place to which the general public has access, except in a container or a place specifically provided for that purpose; or (b) allow any person under that person's control to do any of the acts contemplated in paragraph (a)". However, littering is one of the environmental problems in Univen, as littering is a menace justified by the students under various excuses like difficulty in the type of waste bins provided (dirty handle of bins, heavy

handles). The Table 6.5 below highlights the strength, weaknesses, opportunities and threats of the current waste management at Univen.

Table 6.5: SWOT Analysis of Institutional solid waste management in the University of Venda

	STRENGTH	WEAKNESS
1	There are relevant laws governing the management of solid waste in the country.	Lack of waste segregation at source which makes recycling impossible.
2	The institution is aware of existing environmental laws on solid waste management.	Insufficient budgetary allocation to waste management activities.
3	The institution has a designated land fill site for waste disposal.	Inadequate monitoring of the waste management process by relevant personnel.
4	The institution has department and staff members that are responsible for handling waste management within the institution.	Inadequate awareness and environmental programs targeted at sustainability.
5	There is budgetary allocation for waste management activities.	Poor perception and attitude of students towards waste management.
6		Ignorance of the composition and characteristics of the waste generated in the institution.
7		Absence of recycling and composting facilities on campus.

	OPPORTUNITIES	THREATS
1	Opportunity of implementing sustainable practices in waste management, reduction and diversion.	Continual increase in staffs and student population leading to rise in quantity of waste generated.
2	Collaboration with private waste management sectors thereby opportunity for public-private partnership.	Risk of environmental pollution (air, soil and water) because of inefficient waste management process.
3	To promote and enhance the environmental and academic image of the institution.	Increased carbon footprint through uncontrolled GHG emissions.
4	Creation of job opportunities through recovery of waste resources and conversion of waste to wealth.	Poor brand image of the school as a result of gross littering and inefficient waste system.
5	Promote environmental responsibility through conducting campaigns, awareness programs on waste management.	
6	Investment opportunities for the institution to explore alternative in recycling, incineration, energy and composting.	

From the SWOT analysis, it is important to maximize the strength and opportunities and make all efforts to minimize the weaknesses and threats by taking advantage of opportunities and transforming the institutional weakness into strength. From the above SWOT, it can further be seen that there are many opportunities that the institution can tap into for its overall development as shown in Figure 6.7 below.

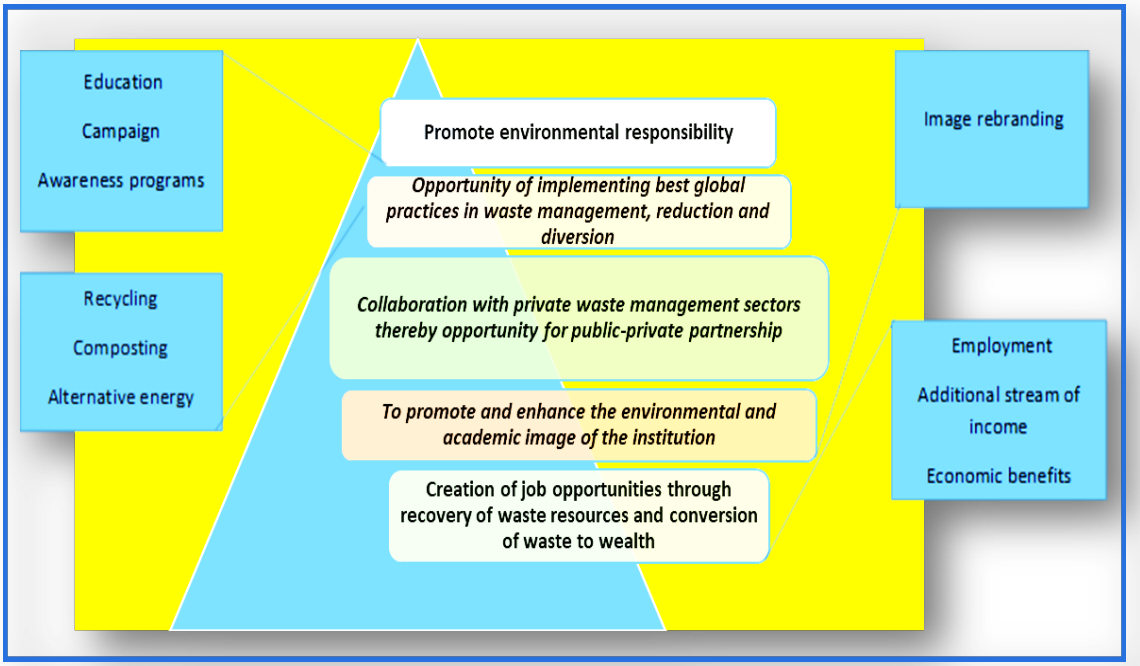

Figure 6.7: Potential opportunities and their resultant effect identified from the swot analysis in Univen (Source, Fieldwork)

6.5 Designing a sustainable solid waste management system

Having conducted the waste characterisation study and assessed the existing waste management practices, this study therefore develops a waste management system to improve recycling and diversion of waste from landfill, promoting sustainability and adding value to waste resources (see Table 6.6). The waste hierarchy forms the building block of this solid waste management design. The hierarchy prioritizes the management of waste as follows: reduce, re-use, recycle, recovery and disposal. This institutional waste management design is based on activity areas as per earlier segmented (Figure 6.8).

Table 6.6 Sustainable strategy for solid waste at the activity areas

Activity area	Strategy	Possible impact
Residence	There should be a residential hall week training at beginning of each session to train and sensitize students on solid waste management in residences and the principle of the 3 R's.	Awareness and information
	Develop and give out brochures on how to reduce and recycle waste in residences to students as part of their move-in packages when moving into allocated residences.	
	Provide a three color-coded recycling bins (monkey -proof) in the residences to facilitate segregation at source.	Waste segregation to reduce contamination
	Liaising and partnering with waste recyclers for collection of the recycled waste	Source of income and value.
	Collection of food scraps for animal feed. This can be fed to the institutions animal husbandry and excesses commercialized.	Reduce cost of feeding and reduces waste from land-fill
Academic areas	Create a campus-wide campaign at successive intervals for both workers and students in the University to be educated on recycling.	Education and awareness

	Establish a deliberate targeted campaign at the academic and administrative units to kick-start paper and plastics recycling. Provide three color-coded bins, for recyclable, compostable and trash at the academic and administrative buildings to facilitate recycling. Develop policies to eliminate paper wastage and reduce the use of paper from printing and copying and submission of paper projects. Formalize electronical mode in passing out memorandum and submission of projects by students	Waste segregation Eliminate policies of wastage Paper wastage is ultimately reduced
Cafeteria and kitchen	Partner with the immediate community for the collection of food scraps and pre-consumer food waste Establish a compost facility on-campus where organic waste is composted and delivered to the school farm or community farmers. Develop a center for collection for food scraps and waste for animal feed for the school farm and immediate community. Provide colored coded recycling bins for the facilitation of recycling and separation at source.	Source of income Recovery of waste Eliminating contamination

	Provide a compost bin in the cafeteria and set-up a compost site on campus to produce nutrient rich soil as manure for growing vegetables	

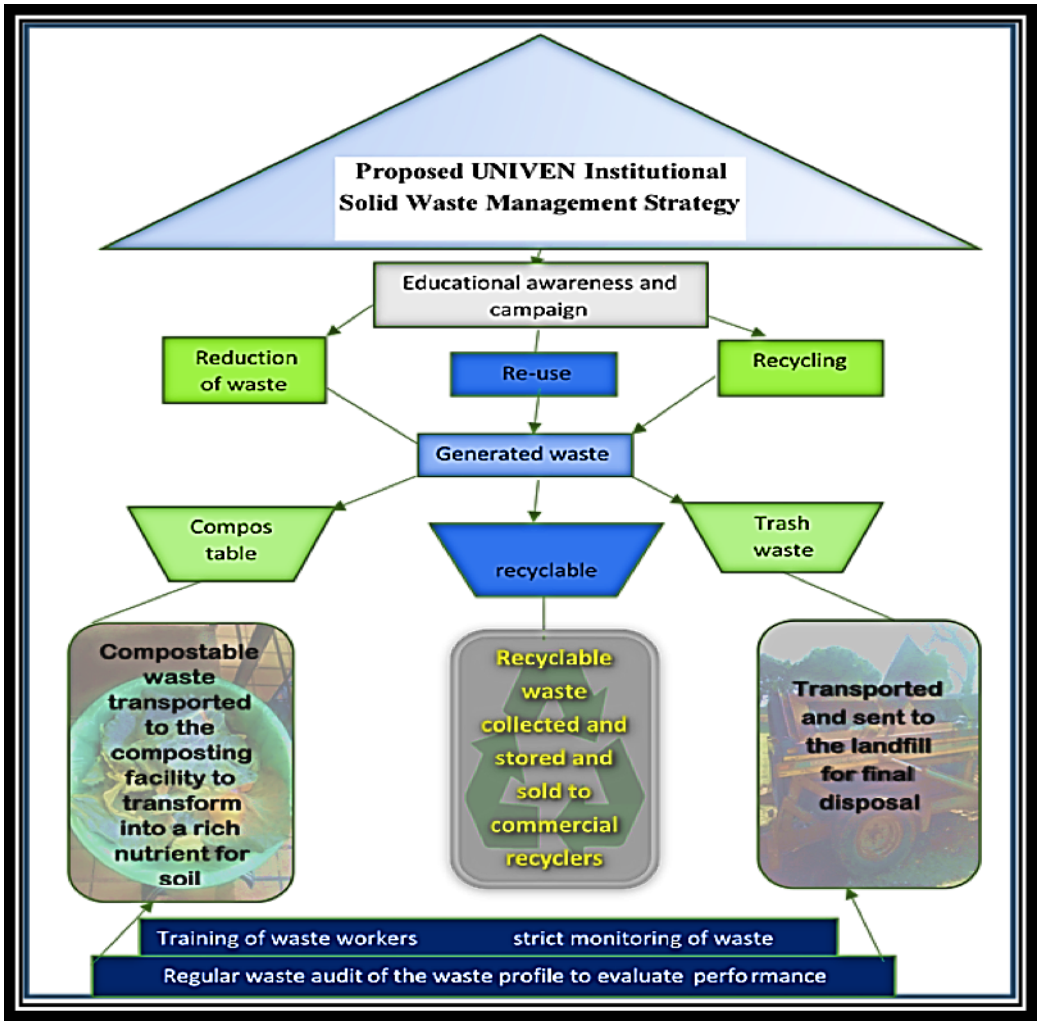

Figure 6.8: Sustainable waste management framework for the institution (Source; Field work)

6.6 Conclusion

Universities are to take the lead in portraying a good example of sustainable solid waste management practices which can be replicated in their immediate environment, sustainability, reduction of waste and even zero- waste on campus can be achieved at the University of Venda, through the integrated waste management (reduce, re-use, recycle and recover). The existing waste management system is inefficient and inadequate, there is a need to move the waste hierarchy by incorporating sustainable and sound waste management practices. A systematically carved out model of waste separation, collection, storage, disposal, transport, recycling and recovery is paramount to upgrade the esteemed campus to a zero-waste campus through various means that have been highlighted in the study.

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CHAPTER SEVEN
CONCLUSION AND RECOMMENDATIONS

'' The hall mark of successful waste management practices starts with making sustainable decisions and taking sustainable actions''

Oluwatobi owojori

This chapter summarizes and concludes this study and proposes suitable recommendations for this institution. Moreover, limitations to this study are identified and possibility of extended research in the future is raised.

7.1 Review

This study has successfully investigated the existing solid waste management practices in the institution and has achieved its objectives through the assessment of the existing institutional waste collection, storage and disposal process. The strength and weaknesses of the current practice was drawn in comparison to acceptable legal standard. Also, waste auditing of the key activity areas in the institution was carried out to determine the waste profile, the generation rate and the amount of recoverable waste, thus providing this institution with a first-time base-line data on campus waste profile. The perception of students towards waste management in the institution was further assessed to know the opinion and challenges from their point of view. Furthermore, interview was conducted with relevant personnel within and outside the institution to achieve the over-all goal of this study. The result discussed in this study has stressed the potential of educational institutions to recover and divert a high percentage of their waste from land-fill site thereby projecting the institution on a path of sustainability.

7.2 Summary on students' perception, attitudes towards solid waste management in the institution

Inadequate awareness on environmental and waste management programs was found to be a major setback to efficient waste management in Univen. Many of the students are not well-informed and lack adequate knowledge about waste management and environmental sustainability. Responses from questionnaires show that respondents are unsatisfied with waste management in the institution. Most of the students are willing to undertake recycling if they are sensitized about it and if they are provided with the necessary materials for recycling (this is in terms of separate color-coded recycling bins) and only a few expressed interests in incentives for recycling.

7.3 Summary on the characteristics of the waste profile generated in the institution

The waste audit carried out in the student residences as discussed in chapter four showed the highest percentage of waste generated in the residence to be food waste (40.6%) while when compared with that for the academic areas is 12.9% (average of all audited academic areas). This shows that based on the activity areas, residences have higher percentages of compostable food waste which can be targeted for diversion to composting. Also, the results have shown that academic area generates the highest percentage of recyclable waste which was recorded at 89.1% (inclusive of paper, plastic, plastic bags, plastic bottles) while recyclable percentage for the cafeteria and kitchen is 80.2% and 56.9%, respectively. The recyclable percentage at the residence is 52.4%. The average of all recyclables in the selected areas is 69%. This implies that approximately 69% of waste generated in the institution can be recycled and 26% can be diverted through composting.

7.4 Summary on the assessment of existing waste management practices

The current waste management system of this institution is unsatisfactory based on the acceptable environmental standards and principles of the waste management hierarchy of

reduce, reuse and recycle. It was found that the University has not considered this principle in its waste management activities. The only waste management activities done is collection, storage and disposal at the landfill. Waste separation at source is not practiced in the institution which gives rise to contamination of valuable materials that can be reused and recycled. The types of waste receptacles used in the institution have repelling attributes such as having heavy and dirty handles. Therefore, many are not motivated to use it efficiently hence the indiscriminate littering.

7.5 Recommendations

Although the institution fulfills its duty of the routine waste collection and disposal, but it needs more to be done and more miles to walk to be at par with acceptable standards of sustainability in higher institutions. The following recommendations are given to improve the solid waste management of the institution:

- ✓ The first step in getting the institution (students, staff and management) to re-think its waste management strategy is through education and awareness campaign, and therefore there is a need to set-up a media using a website which can be connected to the existing institutional website where information on reduce, re-use and recycling of waste is posted alongside with motivating and interesting programs on waste reduction and sustainability.
- ✓ This research found that although there is an environmental club in the institution, however, this club has not focused on solid waste management in the institution. Therefore, it is necessary that this club be resuscitated or a new club be set-up for the purpose of facilitating waste reduction through reduce, re-use and recycle on campus.
- ✓ If generated waste is to be recovered, there must be waste separation at source in all activity areas (schools, cafeteria, residences and administrative buildings) to eliminate contamination and preserve value. Therefore, the institution should embark on the purchase and provision of waste recycling bins which are color coded and convenient for

use to be distributed at the residences, cafeteria, kitchen, schools and administrative buildings.

- ✓ It is also recommended that the institution provides a temporary storage location on-campus for the collection of recyclable waste generated.
- ✓ In order to motivate students and workers to recycle and reduce paper wastage, a competition should be conducted per semester on which schools recycle the highest papers as received from the paper bins provided.
- ✓ Public-private partnership with the recyclers in the community is recommended for the commercialization of the recovered recyclables.
- ✓ Auditing of waste to track the progress of recycling and adherence should be conducted per semester by engaging the students as part of their course work.
- ✓ The University should establish a composting facility to convert its solid organic waste into a nutrient rich compost to nourish the plants and greenery of the University and excesses of this can be traded to farmers in the immediate community as a commercial venture. This is an anaerobic activity in which microbes degrade the waste in the condition to produce a nutrient rich fertilizer which is useful and cheap for farming. This composting facility will also present opportunity to compost other types of organic waste generated in the University such as the garden waste which also contributes to organic waste.
- ✓ The need to employ more waste management team for effective co-ordination of activities.
- ✓ Establishment of laws against littering and ensure compliance, strict monitoring of waste bins provided and sanction for any caught erring.
- ✓ Timely collection of waste from residences and within campus, the frequency of collection should be increased.
- ✓ Employ an external waste manager to oversee and develop sustainable waste management programs.

- ✓ It is also recommended that further research be conducted outside the scope of this study such as laboratory test of the energy and moisture-content of the organic waste in order to consider solid waste as a possible means of energy and diversion into bio-gas creation.
- ✓ Also, clinical and hazardous waste as well as waste from the school agricultural farm can be investigated for further studies.

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APPENDICES

APPENDIX A: Waste characterisation results

1a) Riverside Residence week1					
Date: 13-15th	may-2019	Day1	Day2	Day3	Average
	Category				
Recyclables	Paper	24.30	23.49	29.25	25.68
	Plastic bags	17.15	17.85	19.25	18.08
	Plastic bottles	27.18	30.11	23.39	26.89
	Aluminum cans	21.51	16.55	22.43	20.16
	Glass bottles	17.12	16.09	12.44	15.22
Compostable	Organic	81.92	77.35	81.46	80.24
Others	Non-recoverable	16.05	14.97	10.52	13.85
Total		205.22	196.40	198.75	200.12

1b) Riverside Residence week2					
Date: 20-22nd	may-2019	Day1	Day2	Day3	Average
	Category				
Recyclable	Paper	22.16	25.32	28.69	25.39
	Plastic bags	20.91	21.52	18.66	20.37
	Plastic bottles	19.30	27.20	29.24	25.25
	Aluminum cans	19.26	17.21	17.00	17.82
	Glass bottles	14.78	12.84	16.70	14.77
Compostable	Organic material	85.48	89.21	87.97	87.56
Others	Non-recoverable	18.05	14.78	10.97	14.60
Total		199.95	208.08	209.23	205.75

1c) Riverside Residence week3					
Date: 27- 29	may-2019	Day1	Day2	Day3	Average
	Category				
Recyclables	Paper	21.71	20.87	28.36	23.65
	Plastic bags	17.41	18.10	22.66	19.39
	Plastic bottles	30.65	29.22	28.33	29.40
	Aluminum cans	19.69	21.75	26.27	22.57
	Glass bottles	13.28	12.90	16.77	14.32
Compostable	Organic material	76.61	81.47	81.60	79.89
Others	Non-recoverable	13.17	17.76	10.50	13.81
Total		192.52	202.08	214.48	203.03

2a) Cafeteria dining week1					
Date: 8-10th	May-2019	Day1	Day2	Day3	Average
	Category				
Recyclables	Paper	1.56	0.49	2.05	1.37
	Plastic bags	3.14	3.38	4.03	3.52
	Plastic bottles	21.51	16.55	22.43	20.16
	Aluminum cans	20.41	17.74	17.29	18.48
	Glass bottles	5.82	6.11	4.60	5.5
Compostable	Organic materials f	46.25	42.06	47.53	45.28
Others	Non-recoverable	0.20	0.20	0.20	0.20
Total		98.88	86.53	98.13	94.52

2b) Cafeteria dining week2					
Date: 16-18th	May-2019	Day1	Day2	Day3	Average
	Category				
Recyclables	Paper	1.56	0.49	2.05	1.37
	Plastic bags	0.60	2.24	3.40	2.08
	Plastic bottles	21.40	18.69	15.98	18.69
	Aluminum cans	15.67	22.65	25.09	21.14
	Glass bottles	1.46	5.13	3.06	3.22
Compostable	Organic materials	39.96	37.84	36.37	38.06
Others	Non-recoverable	0.65	0.40	0.10	0.44
Total		81.30	87.43	86.04	84.98

2c) Cafeteria dining week3					
Date: 23-25th	May-2019	Day1	Day2	Day3	Average
	Category				
Recyclables	Paper	1.90	1.70	1.80	1.80
	Plastic bags	6.77	2.55	2.36	3.89
	Plastic bottles	26.35	22.52	25.68	24.85
	Aluminum cans	19.21	17.44	12.59	16.41
	Glass bottles	6.77	2.55	2.36	3.89
Compostable	Organic materials,	30.32	27.60	36.44	31.46
Others	Non-recoverable	0.20	0.20	0.20	0.20
Total		91.53	74.56	81.43	82.51

3a) Cafeteria kitchen week1					
Date: 8-10th	May-19	Day1	Day2	Day3	Average
	Category				
Recyclables	Paper	29.26	31.84	28.50	29.87
	Plastic bags	10.99	12.03	15.29	12.77
	Plastic bottles	29.55	31.51	27.64	29.57
	Aluminum cans	21.14	19.74	20.33	20.40
	Glass bottles	1.70	3.60	2.00	2.43
Compostable	Organic materials,	70.65	71.43	70.26	70.78
Others	Non-recoverable	5.03	5.51	4.18	4.91
Total		168.32	175.65	168.20	170.72

3b) Cafeteria kitchen week2					
Date: 16-18th	MAY-2019	Day1	Day2	Day3	Average
	Category				
Recyclables	Paper	37.21	37.18	38.98	37.79
	Plastic bags	16.78	20.40	15.14	17.44
	Plastic bottles	34.33	35.50	33.16	34.33
	Aluminum cans	21.62	22.47	21.84	21.98
	Glass bottles	2.70	3.70	1.70	2.70
Compostable	Organic materials,	74.20	79.75	81.99	78.65
Others	Non-recoverable	5.03	5.51	4.18	4.91
Total		191.87	204.51	197.00	197.79

3c) Cafeteria kitchen week3					
Date: 19-21st	May-19	Day1	Day2	Day3	Average
	Category				
Recyclables	Paper	37.98	42.01	42.40	40.79
	Plastic bags	17.33	19.65	20.89	19.29
	Plastic bottles	41.67	42.63	32.64	38.98
	Aluminum cans	22.24	22.99	25.75	23.66
	Glass bottles	1.46	5.13	2.80	3.13
Compostable	Organic material fc	87.39	92.61	86.97	88.99
Others		4.72	4.65	6.13	5.2
Total		212.79	229.67	217.58	220.01

4a) school of Education week 1					
Date: 10-12th	July-2019	Day1	Day2	Day3	Average
	Category				
Recyclables	Paper	13.19	9.68	8.52	10.47
	Plastic bags	6.13	6.21	4.77	5.7
	Plastic bottles	6.13	6.21	4.77	5.7
	Aluminum cans	2.35	2.81	2.74	2.63
	Glass bottles	0.55	0.52	0.91	0.66
Compostable	Organic materials	4.69	5.05	4.82	4.85
Others	Non-recoverable	0.71	1.53	1.40	1.21
Total		33.76	32.02	27.94	31.24

4b) school of Education week 2					
Date: 15-1	Jul-19	Day1	Day2	Day3	Average
	Category				
Recyclable	Paper	18.8	15.5	18.1	17.5
	Plastic bags	2.85	6.87	8.75	6.16
	Plastic bottles	3.51	8.25	3.94	5.23
	Aluminum cans	1.30	1.26	1.35	1.30
	Glass bottles	0.21	1.47	0.53	0.74
Composta	Organic materials	1.44	8.45	8.89	6.26
Others	Non-recoverable	0.73	1.53	1.38	1.21
Total		28.85	43.34	42.90	38.37

4c) school of Education week 3					
Date: 22-24th	Jul-19	Day1	Day2	Day3	Average
	Category				
Recyclables	Paper	10.27	8.97	6.58	8.60
	Plastic bags	4.66	2.25	5.50	4.1
	Plastic bottles	3.92	10.10	5.50	6.50
	Aluminum cans	0.66	0.74	1.01	0.80
	Glass bottles	1.03	0.97	1.04	1.01
Compostable	Organic materials	7.09	7.42	5.34	6.62
Others	Non-recoverable	0.68	1.53	1.40	1.20
Total		28.30	31.98	26.36	28.88

5a) school of managementweek 1					
Date: 10-12th	Jul-19	Day1	Day2	Day3	Average
	Category				
Recyclables	Paper	13.89	17.69	16.95	16.18
	Plastic bags	4.07	2.45	6.08	4.20
	Plastic bottles	3.50	2.13	2.20	2.61
	Aluminum cans	0.73	1.90	2.30	1.64
	Glass bottles	0.17	0.40	1.22	0.60
Compostable	Organic materials	2.22	2.22	1.75	2.06
Others	Non-recoverable	2.27	1.73	1.42	1.81
Total		26.86	28.52	31.92	29.10

5b) school of managementweek 2					
Date: 15-17th	July-2019	Day1	Day2	Day3	Average
	Category				
Recyclables	Paper	16.45	9.50	13.81	13.25
	Plastic bags	1.19	2.16	1.87	1.74
	Plastic bottles	5.50	3.00	5.60	4.70
	Aluminum cans	2.12	1.30	1.85	1.76
	Glass bottles	0.28	0.25	0.23	0.25
Compostable	Organic materials		3.38	2.74	3.06
Others	Non-recoverable	0.42	0.43	0.31	0.39
Total		25.96	20.02	26.41	25.15

school of managementweek 3					
Date: 22-24th	July-2019	Day1	Day2	Day3	Average
	Category				
Recyclables	Paper	13.89	17.69	16.95	16.18
	Plastic bags	2.46	3.93	3.77	3.39
	Plastic bottles	2.90	2.90	2.90	2.90
	Aluminum cans	1.10	1.26	1.85	1.40
	Glass bottles	0.50	0.49	0.07	0.35
Compostable	Organic materials	3.90	4.17	4.15	4.07
Others	Non-recoverable	0.54	0.21	0.75	0.50
Total		25.29	30.65	30.45	28.79

6a) school of Environmental scienceweeek1					
Date: 18-20th	July-2019	Day1	Day2	Day3	Average
	Category				
Recyclables	Paper	8.35	9.61	9.24	9.07
	Plastic bags	3.25	5.87	3.45	4.19
	Plastic bottles	4.26	7.15	5.15	5.52
	Aluminum cans	1.65	1.99	1.15	1.60
	Glass bottles	0.42	0.31	0.54	0.42
Compostable	Organic materials	3.66	2.60	2.64	2.97
Others	Non-recoverable	1.13	1.06	1.82	1.34
Total		22.72	28.59	23.99	25.10

6c) school of Environmental science week 3					
Date: 29-31st	July-2019	Day1	Day2	Day3	Average
	Category				
Recyclables	Paper	7.88	6.75	5.91	6.85
	Plastic bags	2.34	2.45	2.83	2.54
	Plastic bottles	4.27	5.48	8.94	6.23
	Aluminum cans	1.69	1.46	1.42	1.52
	Glass bottles	0.60	0.51	0.26	0.46
Compostable	Organic materials	3.21	6.13	2.88	4.07
Others	Non-recoverable	1.31	0.84	1.25	1.13
Total		21.30	23.62	23.48	22.80

6b) school of Environmental science week 2					
Date: 25-27th	July-2019	Day1	Day2	Day3	Average
	Category				
Recyclables	Paper	6.83	8.78	10.74	8.78
	Plastic bags	2.73	4.21	2.85	3.26
	Plastic bottles	3.17	5.08	4.20	4.15
	Aluminum cans	0.11	0.33	0.12	0.19
	Glass bottles	0.30	0.40	0.23	0.31
Compostable	Organic materials	5.45	3.01	4.62	4.36
Others	Non-recoverable	1.10	0.90	0.52	0.84
Total		19.69	22.70	23.29	21.89

7a) Main Admin Block weeek1					
Date: 18-20th	July-2019	Day1	Day2	Day3	Average
	Category				
Recyclables	Paper	14.10	14.35	14.53	14.33
	Plastic bags	2.18	3.06	1.82	2.35
	Plastic bottles	2.30	5.56	4.91	4.26
	Aluminum cans	1.93	1.71	2.16	1.93
Compostable	Organic materials	1.65	1.99	1.15	1.60
Others	Non-recoverable	0.95	2.05	0.98	1.33
Total		23.11	28.72	25.55	25.79

7b) Main Admin Block weeek2					
Date: 25-27th	July-2019	Day1	Day2	Day3	Average
	Category				
Recyclables	Paper	16.18	14.20	16.18	15.52
	Plastic bags	1.86	1.10	2.19	1.72
	Plastic bottles	5.21	5.11	5.13	5.15
	Aluminum cans	2.35	2.24	1.65	2.08
Compostable	Organic materials	2.22	2.22	1.68	2.04
Others	Non-recoverable	0.95	2.00	0.79	1.25
Total		28.77	26.87	27.62	27.76

7c) Main Admin Block weeek 3					
Date: 29-31st	July-2019	Day1	Day2	Day3	Average
	Category				
Recyclables	Paper	16.8	17.3	14.3	16.1
	Plastic bags	2.18	2.32	2.23	2.24
	Plastic bottles	8.61	5.51	5.42	6.51
	Aluminum cans	1.90	1.56	1.66	1.71
Compostable	Organic materials	1.59	2.30	1.51	1.80
Others	Non-recoverable	1.38	0.74	0.17	0.76
Total		32.46	29.77	25.30	29.18

APPENDIX A2: Calculation for standard deviation

Standard deviation=

$$\sigma = \sqrt{\frac{\Sigma\,(X - \overline{X})^2}{n - 1}}$$

Mean =χ'= X= average of each week

N= number of weeks x_i=Value of the *ith* point in the data set, x= mean value of the data set, *n*=number of weeks in the data set

APPENDIX B: Calculation on per-capita waste generation rate riverside residence

Average waste generated per day for the three weeks / no of persons =203/ 256 =0.7/kg/day
Calculation on annual waste generation riverside in ton Per-capita rate/Total population/1000 =0.7*256/1000 =0.18 Calculation for annual waste generation rate Average number of days in a school year taken as 245 Annual waste generation rate X average number of school days in a year =0.18 x 245 =44.1

APPENDIX C: Research questionnaire

QUESTIONNAIRE FOR KNOWLEDGE, ATTITUDES AND PRACTICES OF WASTE MANAGEMENT IN UNIVEN (STUDENTS)

IMPORTANT NOTICE: *kindly note that this questionnaire focuses only on solid waste (excluding liquid, and gaseous waste)*

This questionnaire is strictly designed for purpose of academic research in partial fulfillment of the award of master degree. This survey seeks to explore ways of managing institutional waste more effectively with the potential for recycling. All information provided will be treated with confidentiality and used only for the purpose of the research.

Researcher: Owojori Mary **supervisor: Dr Edokpayi**

***kindly mark the appropriate box or write an answer in the space provided**.

DEMOGRAPHIC INFORMATION:

Date of completion of Questionnaire. dd /mm/yy ……/……/…….

Gender

Male	
Female	

Age: (yrs.) Under 21 ☐ 21-30 ☐ 31 – 40 ☐ 40 and above ☐

Level of study

1st year ☐ 2nd year ☐ 3rd year ☐ 4th year ☐

Honours ☐ Masters ☐ PhD ☐

School in which you are registered, please specify

……..

(Please tick the appropriate box)

1 Do you know who is responsible for waste management in this institution?

Yes ☐ no ☐

If yes, please mention ……

2. In your opinion, what is the state of the cleanliness of Univen?

Highly satisfactory ☐ Satisfactory ☐ non-satisfactory ☐

If non-satisfactory, which areas do you see as unclean?

Student halls ( ) lecture rooms ( ) Lawns ( ) cafeteria ( ) others ( )

If others, specify……

3.How can you rate the effectiveness of the current waste management practices at Univen?

Excellent ☐ Good ☐ bad ☐

4. is littering more of a problem in some areas on campus than others?

Yes ☐ no ☐

Please help us by identifying those areas where litter is a problem in Univen

Student halls ( ) lecture rooms ( ) Lawns ( ) cafeteria ( ) others specify

If others, specify……

5. Who is responsible for littering on campus? (You can tick more than one answer)

STUDENTS ☐ STAFF ☐ VISITORS ☐ VENDORS ☐ EVERYBODY ☐

6. Where do you dispose your solid waste on campus?

Waste bins ( ) On the road side ( ) On the field( ) In the lecture room( ) Any other ( )

7. Are there sufficient refuse bins located at the academic areas? Yes ☐ No ☐

8. Are there sufficient refuse bins located at the halls of residence? Yes ☐ No ☐

9. Are there difficulties associated with the type of waste bin provided Yes ☐ No ☐

If yes, what kind of difficulties? Difficulty in opening ( ) dirty handles ( ) unsuitably located ( ) others specify ( )

10. Do you know what waste separation or segregation is?

YES ☐ NO ☐

If yes, please explain

……

11. Do you know the advantage of waste segregation?

YES ☐ NO ☐

12. Are there various bins for different types of waste at Univen?

YES ☐ NO ☐

13. Why is waste not currently segregated in Univen?

Lack of separate bins for separation ( ) lack of awareness ( ) too stressful to use ( )

14. Please tick the box that reflects most accurately your opinion towards separation of waste

	Agree	**Undecided**	**Disagree**
I believe separation of waste add value to waste resources			
If provided with the necessary materials, I will separate my wastes			
I believe there must be economic incentives for me when I separate my waste			

15. Do you know what recycling is? Yes ☐ no ☐

16. Do you know what the financial benefits of recycling are? YES ☐ NO ☐

If yes, please explain

……

……

17. Do you know what the environmental benefits of recycling are? YES ☐ NO ☐

If yes, explain……

18. Do some of the waste generated have potentials to be recycled? Yes ☐ no ☐

If yes, what type of waste generated can be recycled (***please tick***)

Cans ( ) garden waste ( ) paper ( ) plastic bags ( )

19. Does this University have an environmental/sanitation club?

Yes ☐ NO ☐

If your response is ''YES'', please name the club.

.....

20. What items of waste may be recycled in Univen?

Paper ☐ Cans ☐ Polystyrene ☐ Glass ☐ Cardboard ☐

Others (Please specify) ……

21. Do you think the current waste management by the institution pose environmental problem

Yes ☐ no ☐

22. Suggest ways of improving the current situation of waste management by the University

i)……

ii)……

23. Any other comment:……

……

Your participation and contribution to this study is appreciated. Thank you.

APPENDIX D: Ethical consideration and certificate

RESEARCH AND INNOVATION
OFFICE OF THE DIRECTOR

NAME OF RESEARCHER/INVESTIGATOR:
Ms OM Owojori

Student No:
18018874

PROJECT TITLE: Investigation of institutional solid waste management, its characterization and potential for recycling: A case study of University of Venda, Limpopo Province, South Africa.

PROJECT NO: SES/19/ERM/05/1206

SUPERVISORS/ CO-RESEARCHERS/ CO-INVESTIGATORS

NAME	INSTITUTION & DEPARTMENT	ROLE
Dr JN Edokpayi	University of Venda	Supervisor
Mr R Mulaudzi	University of Venda	Co - Supervisor
Ms OM Owojori	University of Venda	Investigator – Student

ISSUED BY:
UNIVERSITY OF VENDA, RESEARCH ETHICS COMMITTEE

Date Considered: June 2019
Decision by Ethical Clearance Committee Granted
Signature of Chairperson of the Committee: .....
Name of the Chairperson of the Committee: Senior Prof. G.E. Ekosse

UNIVERSITY OF VENDA
DIRECTOR
RESEARCH AND INNOVATION
2019 -06- 20
Private Bag X5050
Thohoyandou 0950

University of Venda
PRIVATE BAG X5050, THOHOYANDOU, 0950, LIMPOPO PROVINCE, SOUTH AFRICA
TELEPHONE (015) 962 8504/8313 FAX (015) 962 9060
"A quality driven financially sustainable, rural-based Comprehensive University"

APPENDIX E: Structured Interview

Structured interview questions for waste management officer

Name of interviewer…OWOJORI MARY

Name of interviewee……....

1. How is waste currently managed in the University?

2. who are those responsible for the management and disposal of waste within the school?

3. Are there contractors or service providers who renders waste collection services for the school?

4. Are there sufficient resources for effective solid waste management in the school?

5. Do you have any idea of the amount of waste generated per day within the school?

6. where are the wastes generated in the school transported to?

7. Is there a permitted landfill site or waste are just transported to a general dumpsite?

8. which waste management activities are emphasized at the point of generation?

9. What are the waste management strategies put in place for the reduction of waste generated within the school?

10. Are there provisions for segregation of waste at generation, recycling?

11. Are staffs and student involved in the management of waste through reduce, reuse and recycling?

12. what are the challenges faced in managing waste within the institution?

What areas do you want the school to improve on concerning waste management?

APPENDIX F: Calculation of paper used yearly

The adopted average weight of a A4 ream is 2.8kg which is used to extrapolate for the annual paper used.

	Yearly amount of ream	Yearly weight	
		Per Kg	Per ton
	19528	2.8*19528 =54678.4	54678.4/1000 =54.7