EXPLORING EFFE CTIVE WASTE MANAGEMENT AND DISPOSAL: A STRATEGY TO MITIGATE THE RISKS ASSOCIATED WITH IMPROPER WASTE DISPOSAL IN NIGERIA

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DISCLAIMER

ABSTRACT

The potential environmental and human health risks of pollution exposure associated with solid waste management processes, especially in developing countries, cannot be overemphasised. This study examines the risks to human health and the environment of improper waste treatment and disposal in developing countries, with a focus on Nigeria. The research compares Nigeria's waste management practises to those found in Scotland to determine if lessons can be learned and recommendations made to improve process in Nigeria. This research aims to reduce environmental and health concerns from solid waste management and promote more sustainable waste management in Nigeria and other low to middle income countries.

In the study, the potential emissions at the Olushosun landfill in Lagos State, Nigeria, was compared with that of Patersons of Greenoakhill landfill in Glasgow, Scotland. The research also examined waste generation patterns, its characteristics, cost benefit analysis, and the recycling system and other treatment practises on university campuses; the University of Lagos (UoL) and the University of Strathclyde (UoS) were used as case studies, as they serve as miniature communities to find management solutions that can be scaled up. Finally, a public questionnaire was implemented in Lagos State to comprehend what challenges are perceived by the public in relation to waste management, and how they engage with the process to better reduce environmental and health concerns from solid waste management, thereby, enhancing more sustainable waste management.

The estimated emissions of the two landfill sites were evaluated. While the emission data for Greenoakhill landfill was sourced from the Scottish Environment Protection Agency, the LandGem Model was used to evaluate emissions from the Olushosun

landfill site, and the risks to landfill exposure of the two sites were assessed by conducting a proximity analysis with respect to residential structures within proximity to the landfill site. The result shows that Olushosun and Patersons landfill have presence of chemical pollutants, e.g., carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4), and Non-Methane Volatile organic compounds (NMVOCs) which are known as contributors to global warming and climate change. For instance, when Patersons has CO of 110,000kg/year, Olushosun has 4,337,631kg/year (against the 100,000kg/year SEPA reporting threshold. This SEPA's reporting thresholds are unique to Scotland, however, they provide Nigeria a framework to understand acceptable levels of pollutants that can be released from landfills, which is insightful to improving it's sustainable landfill management.), and when Patersons has CO_2 of 31,900,000kg/year, Olushosun has 15,495,141,000kg/year (against the 10,000,000kg/year reporting threshold). Hence, both Olushosun and Patersons Greenoakhill landfills poses potential risk to the environment and public health. In assessing the potential risk exposure of the sites, the results show that Olushosun landfill has about 355 and 856 residential building structures that are exposed within 0.25 and 0.5 km, respectively, of the landfill. While Patersons Greenoakhill, an engineered landfill site, has only 28 building structures, which are potentially office structures, within 0.25 km and 255 building structures within 0.5 km of the landfill. When demographic and household survey data for Nigerian were applied, i.e. 4.9 individuals per urban household and 1.1 households per block, the results reveal an estimated population of approximately 89,393 within 2 km of the Olushosun landfill site, in contrast to a population of 28,712 within 2 km of the Patersons landfill site. The estimated per capita emissions within a 0.25 km radius of Olushosun were- 16,199 tonnes (16,199,833 kg) of CO2 equivalent (CO2e), and for Patersons were- 295 tonnes (295,000 kg) of CO_2e. The presence of residential structures within the landfill sites shows that people still live close to landfill sites, not minding the potential risks associated with such practice.

The result of the waste generation pattern at the two higher education institutions shows a slight negative circular trend in the seasonality of waste generation, with the peak generation observed in March–June, while the lowest is observed in July over time in both case studies. The reduction may stem from waste reduction strategies from at both institutions, which could encourage environmental sustainability. However, UoL landfills 99% of its waste, while UoS recovers 100% of its waste from going to landfill. The result further shows that at UoL, material recovery of organic waste, mixed plastic, and mixed paper could be maximised. For instance, the waste characterization study suggests that 88% of the UoL's waste could be diverted from landfill; 30% is organic material that could be composted; and the rest has the potential to be recycled. The result show the recycling system is not being used by people as it should be. This study will help universities develop more strategies for enhancing the implementation of their waste and recycling policies.

The UoL's recycling cost evaluation result also suggests that at a 51% recycling target, the Net Present Value (NPV) was £4,725,372. This indicates that the recycling target of >50% is potentially economical and environmentally sound. This further demonstrates a high payback time because, at that point, the recycling benefits outweigh their individual costs after discounting the net cash flows, for which their cumulative values maintain a continuous positive trend, when compared to UoS, which has an NPV of £33,728,493 as about 85% of the monthly waste generated is recycled and 100% of its waste is diverted from landfill sites (the above analysis integrated environmental values into the evaluation process). Finally, when considering the best strategic solution to solving the peculiarities of the waste management issues in the main case study, Lagos, Nigeria, the consultative approach in the form of a survey was used, which is critical to sustainable waste management according to the United Nations Environmental Programme (UNEP). The result shows that the littering of the roads, especially in low-income areas, is a result of the lack of waste collection services in those areas, which demonstrates that efficiency in management structure is a key to more effectiveness in the waste sector, especially in waste collection delivery. There is a notion that corruption is one of the reasons there is inadequate waste collection coverage in Lagos. Another issue is a lack of communication with the public, resulting in limited public participation in waste reduction and recycling. Good waste management practises and a communication strategy that focuses on environmental education have proven to be effective in increasing public participation in sustainable waste management.

The novelty of this research is in tailoring waste audit, which is specific to a university setting revealing the unique challenges and opportunities at the case study that are not typically addressed in broader studies. The results can guide the university policy makers in developing targeted interventions including designing waste reduction strategies, improving recycling targets, optimizing waste collection by the understanding of seasonal indices specific to the university of Lagos, efficient resource allocation and ultimately fostering a culture of sustainability among students and staff. Another novelty is the unique findings about the chemical emissions and proximity risks specific to Olushosun case study that advances the understanding of the potential risk associated to the landfill sites. Results can assist town planners and government bodies in sustainable building and waste management practices including influencing positive future legislation. The final novelty from the study shows the utilization of mixed methods of qualitative survey application to gain insight of public perspective and waste management challenges peculiar to the case study. This data-driven method to solving real time problem helps to provide actionable recommendation for the government and guiding in policy development to manage waste problems efficiently.

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ABBREVIATIONS AND MEANING

AEPA	Abuja Environmental Protection Agency
ANOVA	Analysis of Variance
ASTM	America Society of Testing Material
BRT	Below Reporting Threshold
BTEX	Benzene, Toluene, Ethylbenzene and Xylene
CBA	Cost Benefit Analysis
CCME	Canadian Council of Ministers of the Environment
CSC	Collection and Separation Costs
CSCT	Collection and Transportation Cost
DEFRA	Department for Environment, Food and Rural Affairs
DVT	Deep Vein Thrombosis
DWPP	Department of Works and Physical Planning
EAF	Electric Arc Furnaces
ESRC	Economic and Social Research Council
EU	European Union
EPC	Equipment Purchasing Cost
GCCC	Glasgow City Council Councilors and Committee
GCU	Glasgow Caledonian University
GHG	Green House Gas
GIS	Geographical Information System
GP	General Medical Practice
GPS	Geographical Information System
HEI	Higher Education Institution
IARC	International Agency for Research on Cancer
ISWM	Integrated Solid Waste Management
JWSK	James Wier Staff Kitchen
JWSO	James Weir Staff office
JWSZ	James Weir Student Zones
KML	Keyhole Markup Language
KU	Kean University
LAWMA	Lagos Waste Management Agency
LDPE	Low-Density Polyethylene
LPG	Landfill Gas
MSW	Municipal Solid Waste
NB	Net Benefit
NSWMPG	Nigeria Solid Waste Management Policy Guidelines
NMOC	Non-methane Organic Compounds
NMVOC	Non-Methane Volatile organic compounds
NPV	Net Present Value

OECD	Organization for Economic Co-operation and Development
PET	Polyethylene Terephthalate
PPC	Pollution, Prevention and Control
PPE	Personal Protective Equipment
PVC	Polyvinylchloride
RCM	Risk Control Measures
RDF	Refuse Derived Fuel
RSM	Revenue generation from selling of sorted material
SC	Storage Cost
SEPA	Scottish Environment Protection Agency
SPRI	Scottish Pollutant Release Inventory
SWM	Sustainable Waste Management
SOP	Standard Operating Procedure
SPSS	Statistical Package for Social Sciences
SSOW	Safe System of Work
TB	Total Benefit
TC	Total Cost
TCE	Trichloroethane
UK	United Kingdom
UNECE	United Nations Economic Commission for Europe
USEPA	United States Environmental Protection Agency
UoL or Unilag	University of Lagos
UoS	University of Strathclyde
USA	United State of America
UNEP	United Nation Enviromental Protection
UNBC	University of Northern British Columbia
UN	United Nations
VLOOKUP	Vertical Lookup
VOC	Volatile Organic Compound
WFD	Waste Framework Directive
WHO	World Health Organization

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DEDICATION ,

I dedicate this thesis in honour to my late father, Late Mr. Kevin Onyemauchechukwu Mbama, whose desire was to see me attain to this educational height, but unfortunately, death could not allow him to witness it. To God be the glory, for His grace and mercy making this great achievement a reality.

PUBLICATIONS FROM THE THESIS

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2. Mbama, C.A.; Otegbulu, A.; Beverland, I.; Beattie, T.K., (2024). Evaluation of the University of Lagos Waste Generation Trend. *Engineering Proceeding*: 68 (14); 1-9. https://doi.org/10.3390/engproc2024068014

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3. Mbama, C.A., Otegbulu, A., Beverland, I., Beattie T.K., Evaluation of the University of Lagos waste generation trends. International Conference on Time Series and Forecasting. July 15-17, 2024. Gran Canaria (Spain).

Manuscripts under preparation:

4. Mbama, C.A., Otegbulu, A., Beverland, I., Beattie T.K. The application of seasonal index and regression model for sustainable waste management: University of Lagos case study. For submission to International Journal of Environment
5. Mbama, C.A., Otegbulu, A., Beverland, I., Beattie T.K. Solid waste disposal and proximity analysis: Olushosun landfill case study. For submission to International Journal of Environmental Research and Public Health.

CHAPTER 1

INTRODUCTION

1.1 Background of Study:

Municipal Solid Waste (MSW), as defined by the European Union's Organization for Economic Co-operation and Development (OECD), includes waste from households, schools, hospitals, offices, commerce and trade, and waste from selected municipal services e.g., garden and park waste, street and market cleanings waste if managed as household waste (OECD 2022). This waste can be collected directly by municipal councils or on their behalf by the private sector (business or private non-profit organizations). Waste excluded from this definition includes that, from municipal construction and demolition, or waste from municipal sewage networks and treatment facilities (Greenfield, 2015). Therefore, the exact definition of MSW may depend on the defining body, *e.g.,* the regulatory agencies, but in general, they areconsidered as solid waste materials which are generated from civic society which are managed by, or on behalf of, municipal councils.

MSW varies in composition, and is influenced by socioeconomic or income level (Department for Environment, Food and Rural Affairs (DEFRA), 2015). For example, the typical global MSW composition shows that organic waste accounts for 46% (Pace et. al., 2018). However, based on economic classification, low-income countries generate more organic waste compared to high-income ones; organic wastes make up 64% and paper 5% of waste in low-income countries, whereas for high-income countries, organic waste is 28%, while paper is 31% (Hoornweg and Bhada-Tata 2012).

In addition to the variation in MSW composition, there is also variation in the methods of it's management like landfilling, composting, incineration, recycling *etc.* However, the management of MSW is noted as typically involving a combination of collection, transportation, treatment methods, *e.g.,* recycling, composting, *etc*., and final disposal (Mohamed *et. al*., 2009; Chang and Lin 2013; Zhang *et al.,* 2014)., and can involve many stakeholders, e.g., local authorities, service users, private formal sector, private informal sector *etc.* These are commonly integrated under the Integrated Solid Waste Management (ISWM), a collaborative framework that involves formal as well as informal sectors to enhance efficient policy formulation, economics and operational planning (Anschutz *et al.,* 2004). For example, recycling as a treatment option to enhance economic recovery from waste is encouraged when high levels of recyclable resources are found in MSW, and policy may be formulated to prevent such recyclable materials from being disposed into landfills, which aligns with the sustainable development goal (SDG) 12, target 12.5 that centers to reduce waste generation through prevention, reduction, recycling and reuse by 2030 (Gasper et al., 2019; Hales and Birdthistle, 2023; Our World in Data team 2023).

Some of the various waste management methods like incineration, composing, and landfill are placed at the lower pyramid of waste hierarchy when compared with recycling as a management method due to its ability to recover economic values from waste. However, often recovery of economic value from waste within municipal councils is hindered by limitations in recycling infrastructure, especially in developing countries, leaving the major role to the informal sector, e.g. scavengers who move between waste disposal sites picking recyclable materials for personal gains; often work without any personal protective equipment (PPE) and not minding the potential risks involved (Marshall and Farahbakhsh 2013).

The understanding of waste streams and stakeholders' participation in MSW planning can improve waste management which can be achieved through waste audit and sampling of people's perception on the subject (Mbeng *et al.,* 2012; Lederer *et al.,* 2015). In addition to concerted study to identify cost effective waste treatment options for handling solid waste. These areas are the core focus for this research.

Of all the waste management options available, landfilling is recognized as the most detrimental to human health and the environment. This is evident in the Waste Framework Directive's Waste Hierarchy, as it has landfill as the least preferred management option (Figure 1.1). Unfortunately landfilling remains the prevalent waste treatment option in many countries, particularly developing countries (Baki *et al*., 2015; Kusi *et al*., 2016; Zhan *et al*., 2017).

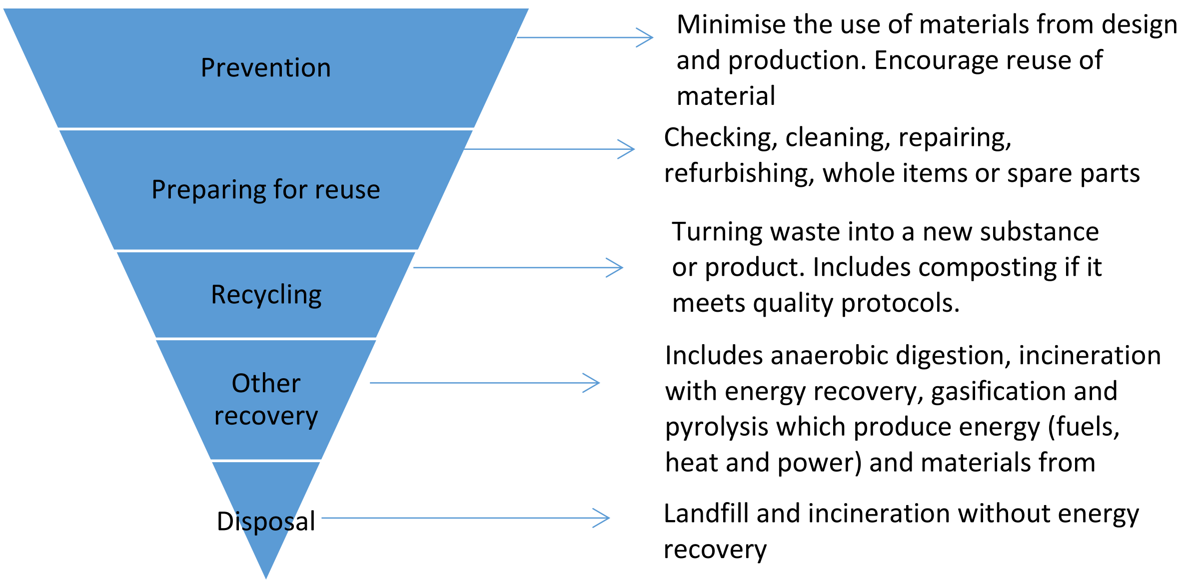

Figure 1.1: Waste Hierarchy (DEFRA, 2011)

Many environmental and human health problems associated with landfill have been documented in literature, however, most of the studies are limited to the incidence of the health issues, whereas, the prevention of these health issues lies in adequate pollution control measures set in place to control the impact of the release of chemical emissions of environmental and health concern from landfill site *e.g.* methane, volatile organic compounds ((VOCs) and hazardous air pollutants (HAP) such as benzene, dichlorobenzene, dichloromethane, toluene, phthalate *etc*., nitrogen compounds, hydrogen sulphide *etc*. These emissions are the primary factors causing the environmental and health impact in people residing close to such sites (Porta *et al.,* 2009; International Agency for Research on Cancer (IARC), 2010; Kah *et al.,* 2012), hence, the need to evaluate the emissions associated with landfill sites. In addition to cancer, landfill emissions have been associated with other serious health risk when exposed to it, which include respiratory problems (bronchitis and asthma) in elderly and the children, as well as neurological problems (like dizziness, headache and sleep disturbance (Vrijiheid, 2000; Rushton, 2003; Kah *et al.,* 2012). Birth defects have also been linked to proximity to landfills, especially in landfills that emits VOCs like benzene, and further chronic exposure may weaken immune system (Elliott et al., 2001; Vrijheid *et al.*, 2002; Porta et al., 2009).

More so, studies on the possible hazards to public exposure based on proximity to landfill sites including evaluation of its harmful chemical emissions have been mostly unexplored, even though research highlight proximity to residential areas as the most critical factor in referencing landfill due of the human health risk (Olawoye et al., 2019; Chafiq et al., 2023). While waste management continues to be through landfill, especially in developing countries (Anschutz *et al.,* 2004), the purpose of this research is to investigate the emissions from landfill that are known to cause environmental and health issues, as well as the exposure to such potential risk based on proximity to such waste management site. The work will focus on comparing landfill in a developing country, Nigeria, with that of landfill in a more developed nation, Scotland. The risk assessment used consists of identification of hazards and the evaluation of risk associated with exposure to those hazards (WHO 2012), proximity analysis is used to assess the risk of exposure by identifying potential hazard and those at risk with the help of spatial tool that helps identify area of potential human health risk (Bien *et al.,* 2005).

An in-depth knowledge of GIS in proximity analysis is helpful in this study; GIS is commonly used for investigation in the environment, water, health and so many other sectors to understand how things interact or relate with each other within various locations.

Thereafter, the work will focus on evaluating comparative recycling efficiency in Nigeria and Scotland to propose strategies for sustainable waste management, especially in Nigeria which can help to reduce high reliance on landfilling which is essential steps towards aligning with SDG 12, target 12.5, that aims to substantially reduce waste generation through prevention, reduction, recycling and reuse by 2030 (UN SDG Report, 2023).

Firstly, typical landfill sites from developed and developing countries were investigated and compared for their distinctive impacts on human health and the environment. Increased understanding of the management structures and risks of exposure associated with landfill sites in a developed country will inform a set of recommendations on better sustainable waste management approaches for developing countries, from the lessons learned. Secondly, the assessment of Municipal Solid Waste (MSW) composition and management in two universities (one from Nigeria, the other from Scotland) as case studies for comparative analysis were investigated to understand the efficiency of their recycling scheme as a waste management option. While studies of solid waste characterization at household level are common, such studies at higher educational institutions (HEI) have been unexplored (Smyth *et al.,* 2010), this is surprising considering the role HEIs have in championing environmental sustainability (Peer and Stoeglehner 2013; Dagiliūtė and Liobikienė 2015). However, HEIs can be considered as small municipalities due to their population size and complex activities that contribute to high MSW generation (Schmieder, 2012; Ezeah et al. 2015; Ishak *et al*., 2015).

1.2 Motivation:

This study is motivated by a personal desire to see improvement in waste management in Nigeria to reduce human health and environmental risk especially the risks emanating from improper disposal and landfilling which remains a common waste management practice in the country (Babayemi and Dauda 2009; Ogwueleka, 2009). Secondly, to proffer recommendation to effectively manage increasing wastes that could potentially help mitigate health and environmental problems arising from improper waste manage in Nigeria as shown in Figure 1.2, Figure 1.3, Figure 1.4, and Figure 1.5.

Figure 1.2: Picture showing plastic waste clogging a drainage system.

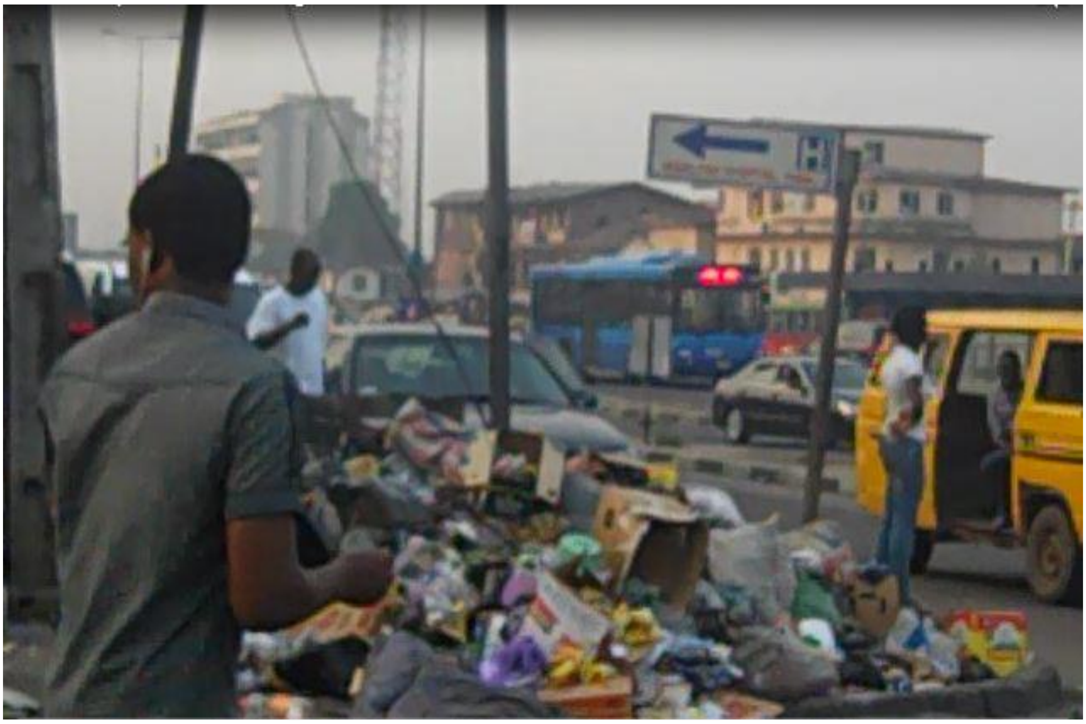

Figure 1.3: Improper waste disposed on the street of Lagos State, Nigeria.

Figure 1.4: Scavengers working on waste dump at Olushosun landfill recovering recyclable materials to generate income.

Figure 1.5 Scavenger's accommodation at Olushosun landfill site. Source: Mbama 2017.

Although a key focus of the research was on improving understanding of the health and environmental risks associated with landfill, it is important to highlight that the composition of SMW, was also investigated in this thesis to inform decision making on better waste management approaches to undertake in addition to using cost benefit analysis as a decision making tool (Fuster *et al*., 2004; Hockley, 2014). While investigation of waste composition, through waste audit, is a common research technique used to proffer recommendations on the best waste treatment and management options to explore (Hoang, 2005; Byer *et al*., 2006; Coggins, 2009; Mbeng *et al*.; 2012; Ishak *et al*., 2015), research of the cost benefit analysis incorporating environmental factors in the decision making process are limited (Da Cruz *et al*., 2014). The waste audit was conducted in-line with recommended procedures for better waste management practice, to understand the waste streams, as waste not usually segregated ends up landfilled. The determination of various waste streams and categories through waste audit and cost benefit analysis helped to identify the best management approach and potentially reduce the amount of recyclables and biodegradable wastes that are sent to landfill, which would lead to emission reduction, thereby, reducing the potential risks posed by such landfill. This buttresses the need to understand MSW streams and their contribution to emissions when sent to landfill to fully maximize the scarce resources and preserve the environment (see Figure 1.6).

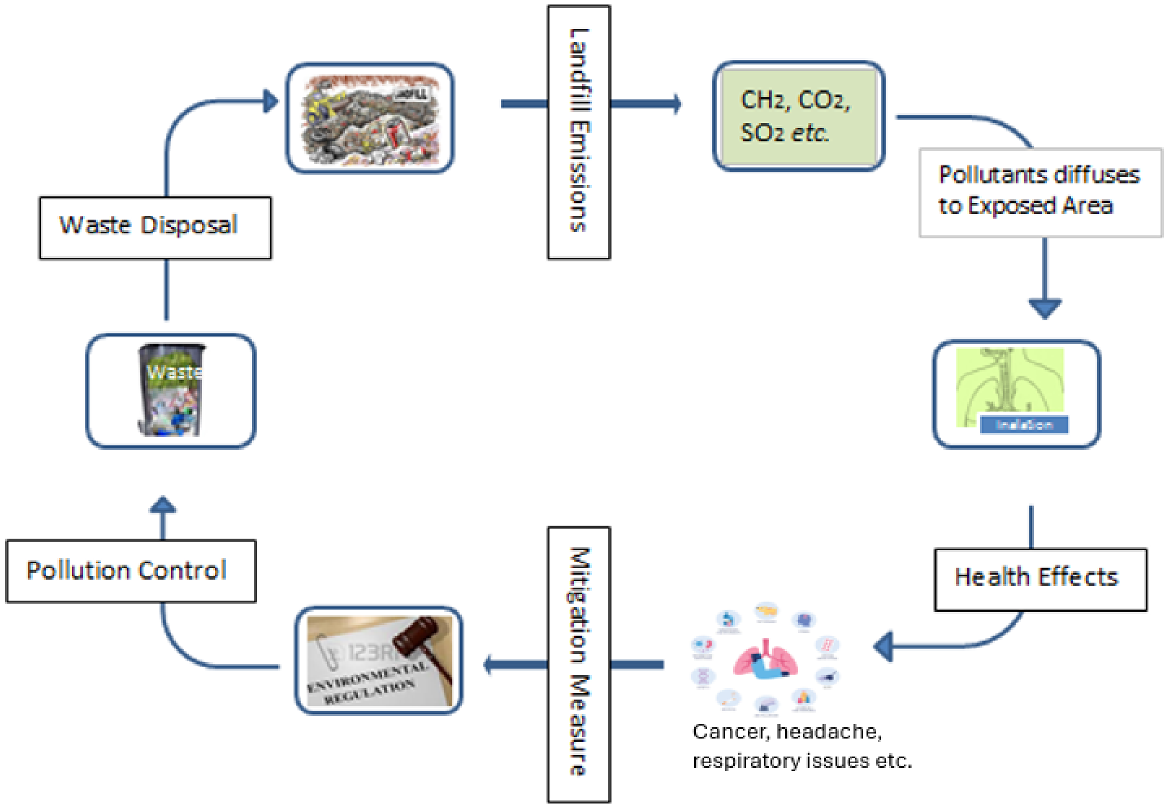

Figure 1.6: Schematic of Landfilling, its emissions effects and control measure.

1.3 Aim and Objectives:

Many developing nations are heavily reliant on landfilling, whether in open dump sites, or more manufactured sanitary sites, for disposal of municipal waste generated by the populace, with limited consideration of both direct (environmental pollution) and indirect (use of limited resources) environmental impacts.

The aim of this research was to evaluate the emissions of landfill in a developing nation, i.e., Nigeria, and through waste composition analysis, determine more effective routes of municipal waste management, and for which the processes will be compared with those of a developed nation, i.e., Scotland. This overall aim was addressed through five primary objectives as stated below. The chapters of the thesis presenting these objectives are given in brackets.

(i) Assess the potential risk of human exposure to chemical emissions, based on proximity of residential buildings to landfill sites: case studies in Lagos, Nigeria and Glasgow, Scotland were compared. This objective involved estimation of the waste streams received and treated, and the emissions generated from the landfill sites in Nigeria and Scotland. Additionally, this objective utilizes proximity analysis buffering, one of the GIS spatial tools that examines distance, to investigate the potential risks of exposure to landfill site emissions. Buffering of 2 km from the landfill sites was considered, based on the knowledge that health effects may occur from harmful chemical pollutants emitted within this proximity to a typical landfill site. To achieve this, the buildings and potential population at risk were examined at the Olushosun landfill site in Lagos State and the Patersons Greenoakhill landfill site in Glasgow. (Chapter 3)

ii) Assess the temporal pattern of MSW generation and composition in the University of Lagos, Nigeria (developing country) and compare this with the University of Strathclyde, Scotland (developed country) to understand variations across time, as well as different waste streams. In this case study, the waste composition and management approach were also studied, with a view of understanding the recycling efficiency to assist in the development of a set of recommendations on how to improve the sustainability of waste management in developing countries from the lesson learned (Chapter 4).

iii) To explore the cost effectiveness of recycling as a waste management option, using the landfilling management practice as a basis, while considering the environmental risk, especially greenhouse gas (GHG) emissions from the current landfill practice in University of Lagos, Nigeria and the University of Strathclyde, Glasgow. This was achieved by examining the impacts of the waste streams and further examining the cost benefits of the different recycling targets, while considering the environmental risks associated with them, which is important for proper decision making in waste management. It is based on the knowledge of the environmental and economic viability of the management processes that a potential cost-effective treatment option could be chosen (see Chapter 5).

iv) Review the effectiveness of organizational structure and public engagement for better MSW management to enhance environmental sustainability in Nigeria. This was achieved by investigating the waste management practice in Nigeria using Lagos State as a case study. One of the challenges of municipal solid waste management is ineffective organisational structure, and ineffective management of waste through service delivery. With the identification of issues associated with waste management, it becomes easier to plan for the better management of such waste. This objective examines the gaps identified in waste management practice in Nigeria to understand the extent to which a given programme, policy, or condition could be improved. This was achieved through stakeholders and public engagement opinion sampling via administering questionnaires and field visits to the waste management facilities at the case study area (see Chapter 6).

v) Evaluate potential factors influencing waste management problems in Lagos. This will help to establish evidence of the root of the problem, thereby improving the method of solving such waste management problems (see Chapter 6).

1.4 The Scope and Structure of the Thesis:

This thesis focuses on the assessment and management of the impact of improper waste management practices *e.g*. landfilling in a low income setting, which will be compared to a developed nation with a view to developing a set of recommendations, through lessons learned, to enhance environmental sustainability; Lagos, Nigeria and Glasgow, Scotland were chosen as case studies for developing and developed countries respectively.

The thesis is divided into 8 Chapters. Firstly, Chapter 1 presents an introduction to the research, while Chapter 2 presents a concise literature review to identify the strengths and gaps in the literature of the topic area, which focuses on improving municipal solid waste management. Chapter 3 presents the result of the risk of exposure to chemical emissions, based on the proximity of residential buildings to landfill sites: Lagos/ Nigeria and Glasgow/Scotland for comparative purpose. Chapter 4 presents the result of the temporal pattern of MSW generation and composition in University of Lagos, Nigeria (developing Country) compared with the University of Strathclyde, Scotland (developed country).

Chapter 5 presents result of the cost effectiveness of recycling as a waste management option, using the landfilling management practice as a bases, while considering the environmental risk especially the Green House Gas (GHG) emissions from the current landfill practice in University of Lagos, Nigeria and the University of Strathclyde, Glasgow.

Chapter 6 presents result of the review of the effectiveness of organizational structure and public/ business engagement for better MSW management that will enhance environmental sustainability in Nigeria. While Chapter 7 presents the synthesis of results from this research, Chapter 8 summarizes the significant conclusions obtained from the work as presented in this research and areas for future research, and finally Chapter 9 shows the list of references.

CHAPTER 2

LITERATURE REVIEW

2.1. Background:

Urbanization, population growth and consumption patterns have globally caused a surge in municipal solid waste (MSW). The global annual MSW generation exceeds 2 billion tons, which is projected to reach about 3.4 billion tons by 2050 (Kaza et al., 2018; Zhang et al., 2024). Meanwhile, acute waste management challenges are faced by developing countries, with about 30 – 60% of municipal waste uncollected (World Bank, 2022; Zhang et al., 2025), when compare to developed countries that have better efficient waste collection coverage, and complex regulatory compliance (Laureti et al., 2024).

Like many developing countries, Nigeria has an increasing population, rising to the current level of over 200 million from 140 million in 2006 (Reed and Mberu 2014; Worldometers, 2019), and as such, has many industrial and manufacturing companies emerging to meet population demand for consumable goods. This population growth and increasing consumer demands have been associated with an increase in municipal solid waste (MSW) generation in the country (Kawai and Tasaki 2016; Alfaia *et al*., 2017; Malinauskaite *et al*., 2017). Nigeria is known to lack efficient and modern technology for the management of its municipal solid waste (Babayemi and Dauda 2009; Ogwueleka, 2009), so the management of this increased level of waste is challenging as a result of inefficient planning, and a lack of coherent and stringent enforcement of sanitation laws, especially in the large Nigerian cities like Lagos, Kano etc. (Ogwueleka 2009; Ijaiya, et al., 2014; Ogunkan, 2022).

Nigeria is divided into 774 local government areas within the 36 States and the Federal Capital Territory; Lagos State is the most populous Nigerian State (FamilySearch 2020). Although, efforts are being made by the Nigerian Government in the management of MSW, through their state environmental agencies like Lagos Waste Management Agency (LAWMA), and Abuja Environmental Protection Agency (AEPA), who have statutory responsibility to manage the states' MSW. However, these government agencies are often accused of being either inept in waste management or corrupt due to their poor waste collection services (Taiwo, 2009). This is further supported by Ogwueleka (2009), who investigated waste management in cities such as Lagos, Kano, Abuja, Onitsha etc, and showed that Nigeria is characterised by inefficiency in waste collection and improper waste disposal though open dumping and unsanitary landfill.

Large urban populations with high consumption rates contribute to the rise in MSW generation, making it difficult for state authorities to manage the waste, despite the large financial allocations the waste management agencies receive from the federal government (Taiwo, 2009). The inability of waste management authorities to manage waste efficiently results in environmental and public health risks (Abdel-Shafy and Mansour 2018). Some of the known environmental risks include the production of greenhouse gases (GHGs) such as methane and carbon dioxide, while the health risks include production of toxic non-methane organic compounds that could cause birth defects, respiratory disease *etc.* (Irvine, 2001; Ritchie and Roser, 2020). From available studies, it is easy to point out that one of the main problems faced in waste management is the inability of waste management authorities to understand solid waste generation patterns, waste composition, and associated risks posed by the exposure to improperly disposed waste. It is only by improving knowledge of the risks posed by improper waste disposal that better cost-effective waste technological treatment options can be utilized. Hence, this chapter addresses gaps in sustainable waste management literature by it's comparative framework evaluating developing country like Nigeria, with a developed country like Scotland.

2.2. Solid Waste Generation:

The legal definition of waste, as used for over two decades by Article 3(1) of the EU Waste Framework Directive (WFD), is *"...any substance or object which the holder discards or intends or is required to discard...".* However, Nakamura and Kondo *(*2009), had a different view of what waste is, considering it to be an alternative resource, as what could be counted as waste, can also be used for other purposes in another sector, e.g. "…*iron scrap used in EAF (electric arc furnaces) to produce steel bars for construction purposes, aluminium scrap used in die casting, waste paper used in paper mill*…" (Nakamura and Kondo 2009). It is ideal to note that what is waste in the eyes of one person can be a resource to another. Therefore, during this project, solid waste can be seen as the unwanted material at a particular time which can either be reused by another person or processed into another form. This implies that solid waste can be resource (Nakamura and Kondo 2009). When these solid wastes originate from households, schools, markets, public offices, and industries, and are collected and managed by or on behalf of municipal councils it is known as Municipal Solid Waste (MSW).

Compared to developed countries, the solid waste generation in developing countries is on the increase and its management has been poor; about 30 – 60% of waste generated in the cities is collected according to World Bank statistics (Wilson *et al*., 2013). Waste generation exceeds the collection capacity of the solid waste management agencies in many developing countries (UN Habitat, 2010), including having 40-60% uncollected waste rate as shown in Table 2.1 below

Table 2.1: Waste generation status of Nigeria and Scotland

Variable	Nigeria (Lagos)	Scotland (Glasgow)	Reference
Per capita waste generation	0.5-0.8 kg/day	1.1 kg/day	Olukanni and Oresanya, (2018); Glasgow City Council (2021); Akpokodje et al., (2022); LAWMA (2022)
Organic fraction	60-75%	30-40%	Ogwueleka (2009); Ziraba et al. (2016)
Recycling rate	Less than 10% (the formal form of recycling)	45%	FMEnv (2020); Zero Waste Scotland (2022)
Uncollected waste	40-60%	Less than 2%	Word Bank (2021); Zhang et al., (2025)

Packaging waste is more of an issue in the developed economies, compared with developing countries which have a higher level of organic waste material and lower collection efficiency (Zandieh et al., 2024). Lagos, Nigeria which has about 25 million ppeople generates between 13,000 - 14,000 tons of waste per day, but has an ineffective waste collection system (Olawoye et al., 2019; Oghifo, 2021), while Glasgow, Scotland, which has population of 600,000, generates slightly less than 1,000 tons of waste per day, but has more efficient waste collection (Glasgow City Council (GCC), 2021; Dump It Scotland, 2023). In developing countries like Nigeria, when the increased solid waste generation is not sustainably managed, it can cause serious problems to the environmental and human health. As waste generation increases, it is important to understand the composition of waste to effectively manage such waste. Waste compositional analysis or audit has been used as a waste management tool to support sustainable waste management. It helps identify recoverable materials and to set targets to reduce biodegradable waste going to landfill, hence, reducing disposal concerns (Hoang, 2005; Byer et al., 2006; Coggins, 2009; Mbeng et al., 2012; Ishak et al., 2015). A common waste audit tool is the output analysis (Tchobanoglous et al., 1993 cited in Sharma and MCBean 2007). This method tracks and analyses discarded solid waste as cited in the Waste Audit User Manual: A Comprehensive Guide to the Waste Audit Process (Canadian Council of Ministers of the Environment (CCME), 1996), which will be discussed further in Chapter 4.

2.3. Municipal Solid Waste Disposal and Landfill Emission:

MSW disposal has become a subject of interest among researchers and decision makers because of the potential health impacts if waste disposal is not undertaken appropriately. Globally, substantial amounts of generated solid wastes are disposed of through landfill as it is believed to be the cheapest waste management option (Abdel-Shafy and Mansour 2018)). However, waste management through the landfill in developing countries is predominantly through open dumping, and un-engineered landfills; without leachate collection, no liners or gas capture which increases the risks of environmental contamination (Siddiqua et al., 2022).

Literature has shown that the main route for MSW disposal, both hazardous and non-hazardous material, in Nigeria, as in other developing countries, has been landfill and open dumping (Arukwe *et al.,* 2012), or open burning and discharging of domestic solid waste directly into running water (Ogwueleka, 2009), without consideration of the health and environmental impacts (Kah *et al.*, 2012). When solid waste is left in landfills/dump sites, it decomposes to release pollutants into all environmental compartments, i.e. air, land, and water. Some of these pollutants include toxic organic materials *e.g.* volatile organic compounds (VOCs), non-methane organic compounds (NMOCs) and polycyclic aromatic hydrocarbons (PAHs) (Ho, *et al.,* 2002; Lee, 2010; Alegbeleye *et al.*, 2017). However, if domestic and commercial solid wastes are disposed of and managed well, waste can become a resource for other processes, thereby helping to control environmental pollution, and enhance cleanliness and environmental sustainability.

Emissions like naphthalene, chrysene, benzene *etc.* from these waste disposal landfill sites pollute the environment, for example, leachate can pollute surface and underground water (Arukwe *et al.,* 2012), and contaminate the soil (Kah *et al.*, 2012), while the gaseous emissions cause air pollution (Irvine, 2001; International Agency for Research on Cancer, 2010), through the release of greenhouse gases (Saveyn and Eder 2014; Zhang *et al.*, 2019).

Notwithstanding the potential risk associated with un-engineered landfill sites, people also erect structures of habitation in areas close to such landfill sites, which exposes them to potential health risk, and town planners find it difficult to assess the level of vulnerability/risk to the structures/ population around such waste management facilities (Elliott *et al.* 2001; Vrijheid *et al.* 2002; Olawoye *et al*., 2019). Understanding the environmental and health risks posed by unsanitary landfill sites through site pollution inventories is necessary in managing the risks posed by such sites, hence, helping to set preventive measures that could mitigate such environmental and health risks. Although, quantifying these chemical pollutants is difficult, various models have been developed to quantify landfill emissions (Alexander *et al.,* 2005; Kalantarifard and Su 2012; Keelson 2013; Rafiq et al. 2018) (further discussed in Chapter 3). Two models have been utilised frequently in the process of quantifying the chemical emissions produced by a typical landfill site; the stoichiometric model, which involves chemical reactions that occur during waste decomposition to produce methane (CH_4) and carbon dioxide (CO_2) and represents the sum of volatilization processes (Paraskaki and Lazaridis 2005, Chalvatzaki *et. al.,* 2010), and LandGEM, a simplified model with an Excel interface produced by the EPA's Office of Research and Development; this latter model is based on first-order decomposition rate reactions, and determines total methane generation rates (Alexander et al., 2005). The LandGem model is preferred to the stoichiometric model because it is used in quantifying uncontrolled landfill emissions, creating landfill pollutants inventories, and determining more representative landfill gas emissions (Alexander et al., 2005; Kalantarifard and Su 2012; Keelson 2013). Even though Cho et al., (2012) found that the LandGEM frequently underestimates the annual methane potential, it is still more accurate than the stoichiometric model (Chalvatzaki et. al., 2010). According to Rafiq *et al* (2018), who estimated greenhouse gas emissions from Muhammad Wala open dumping site in Faisalabad, Pakistan, the using LandGem model, it was noted that the estimated total volume of carbon dioxide, methane, non-methane organic compounds and LPG were $9.026 \times 10^{+07}$, $1.354 \times 10^{+08}$, $5.416 \times 10^{+05}$ and $2.257 \times 10^{+08}$ m^3/year, respectively, and the dumpsite was expected to have its maximum volume of emitted gas, a year after site closure. The decay rate, k and the estimated methane, Lo in the LandGEM Model is temperature dependent (Alexander et al., 2005). Lagos which has a tropical climate of average of 28^oC accelerated decay, k=0.15 per year, when compared Glasgow which has an average temperature of 10^oC, with decay, k = 0.04 per year, which has a significant effect on emission projections (Fallahizadeh et al., 2019). The assertion has been confirmed that effect of temperature especially in tropical climate with hot and humid environment increases the breakdown of organic matter in landfill leading to the high yield of methane (Srivastava et al., 2023). In that regard, Fallahizadeh et al, (2019) suggested that methane has the potential to be used as an energy source after investigating methane gas by the LandGEM model from Yasuj Municipal Solid Waste Landfill in Iran, as the authors found high annual methane generating capacity at the landfill site.

2.4. Legislation:

Improper waste disposal and the associated potential environmental and health impact necessitated its management through legislation. The management of solid waste started in the United Kingdom (UK) as far back as 1846 through the establishment of the Nuisance Removal Act 1846. This law was enacted due to an outbreak of cholera in London, which resulted from poor sanitary conditions in the environment (Sigsworth, 1991). The Act empowered the local authorities to oversee the removal of solid wastes which had become a threat to public health.

Unlike the UK, the development of environmental policy or a strong legal framework to safeguard the Nigerian environment was not taken seriously until an incident in 1988 when toxic waste from Italy was dumped at Koko port in the then Bendel State (Nwufo, 2010). This led to the development of the Federal Environmental Protection Agency to move Nigeria in the enviable direction of good environmental protection management and regulations, that will enhance sustainable development. As indicated by Nwufo, (2010), “70% of environmental legislation applied in Nigeria today is derived from norms and principles of international laws in form of treaties, conventions, customary international law, protocols, and other agreements of a binding nature”. However, according to Adelagan (2004), despite environmental policy in Nigeria, there are no clear objectives and strategies to achieve the aim of its formation, and the implementation/ enforcement of these environmental laws remain a challenge (Adelagan, 2004; Olukanni, *et al.,* 2016).

Comparing Nigeria’s regulatory enforcement with Scotland regulatory compliance system, the former is not effectively enforced, leading to gaps in compliance, while the later has a more established system that investigates compliance breaches with SEPA as the regulatory body, even though its enforcement is handled by a separate body, the police force, as SEPA works in partnership with them (FMoEnv, 2015; DEFRA, 2023; Ichipi and Senekane 2023; SEPA 2024). Lagos state faces barrier in the fiscal deterrents (Ichipi and Senekane 2023; Etim et., al. 2024), while, Glasgow has an effective fiscal deterrent in the form of the landfill tax (£126.15 per ton of waste, according to Revenue Scotland, 2025) paid by site operators and administered by Revenue Scotland with guidance from the Scottish Environment Protection Agency

(SEPA) as shown in Table 2.2 below, which can help to discourage landfilling, even though the revenue is used to also fund most of its circular economy initiatives (Arthur 2023; HM Revenue & Customs, 2025).

Table 2.2: Legislative framework of Nigeria and Scotland compared

	Nigeria	Scotland
Regulation	National Environmental Standards Regulation (NESREA Act, 2007)	Environmental Protection Act (1990)
Landfill requirement	Little engineering standards	EU Landfill Directive (1999/31/EC) compliance
Monitoring of landfill emission	No enforcement	Mandated reporting of the Scottish pollutants report inventory (SPRI)
Informal sector integration	There is no policy recognition	Not explicitly recognized, but through simpler recycling producer responsibility (targeting more recycling and services at household level) of the Environment Act 2021, it targets £10 billion investment in the UK's recycling capability over the next decade (DEFRA, 2024).
Regulation of Plastic	Partial bans (2020)	Plastic tax of £223.69 per ton (HM Revenue & Customs 2025)

Fiscal deterrent to discourage reliance on landfilling	Lagos state faces barrier in the fiscal deterrents (Ichipi and Senekane 2023; Etim et al., 2024)	Effective fiscal deterrent in the form of landfill tax.

Evolution of environmental laws in developed countries, e.g. the Waste Hierarchy (Figure 1) of the EU Waste Framework Directive, has resulted in the disposed of MSW into sanitary landfill sites as a last resort. The Waste Hierarchy principle encourages waste prevention, reuse, recycling, and recovery over disposal, primarily in landfilled (Gregson *et al.,* 2013; Efraimsson *et al*., 2014). More so, landfill sites in developed countries are engineered to capture emissions, that can be used for energy generation, thereby minimising risk from such sites. The organic component of MSW degrades in landfill to produce pollutants, e.g. methane, that pose a risk to the environment and human health. Due to the risk presented by these pollutants, legislation regulates what enters the site (inputs), to control outputs, *i.e*. polluting emissions. For instance, the Waste Framework Directive of the European Union (EU), ensures that member countries develop and apply their national strategy for chemical emission control including such emissions that are emitted from a typical landfill site. Some of these emissions are captured in the Waste Framework Directive classification of pollutants as Priority Substance because of their toxic nature (which potentially causes chronic and acute health effects *e.g.* toluene, benzene, naphthalene, benzo[a]pyrene *etc*., (International Agency for Research on Cancer (IARC), 2010)). This classification of these priority substance helps in regulating and controlling the releases of these pollutants into the environment. Furthermore, there are other stringent measures, for example the Landfill Directive (European Directive 99/31/EC), which set out the pollution control system for all landfill sites and requires classification of sites based on their level of potential risk to the environment. Landfill sites are classified into:

- non- hazardous waste sites.
- hazardous waste sites.
- inert waste sites.

The Landfill Directive mandates Member States to develop and apply a national strategy for waste management, including waste reduction. The strategy includes developing measures that will encourage recycling, composting, anaerobic digestion/ energy recovery, and finally, the reduction of biodegradable wastes that are sent to landfill. Bans are also implemented, *e.g.* on some chemical waste, liquid waste, and clinical and medical waste (European Commission, 2003; Seely, 2009; SEPA, 2016). Key drivers for waste reduction include progressive increments in landfill taxes (see Figure 2.1).

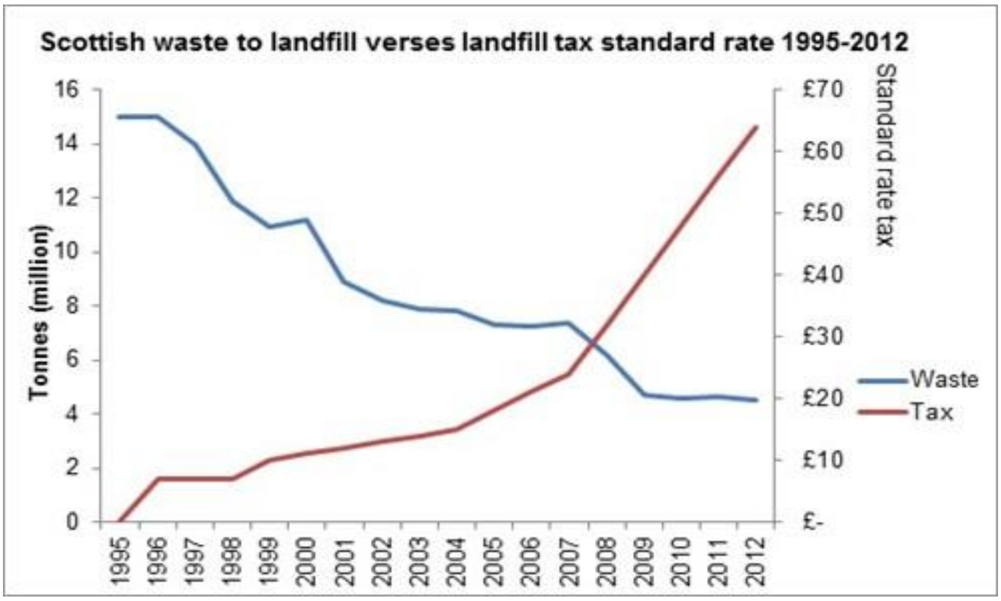

Figure 2.1: Scottish waste to landfill verse landfill tax rate 1995-2012. (Source: SEPA 2016)

Landfill operations in developed countries are controlled/regulated and monitored, unlike in developing countries, where there is little or no control and monitoring. In Scotland, landfill operations are controlled by the Scottish Environment Protection Agency (SEPA), who issue licenses to operators that must work within their permitted capacity limits. The Landfill (Scotland) Regulations 2003, derived from the Landfill Directive (European Directive 99/31/EC), set out the pollution control system for all landfill sites (SEPA, 2015), and SEPA's strong environmental task force team ensures the compliance of available environmental laws (Mill, 2013). Consequently, Nigeria, like other developing countries is yet to address the problems of solid waste management through strong legislation and other implementation measures, although such a gap has been linked to lack of coordination mechanisms and corruption (Taiwo, 2009; Amasuomo and Baird, 2016). This has caused an overflow of waste and improper disposal on the roads, drainage systems, and open dumpsites, which pose a risk to the environment and human health (Pukkala and Ponka 2001). Recently, in Nigeria, the Solid Waste Management Policy Guidelines (NSWMPG) were developed to ensure that waste generated is handled in such a way that more materials are recovered/ recycled, thus minimizing potential risk to environment and public health (FMoEnv, 2015). The enforcement of the available environmental law in Nigeria is key to enhancing waste management performance.

2.5. Health Impact of Landfill Sites:

Notwithstanding the development of legislation and other measures to safeguard the public from the risk of improper waste disposal, the impact of landfill continues to be a challenge, especially in the developing countries (Alegbeleye et al., 2017; Abdel-Shafy and Mansour 2018) because landfill remain the common waste management practice (Abdel-Shafy and Mansour 2018). Over time biodegradable waste in landfill sites degrades to release both leachate (liquid pollutants) and gaseous pollutants, which if not contained, contaminate the environment. If leachate is released from a site, it can contaminate both surface and ground water sources in close proximity, in addition to the gaseous emissions that contaminate the atmosphere, thereby exposing people to health risks when they inhale or come in contact with such pollutants (Ho, *et al.,* 2002; Saveyn and Eder 2014; Alegbeleye et al., 2017).

Vrijheid *et al.,* (2002) and IARC, (2010) argued that most of these chemical pollutants from landfill sites are potential threats to human lives, hence many of these chemicals have been classified by the International Agency for Research on Cancer (part of the WHO that promotes international collaboration and interdisciplinarity in cancer research to identify causes and develop preventive measures) as carcinogenic because of their potential to cause cancer, for example, benzo[a]pyrene, naphthalene, anthanthrene, chrysene *etc*. (IARC, 2010). Irvine (2001) shows that the resultant effect of short- and long-term exposures to chemical emissions from unsanitary landfills include cancer, genital malfunctions in males, birth defect *etc*. which is in line with other literature, as supported by Elliott *et al.,* (2001), Porta *et al*., (2009) and Kah *et al.*, (2012). Elliot et al. (2001), who looked at the risk of adverse birth outcomes for people who lived within 2 km of 9565 active landfill sites in Great Britain between 1982 and 1997, which was prior to the strict guidance set by the Landfill Directive, and compared them to people who lived farther away, found that people who lived near landfill sites had higher risks of birth defects and significantly low birth weight. In partial support of this argument, Porta *et al.,* (2009) examined and evaluated evidence and graded the uncertainties on published and peer-reviewed literature addressing health effects of waste management between 1983 and 2008 in UK. The results demonstrated an increased risk of congenital anomalies and low birth weight in proximity to the landfill sites that deal with toxic wastes and additionally, such hazardous waste disposal sites are also linked to heightened levels of stress and anxiety (Kah *et al.,* 2012).

In the last three decades, there has been concern of proximity to landfill sites resulting in human health issues, such as birth defects, genital defects, and cancer (Vrijheid *et al.,* 2002; Kah et al., 2012). Dolk *et al.* (1998), in the EUROHAZCON study, investigated the risk of congenital anomalies among the population living near 21 hazardous waste landfill sites in Europe. The study reviewed 1089 livebirths, stillbirths, and abortions with non-chromosome congenital anomalies, as well as 2366 control births without malformation, and demonstrated an increased risk of congenital anomaly for populations within 3km proximity to the hazardous landfill sites. This finding was in line with Elliott *et al.* (2001) and Vrijheid *et al.* (2002), who showed higher risks of birth defects in residents within 3km when compared to residence that are more than 3km from landfill sites. Similarly, Pukkala and Ponka (2001) investigated increased incidence of cancer and asthma in residential houses built on a former dump area. The study looked at the population register to identify 2000 persons who had lived in houses built on a dump area in Helsinki, and from this identified an increased risk of asthma. The incidence of cancer also increased progressively with increased time living in the homes, i.e. higher prevalence of cancer among those with more than

5 years of residence at the former dump site (Pukkala and Ponka 2001). Due to legislation, public opinion and unpredictable future hazard, the houses built on the dump sites were demolished by Helsinki City Council (Pukkala and Ponka 2001).
In 2001, a group of researchers from Imperial College London assessed 9565 UK landfill sites (which were operational between 1982-1997), concentrating on over 100 chemical contaminants from the landfill emissions, to evaluate the risks associated with proximity (Jarup *et al.,* 2002). It was discovered that no linear correlation was observed between health issues and pollutants, and there were no substances that were expected to give rise to any negative health issue from the study, e.g. birth defects in young people that live near the landfill sites. The study did however suggest further investigation on substances that have been linked with health effects, *e.g.* formaldehyde, toluene, styrene, arsine, carcinogenic polycyclic aromatic hydrocarbon (PAHs), chromium and 1,2-dichloroethane (Environmental Agency, 2010).

In developing countries, investigation of the risk associated with living near both operational and closed landfill sites have been largely neglected. Njoku *et al.,* (2019), investigated the health and environmental risks of living near a landfill in South Africa. The study tested the hypothesis that the deposition of waste on landfill has an impact on the residents living closer to it. The results showed that 78% of the people who lived closer to the landfill site said that bad smells linked to the landfill site affects them which further demonstrated that the air quality was compromised. People who lived closer to the landfill were sick with things like the flu, eye irritation, and body weakness. In Nigeria, residential buildings are often built near operational/ closed landfill sites, sites which lack operational compliance with standards (Tamunobereton-ari *et al.,* 2012). A study conducted by Mmereki et al. (2016) on hazardous waste management in developing nations evaluated hazardous waste management solutions and attempted to identify the existing waste management situation. It was found that in developing countries, the government can't effectively collect and manage wastes or reduce their negative impacts including regulations been unable to adequately address hazardous waste treatment and disposal. For Tomita et al., (2020), living within 5 km of a landfill waste site in South Africa, increased the risk of asthma, tuberculosis, diabetes, and depression. According to Ogbuehi,et al. (2022) and Daramola & Makinde (2024), informal settlements within Lagos dumpsites are exposed to chemical emissions, and within such landfill sites the pollutant concentrations exceed those set by WHO (Ozabor, et al., 2024). More so, respiratory disease incidence when compared to control settings, was found to be higher among residents within 5km to waste sites (Tomita et al., 2020).

2.6. Gaseous Emissions from Landfill Sites:

According to Saveyn and Eder (2014), the decomposition of biodegradable waste in landfills produces landfill gases. The major components of landfill gas are carbon dioxide and methane, both greenhouse gases that contribution to global warming (Ritchie et al, 2017; Ritchie and Roser 2020; Jones et 2023); landfills are known to contribute to 5% of the global greenhouse gases (Turner et al., 2015), which further contributes to the 1% increase in global temperature since pre-industrial times (Ritchie and Roser 2020). In addition to greenhouse gases, there are other emissions from landfills that may be harmful to human health, like non-methane organic compounds (NMOCs) (IARC, 2010).

In developed countries, *e.g*. Scotland, one of the requirements for siting a landfill site is the available strategies to contain landfill gas to minimise damage to the environment and risk to human health; landfill gas must be collected, treated and, where possible, used (Landfill (Scotland) Regulations 2003). However, in developing countries, e.g. Nigeria, there are no such measures to contain emissions from landfill sites (Tamunobereton-ari et al., 2012). Lack of compliance to international operational standards such as containing gaseous emissions from landfill sites causes deterioration of the environment and human health risk.

A better understanding of the characteristics of these emissions will help town planners develop strategies to safeguard environmental and public health, thereby decreasing the incidence of health impacts. Examples of such strategies could be enacting and enforcing laws with respect to building in proximity to hazardous waste facilities, as the incidence of such health impacts, as demonstrated by the literature, tends to peak within 2 km of a landfill site (Dolk *et al*., 1998; Elliot *et al*., 2001; Vrijheid *et al*., 2002).

The following section reviews the key gaseous pollutants from landfill and their characteristics.

2.6.1. Methane:

Methane (CH_4), considered a volatile organic compound (VOC), is one of the naturally occurring organic compounds present in the atmosphere at a concentration of 1.8 ppm (Rulík *et al.,* 2013). This organic compound has 28 times the global warming potential compared to carbon dioxide (Brander and Davis 2012). Decomposition of organic matter in landfill sites causes the generation of methane, and methane makes up about 60% of the gases generated by landfill sites. However, methane can be harnessed to produce heat and aid in the generation of electricity, as it constitutes the major component of the gases for such processes, making it useful for domestic and commercial applications. Although there is no significant health impact of methane at normal environmental levels, due to the low concentration, at high levels it can be explosive and has suffocation potential. According to Li and Chen (2016), methane's high global warming potential makes it one of the highest contributors to the effect of greenhouse gases. Under the Scottish Pollutant Release Inventory (SPRI), a database of annual mass releases of specific pollutants to the environment from SEPA regulated industrial sites, the emission reporting threshold of methane is 10,000 kg per year (SEPA, 2015).

2.6.2. Carbon Dioxide:

Carbon dioxide (CO_2) is generated from the burning of fossil fuels and the decomposition of organic materials, and in landfill sites, due to the presence of organic waste, about 40% of the gaseous emissions consist of carbon dioxide. According to Ritchie and Roser (2020) as well as Valone (2021), CO_2 concentration in the atmosphere is over 400ppm, the highest level in more than 800 years.

Carbon dioxide has an adverse environmental and health impact when produced in enormous quantities (Sahin *et al.,* 2013; Xu and Lin 2016), and on a global basis causes climate change, as it is one of the greenhouse gases that contribute to global warming (Li and Chen 2016; Ritchie and Roser 2020).

2.6.3. Non-Methane Volatile Organic Compounds:

The group of volatile organic chemicals (VOCs) excluding methane is called non-methane volatile organic compounds (NMVOCs). Products including varnish are produced in industry using NMVOCs. Because of their detrimental impact on the ozone layer, NMVOCs are problematic in uncontrolled dumpsites particularly in occupational health and populations close to the source of release (Majumdar et al., 2014; Laurent and Hauschild 2014; Qiu et al., 2014). Evaluation of NMVOC emissions using a flux chamber measurement at an open dumpsites in Dhapa, an Indian metropolitan city by Majumdar et al., (2014) revealed emission of NMVOCs, and conclusions show that an open landfill releases NMVOC and contributes to tropospheric ozone for the nearby area. Particularly those who work in dumpsites, the NMVOCs cause potential environmental and health hazards. Often the informal sector, or scavengers, dumpsite labourers in developing countries manually sort recyclable debris from the dumpsite for financial benefit without appropriate safety equipment. More so, Pecorini et al., 2020 found more than 50 NMVOCs in the two biofiltration systems used for the evaluation process at the landfill site when assessing the mitigating of methane, NMVOCs and odor emissions in active and passive biofiltration systems at municipals solid waste landfills in Tuscany, Italy. Likewise, Urase et al., (2008) found that parts of the site with higher temperature had more VOCs when assessing emissions of NMVOC such benzene, xylene etc. from solid waste disposal sites in Japan. Heat from the degradation of organic solid wastes (caused by early aerobic degradation in the landfill when anaerobic conditions have yet to fully form) could cause the release of NMVOCs, especially in the case of sites which receive both organic and plastic wastes; the authors suggested improving heat management on the landfill site as a countermeasure to avoid unusually high emission from landfill sites. In many poor nations, including Nigeria, which often has high ambient temperatures, this becomes more of a problem since it suggests possible public risk from elevated VOCs in unsanitary dump sites.

Under several laws, such as the Industrial Plant Air Pollution Directive (84/360/EEC) and the Solvent Directive (99/13/EC), NMVOC is regulated all throughout Europe. The Basel Convention on the Control of Transboundary Movement of Hazardous Wastes and their Disposal and the United Nations Economic Commission for Europe (UNECE)

Convention on Long-range Transboundary Air Pollution comprise the main international laws on reducing emissions of VOCs (Buccina, 2004). Like the Pollution, Prevention and Control (PPC) Regulations, the VOC levels in the air in the UK are controlled under the National Air Quality Strategy. More especially, through its Scottish Pollutant Release Inventory (SPRI) reporting system, SEPA tracks yearly emissions sent to air in Scotland (SEPA, 2015).

Below are a few VOCs and their characteristic nature.

2.6.3.1. Tetrachloroethylene:

Tetrachloroethylene (PER) is a colourless, insoluble liquid which can evaporate very easily, forming a VOC. It does not have any natural sources, but is instead released from waste storage sites like landfills (Leahy and Shreve 2000; Siggins et al., 2021). As one of the VOCs, it can be inhaled from contaminated air and high-level exposure is carcinogenic (Siggins et al., 2021). According to Guyton et al. (2014), neurotoxicity is a sensitive adverse health effect of tetrachloroethylene, and it is carcinogenic to humans. Tetrachloroethylene is one of the hazardous chemicals that occurs or is generated in a landfill (Robertson and Dunbar 2015).

2.6.3.2. Carbon disulfide:

Carbon disulfide is used in making synthetic fibres such as cellophane, rubber, rayon, etc. These products, and thus this compound, find their way into waste facilities like landfills and result in its release to the environment (Lee and Brimblecombe 2016). As a VOC, carbon disulfide can end up in the atmosphere, and at very high concentrations, could cause harm in the vicinity of its release, especially to site staff. Exposure to this VOC can lead to a number of adverse health effects such as loss of memory, muscle pain, loss of feeling in hands and feet, chest pains, weight loss, and most especially liver and kidney damage (Luo et al., 2018). It is listed as one of the top 10 chemicals that pose risk to human health and the environment under the United States revised Toxic Substance Control Act (Luo et al., 2018). Long term exposure can result in damage to the central nervous system and the heart, and in extreme cases cause death (Abadin and Liccione 1996)).

2.6.3.3. Toluene**:**

Toluene is a colourless, sweet-smelling liquid and part of BTEX; BTEX is a group of chemicals related to benzene, e.g. toluene (methyl benzene), xylenes, ethyl benzene, and benzene itself. BTEX is used in the production of chemicals, plastics, rubber, paints, etc., and most of these products end up in landfill sites. They can also be formed through a combustion process or when their products are burned. They can react with other air pollutants to form photochemical smog and ground-level ozone, which damages crops. Long-term exposure to high concentrations of BTEX causes damage to the kidney, liver, eyes and most especially the central nervous system (Filley et al., 2004; Manisalidis et al., 2020). Toulene is controlled in the UK through the National Air Quality Strategy through measures like the Pollution, Prevention and Control (PPC) regulations.

2.6.3.4. Vinyl chloride:

Vinyl chloride, or chloroethylene, is a highly flammable liquid which breaks down when heated to produce toxic fumes. It is used in the production of polyvinyl chloride (PVC) plastic. Vinyl chloride is also emitted from landfill sites (Bellino et al., 2001; Paraskaki and Lazaridis 2005). As a VOC, chloroethylene aids in the formation of ground level ozone and the International Agency for Research on Cancer has designated vinyl chloride as a carcinogen (Montero-Montoya et al., 2018). McLaughlin and Lipworth (1999) critically reviewed the epidemiologic literature on the health effects of occupational exposure to vinyl chloride and concluded that exposure to vinyl chloride does not cause cancer of the lung or brain, but does cause cancer of the liver, known as angiosarcoma. This assertion is supported by Sherman (2009), who assessed vinyl chloride and the liver, and confirmed that exposure to vinyl chloride results in hepatocellular carcinoma, or primary cancer of the liver.

2.6.3.5. Benzene:

Benzene is another of the VOCs that are emitted from landfills (Staszewska and Pawłowska 2012). It is used in the making of plastics, pesticide fibres, lubricants, and some types of rubber. When benzene reacts with other air pollutants, it can cause ground level ozone, which can exacerbate respiratory conditions such as asthma. Khalade et al. (2010) carried out a systematic review from 1950 through 2009 from two databases, "Medline" and "Embase" to estimate the relationship between benzene exposure and cancer risk. The results showed consistent evidence of an increased risk of leukaemia with a dose-response pattern of exposure to benzene at work. High level exposure can result in damage to the blood-forming organs and loss of blood. This is further supported by D'Andrea et al. (2018), who evaluated health risks in children when exposed to benzene and found benzene exposure is associated with abnormalities in haematologic, respiratory, hepatic, and pulmonary functions in children.

2.6.3.6. Chloroform:

Chloroform (trichloromethane) is used as a solvent and as an intermediate in the manufacture of chemicals such as pesticides, and is also emitted from a landfill (Białowiec, 2011). Long-term exposure to higher levels of chloroform can cause damage to the kidneys, skin, liver, and nervous system as long-term exposure to high-level chloroform is toxic (Templin et al., 1996). Kang et al. (2014) conducted a workplace inspection and clinical assessment of hepatotoxicity in a workers' cleanroom due to a reported case of acute liver injury in workers exposed to chloroform inside the cleanrooms, and the result showed high retained chloroform, where it's air concentrations within 40 to 45 days of working at a medical endoscopic device manufacturer, leading to the conclusion that the cases were caused by chloroform exposure.

2.6.3.7**.** Carbon tetrachloride:

The major sources of carbon tetrachloride or tetrachloromethane (TCM) are from industrial spillages and from landfill sites (Białowiec, 2011). TCM has global environmental effects as it is one of the greenhouse gases contributing to global warming. It breaks down to release chlorine, which damages the stratospheric ozone layer, which aids in the protection from harmful UV sun rays (Doherty, 2000). Long-term exposure to TCM damages the lungs, kidneys, liver, and central nervous system, being carcinogenic (Mary et al., 2007).

2.7. Waste Management Options:

The overall responsibility of waste management rests with local authorities, which see that waste is collected, transported, and treated before being disposed of (SEPA, 2016). However, the overall management of waste remains a challenge, especially in developing countries (Ogwueleka 2009; Abdel-Shafy and Mansour 2018).

New approaches to solving waste management problems must be narrowed down significantly. Our ideas should not only be efficient and sustainable in the short term, but also have a high significance in the long term. According to Badgie *et al.,* (2012), the waste management option suitable for developing countries should be based on resource recovery.

In recommending a formal waste management strategy for any waste management project, it is necessary to assess the management option that could be peculiar to the nature of waste generated (waste characteristics) within its given geographical location, and to determine the cost benefits associated with each option (Hanley, 2001; Edjabou et al., 2015). Options for waste management are evaluated based on their operational, financial, and environmental pros and cons (Hanley, 2001; Ferronato et al., 2017).

The purpose of evaluating the waste management option is to ensure a project's long-term viability. The common waste management options for sustainable management of MSW are listed below.

2.7.1. Waste Recycling:

Municipal solid waste (MSW) recycling as a waste management option is a highly effective method for maximising limited resources, as waste materials can be repurposed (Hopewell et al., 2009). Recycling programmes promote resource efficiency, which is essential for sustainable waste management (Kam et al., 2016).

In developed countries, MSW segregation, i.e. separating the waste into different streams, is often done at the source, i.e. where the waste is generated, to facilitate easy collection and processing (Favoino, 2003; Datta *et al,* 2018), whereas in developing countries such as Nigeria, the same MSW segregation at the source is often written into policy, but not implemented (Ogwueleka 2009; Taiwo, 2009; FMoEnv 2015). However, significant plastic/ metals recovery is done in Nigeria by informal recyclers (Ogwueleka and Naveen, 2021; Solaja et al., 2024). According to Solaja et al. (2024), millions of people work in the informal sector as estimated by The International Labour Organization (ILO), however, they still lack legal protection as in the case of Nigeria. Despite the risks associated with informal recycling activities, scavenging is still engaged by teenagers and young people whose motivation and driving factors of their scavenging activities remains the lack of formal education and financial gain (Ogunbode et al., 2024). According to Ademola *et al*., (2020), Olushosun landfill contains organic and inorganic hazardous pollutants which could affect the environment and public health, including scavengers who are often around landfills in developing countries. More so, Al-Khatib et al. (2020) assessed scavengers in Gaza and categorised some of the health risks they are vulnerable to which are accidents, infection, and chronic diseases including respiratory symptoms. This is supported by Ferronato and Torretta (2019) that further highlighted respiratory issues among informal waste workers (scavengers). The informal section could be integrated into policy to help meet SGD 12, particularly Target 12.5, which seeks to reduce waste generation through prevention, reduction, recycling, and reuse by 2030. 2.7.2. Composting:

This process harnesses the natural capacity of microorganisms to breakdown organic matter through an aerobic process; the microorganisms require oxygen during metabolism. Other relevant parameters to aid breakdown include temperature and moisture content (50 - 60% by weight) (Chen *et al*., 2011). The process releases carbon dioxide, water, heat, and compost. The by-product is high in plant nutrients and the compost can be used for agricultural purposes to enhance soil. More so, tcomposting process can easily be carried out at household level, hence, does not require large space (Abdel-Shafy and Mansour 2018)). However, it is accompanied by development of high temperatures that enable the destruction of pathogens and larvae that may be present in the waste material (Mbuligwe *et al*, 2001).

It is cheaper and simpler to implement than other waste management options like incineration or anaerobic digestion, unless large-scale compost is desired, which will need a mechanised aeration (Abdel-Shafy and Mansour 2018). Despite many advantages, there are also some disadvantages using this method of management. Odour problems have been an issue in several installations (John, et al, 1992). The effective reduction of odour and GHG emissions simultaneously is a big problem in compositing, not even a single aeration scheme or additive has been able to address this challenge (Lin et al., 2018). However recently, advances in composting include the reduction of odour from modern waste facilities through the introduction of biofiltration and controlled aeration (Elsabbagh et al., 2025). According to Elsabbagh et al. (2025), biofilters also have the ability to reduce methane emission from site.

2.7.3. Anaerobic Digestion:

Like composting, anaerobic digestion (AD) also utilises natural microbial breakdown of organics, converting organic materials (biomass) into useful products, e.g. biogas and residue. However, this process is completed in the absence of oxygen (Kleerebezem et al., 2015; Rocamora et al., 2020). Energy can be produced via biogas conversion, while the residue left behind has value as a soil conditioner and it helps reduce greenhouse gases, GHG (Paolini et al., 2018). To get organic material away from landfill, AD has been used in the agricultural industry to upgrade organic wastes, but usage with SMW is a more recent advance. The modular process design of many AD systems provides flexibility with respect to plant capacity. The electricity produced from biogas through combined heat and power can be used in generating revenue, which can help pay plant operational costs. One of the challenges of AD is that the digestate most of the time proves difficult to treat, therefore ending up in landfill, which is one of the reasons for setting up the BSi PAS110 in the UK (Philip et al., 2019). This is to ensure that digestate output meets certain standards to ensure quality protocol (Gerardi 2003).

The reduction of environmental pollution e.g. GHG is one of the environmental benefits of AD. However, anaerobic Digestion requires large capital investment to establish bigger capacity facilities when compared to composting. Another issue is poor ammonia-nitrogen removal (as well as other components) in methanogenic anaerobic reactors digesting animal manure (Uludag et al, 2006).

2.7.4. Incineration:

Incineration refers to the combustion of waste material under controlled conditions to reduce its volume and hazardousness (Lee et al., 2020). In developed countries this process is undertaken with energy recovery, hence the process is often referred to as Energy from Waste (EfW) (Adekomaya and Majozi 2020; Lee et al., 2020; National Research Council, 2000). Incineration is a proven technology that helps to achieve waste minimization and enhances metal wastes material recovery (DEFRA, 2013). In most cases, the products (ash) from incineration is useful for construction purposes therefore not categorized as waste. It is robust and capable of treating any type of waste including the digestate from an anaerobic digester (SEPA, 2009). However, the use of incineration reduces the use of recycling, as many recyclable materials (secondary carbon resources) will be combusted (Lee et al., 2020). It also contributes to carbon emission which affects the surrounding air quality and the CO_2 emitted per KWh is two to three times higher when compared to a highly efficient coal power plants (Lee et al., 2022).

2.7.5. Landfill:

A sanitary landfill is designed with a system of layers that promotes safe decomposition of waste and collection of the methane generated during decomposition. The methane, which is a significant contributor to climate change, is collected through a pipe system, treated, and utilize it to generate energy. The deepest locations of a landfill could be 500 feet below the surface. As some waste breaks down, liquid is produced. Additionally, rain can push other pollutants to the bottom of a landfill as it filters through. These liquids, known as leachate, are gathered, and sent to treatment facilities, either on-site or at wastewater treatment plants. The leachate is collected using perforated pipes that are put on top of the liner. Modern landfills are frequently coated with compacted clay that is so dense that liquids cannot get through. As indicated in Figure 2.2, landfill engineers place a high-density plastic liner for further protection on top of the clay. A layer of earth would also be placed over a new waste to help keep odours in check which will at same time minimise gas emissions.

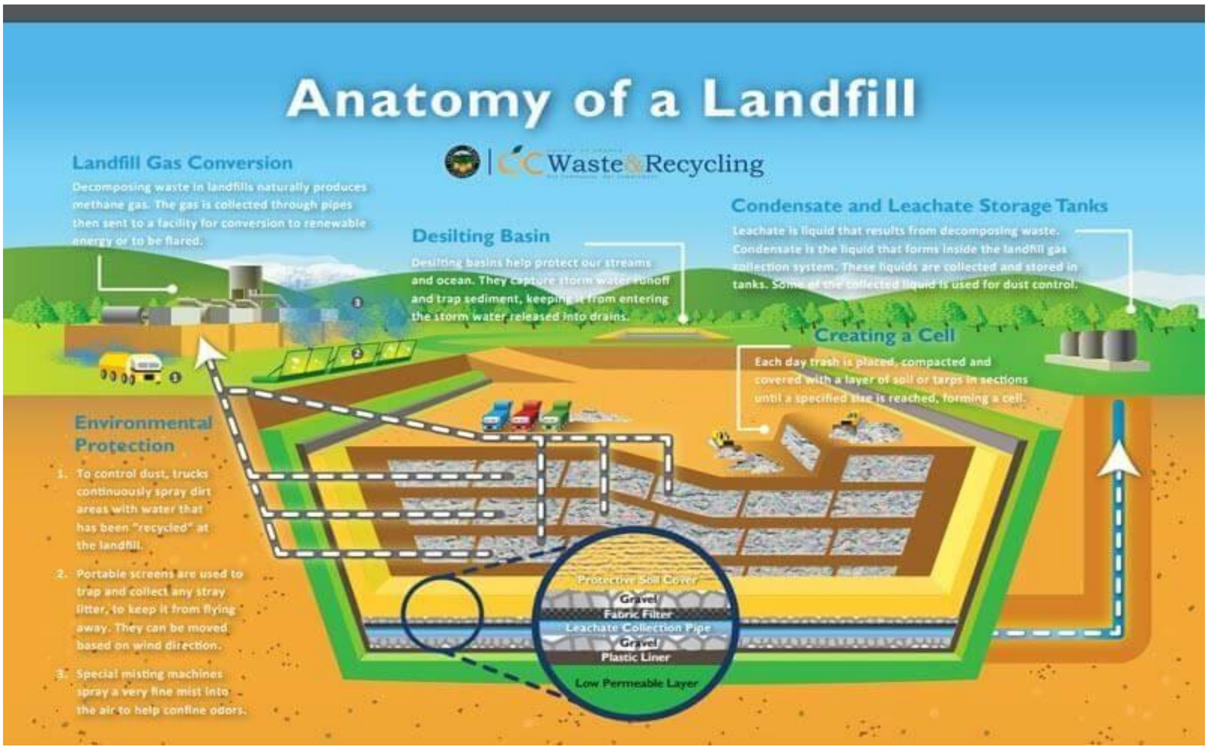

Figure 2.2: Landfill site design (Source: Kasnia, 2021).

As compared with sanitary landfills, open dumpsites are areas where waste is disposed of without sufficient controls, such as the application of cover on a regular basis, restricted access, and other environmental controls (Rim-Rukeh 2014). Waste of all kinds, including industrial, municipal, and clinical/hospital waste, is disposed of together (Remigios et al., 2010). The waste dump sites are associated with several risks, including soil and groundwater contamination, foul odours, the emission of greenhouse gases, accidental fire threats, slope instability, loss of flora, and bird strikes, among others (Rafiq *et al* 2018; Siddiqua et al., 2022; Wiafe, 2024). These issues are brought on by a lack of leachate collection and treatment, the absence of liners, a lack of cover, and either a poor or non-existent site design (Remigios et al., 2010; Yadav et al., 2019).

Open dumpsites are a common waste disposal method used in developing countries because of its simple management (Abdel-Shafy and Mansour 2018; Zhang *et al.,* 2019). Research has identified landfill as a major source of pollutants, as biodegradable waste materials decomposes in landfill to generate emissions of environmental and health concern e.g. methane, VOCs (Kah *et al.*, 2012; Nair *et al.,* 2019). The potential risk associated with landfill is the reason the Landfill Directive (European Directive 99/31/EC) was developed; this directive sets stringent operational and technical requirements on the waste and landfills. The EU Directive encourages member states to further formulate more measures to safeguard public health from potential risk of landfill. In the EU Waste Hierarchy landfill remains the least desirable waste management option, while waste prevention, reuse, recycle, and recovery take the lead. In developed countries *e.g*. Scotland, sanitary landfills are only permitted by the government, via their environmental regulator, e.g. the Scottish Environment Protection Agency (SEPA), when a proposed site meets the standards stated in regulations, e.g. the Landfill (Scotland) Regulations 2003. These regulations require sites to be designed to capture methane gases for the generation of electricity. Such regulation is not common for landfill in developing countries, which pose high risks to the public. In developing countries, like Nigeria, such risk associated with landfill is not well understood, as people are seen residing very close to such sites (Tamunobereton-ari *et al.,* 2012).

2.8. Economics of Waste:

Waste management is a legal obligation of any government authority. The management involves the collection and disposal of waste, a costly activity. Ferronato and Torretta (2019), while reviewing waste mismanagement in developing countries, noted that open dumping of waste was a cause of surface water pollution through uncontrolled waste flow, which had an economic impact, e.g. the cost of clean-up, recovery, and disposal, aside from the social and environment impacts. It is expected that waste management process is done at a minimum cost, for example in the cost of waste truck purchases, fuelling and maintenance of truck, payment of wages and other indirect costs incurred by the waste management authority in discharging its responsibility (Kallel *et al*., 2016; Ferronato and Torretta 2019).

Many countries are faced with the major challenge of efficient waste collection as waste generation is on the increase. The cost of safely managing such waste remains a challenge especially the collection process (Taiwo, 2009). Despite all the efforts by the municipal authorities to encourage reduction, reusing and recycling of waste, there are always certain quantities of waste that still require final disposal. It could take up to the equivalent of 500 truckloads of waste daily for final disposal of waste, if assuming a city of 5 million people generate up to 3000 tonnes/day and having a collection rate of 70% (Ali *et al*., 2005). The disposal of such large quantities of waste is often high and beyond the financial capacity of municipal councils in developing countries (UN Habitat, 2010), thereby resulting to inefficiency in collection, hence, posing health and environmental risk. This is why countries develop policies to reduce, reuse and recycle waste instead of landfilling which has its own health, environmental, and economic impacts (Kah *et al*., 2012; Saveyn and Eder 2014).Despite the recovery of recyclable materials being preferable to landfilling of waste under the EU Waste Framework Directive's waste hierarchy, there is need to always evaluate the economic cost and the sustainability of any waste management recycling options (Ferronato *et al*., 2017), to know when such a system becomes financially and environmentally sustainable. Often, studies of cost benefit analysis in waste management do not integrate environmental risks into the evaluation process, due to the difficulties in monetary weighting of the intangible materials (Da Cruz *et al*., 2014).

Solid waste management contributes to around 5% of the world greenhouse gas emissions (Turner *et al.,* 2015), and the potential effects of these GHGs cannot be over emphasise. Sustainable waste management such as enhanced recycling has been shown to facilitate the reduction of greenhouse gas emissions (Corsten *et al,* 2013). Corsten *et al,* (2013) used iWaste, a simulation model to evaluate the potential contribution of sustainable waste management to energy use and greenhouse gas emission reduction in the Netherlands. These authors showed the reduction of greenhouse emissions when recycling was optimised. Although, Corsten *et al,* (2013) did consider CO_2, they excluded other environmental impacts and economics of various treatment options during the evaluation process. However, these are crucial in such waste management evaluation process, as environment impacts like emissions are of environmental and health concern which can affect sustainable waste management, that enhances waste reduction and reuse (Bernstad, 2010; Kam *et al*., 2016).

Research has shown that these emissions occur majorly because of biodegradation of organic materials especially in landfill sites resulting in environmental pollution (Varma and Kalamdhad 2014). This growing concern about the effects of landfill emission or GHGs has led to the development of international policies and measures aimed at reducing emissions. One major goal in sustainable waste management is the efficient use of limited resources that could potentially reduce GHGs emissions (Varma and Kalamdhad 2014; Turner *et al*., 2015). Reducing GHG emissions requires a cost effective, sustainable management approach, as it implies having projects that are environmentally and financially viable. This kind of economic consideration highlights the usefulness of cost benefit analysis (CBA), where projects or management options are placed into a quantifiable financial value to select a better management option among different alternative (Begum *et al.,* 2006; Atkinson and Mourato 2008). Cost benefit analysis (CBA) is defined by Reniers *et al.,* (2016) as "an economic evaluation in which all costs and consequences of a certain decision are expressed in the same units, usually money".

In a waste management context, the goal of CBA is to investigate which solid waste management options are cost effective from an economical point of view, while also considering the environmental risks associated with each of the waste management activities under consideration. Although there has been criticism in the use of CBA for appraisal (Hansjürgens, 2004; Feuillette *et al.,* 2016), there is also literature highlighting the usefulness of CBA in evaluating efficiency of investment under economic point of view (Reniers *et al*., 2016). According to Feuillette *et al.,* (2016), who evaluated the use of cost–benefit analysis in environmental policies, noted that due to high complexity of ecosystems, lack of information on interactions in the ecological system leads to achieving an unbiased result. For instance, the uncertainty associated with the monetary valuation which is because benefits coming from nature are often under-estimated and costs often over-estimated, this was supported by Hansjürgens, (2004). However, according to Reniers *et al.,* (2016), who used CBA to evaluate investments in safety measures under economic perspective, the research used well-known indicators and measures from economic theory such as net present value (NPV), and internal rate of return, to develop a robust and long-sighted risk and safety analysis for operational safety within any organization and further concluded that CBA is good in evaluating investment decisions. The above literature shows the need to assess waste operational efficiency at minimal cost to enhance sustainable waste management especially in developing countries which often neglect the risks associated with waste management, hence, potentially increasing environmental and health impacts associated with improper waste disposal/ management.

2.9. GIS and its Application in Waste Management:

Geographical Information System (GIS) is designed to accept, store, process, analyse and display spatial data which incorporate geographical locations (Kliskey, 1995; Overman, 2009; Higgins, 2014; Givi *et al*., 2015)**.** Over time, arguments continue to arise as to whether GIS is a science or a tool because of its multidiscipline applications. Kliskey (1995) who evaluated the role and functionality of GIS as a planning tool in natural-resource management, showed the linkage of attribute or non-spatial data to locational data describing real world features. Kliskey (1995), described GIS as a management tool, due to its ability to analyse spatial information systems to provide functionality for planning which help to evaluate conflicting factors, as well as to identify unanticipated or unforeseen issue which can aid planning or natural resource management. It shows the application of GIS was helpful as it provided finality for analysis evaluate or modelling. The result concludes the appropriate use of GIS as a decision support tool.

Wright *et al.*, (2016), attempted to demystifying the persistent ambiguity of GIS as 'tool' versus 'science' argument, and showed that GIS could be understood more by three distinct positions along a continuum ranging from tool to science; as being a science, it analyses the fundamental issues raised using GIS. GIS is viewed more as a science because of its ability to explore visual presentation (in form of a map as an output), while evaluating geographical and environmental features of concern which makes it more unique than other traditional hypothetical and mathematical rigor. However, the acceptance of GIS as a tool or science depends on individual view or who the GIS developer is; as its application remains multi-dimensional which people can view differently (Hasmadi and Imas 2010). Therefore, GIS can enhance the analysis or evaluation of geospatial data to aid decision making.

2.91. GIS and Environmental Planning:

The ecological, economic, and environmental wellbeing of an area can be affected if adequate planning of the area is not taken into consideration; this makes selection of a landfill site a critical issue in the development and planning process of solid waste management. Additionally, making a risk exposure assessment of emissions from such landfill sites for adequate environmental regulation to safeguard public health, is very important. The selection process and risk exposure assessment of such landfill sites evaluates areas that can minimize hazards to public health. Such analysis and visual display capability of GIS (in form of map) provides a better understanding of issues at hand like in risk of exposure of a typical landfill site (further discussed in Chapter 3). Many tools integrated in GIS have made it so effective in spatial query and analysis for decision makers.

More so, another great challenge faced by economics today is to integrate environmental sustainability with economic growth and welfare by eradicating environmental degradation from economic growth and virtually doing more with less. This is one of the key objectives of the European Union, but the consequences of climate change and the increasing demand for energy and resources are challenging this objective (sustainability).

Sustainable consumption and production maximise business potential to transform environmental challenges into economic opportunities and provide a better deal for consumers. The challenge is to improve the overall environmental performance of products throughout their life cycle, to boost the demand for better products and production technologies and to help consumers in making informed choices (European Commission online, 2011). It includes a series of proposals on sustainable consumption and production that will contribute to improving the environmental performance of products and increase the demand for more sustainable goods and production technologies (European Commission online, 2011).

Sustainability involves development which can be both temporal and spatial. This simply points to the fact that population density, geographical area availability for implementation of technology plans, as well as probable cost of these projects are complex and need to be considered (and eventually combined) during the planning process for efficient and excellent result-oriented decision making. This presents another challenge of how different collated data can be combined to make sense, provide accurate results and be finally applicable to real life scenarios.

A Geographical Information System (GIS) remains a tool designed to work with data or data referenced by geographical coordinates. It unites biophysical and socio-economic data and is used by decision makers to solve complex and multi-dimensional problems. The importance of prioritizing GIS during preparation of sustainable development indicators cannot be overemphasized, as it aids in Decision Support System (DSS). This is due to the ability of GIS to bring about objective aggregation of all sustainability indicators for more accurate assessment rather than looking at each indicator individually, while ignoring their apparent interactions and its overall impact on the assessment results (Kliskey, 1995).

2.9.2. Sustainability and GIS:

In 1992, at the Rio Summit, sustainability was embedded into the global agenda and elucidated as ‘development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs’ (Brundtland, 1987).

Sustainability assessments have become common place though it must be pointed out that no generic framework exists for these assessments due to complexity of interrelated ecological and human systems such as the multiplicity of spatial patterns and ecological processes as well as nonlinear interactions among components (Zurlini *et al.,* 2006). Sustainability of a system is characterized by the coevolution of social, economic, and environmental factors.

One of the problems with sustainability assessments is how to collate the indicator information together to determine something about the overall system sustainability. This shows a clear need for robust data handling and visual communication systems to unite these disparate characteristics of sustainability in order to arrive at an efficient and overall acceptable consensus. This is where GIS takes a firm stand, as it was developed as a toolkit for managing problems of distribution and abundance of things in space and time.

GIS has three major goals:

a. Acquiring, storing, managing, and integrating geographically- referenced data;

b. Providing tools for data analysis, with the aid of mathematical models;

c. Representing data and results of data analysis majorly through thematic maps, charts, and tables.

GIS displays objects using two types of data structure: vector models or raster models. In raster models, maps are divided into cells, grids, or pixels, and by assigning a value for each layer and grid cell, information can be displayed. Whereas, in vector models, objects are shown as lines, points or polygons and make use of x-y coordinate system (Gupta 2006; Lloyd 2010). A combination of both for data analysis brings about the results needed to make sense from various incompatible parameters. This makes information represented on GIS quite dynamic and gives it the unique ability to query data in many ways. Analysis can be made to reflect results based on different factors such as geographic areas, attributes or underline specific phenomena and relations among elements. Areas of interest can be made visible while unwanted layers can be made invisible (Kliskey, 1995).

2.9.3. Role of GIS for Sustainability Indicators and Assessment:

Sustainability indicators are important and aid in the gathering of useful and proper data while arranging these indicators or indicator sets in a coherent manner. The quality of data gotten, and the indicator parameters will determine the type of result likely to be obtained using GIS given that major challenges faced by most spatially referenced sustainability data in the EU include limitations in scale, coverage, or content. More so, data comparability over time and closeness of chosen indicators to the sustainability issue to be addressed, hence, GIS use in planning should be viewed as a management process rather than merely a software or hardware (Kliskey, 1995). Merits of using GIS in indicator work for sustainability assessments include:

1. Analysis: GIS provides a range of tools for spatial analysis and tools such as statistical analysis for non-spatial analysis of attribute data associated with geographic features.

2. Database Management: Comprehensive GIS packages are often connected with powerful database management systems. Indicator databases can be stored and maintained by GIS.

3. Visualization; The ability of GIS to produce cartographic output such as spatial indicator maps and reference maps is unique and textual guidance through dropdown menus and text boxes for users is also key. Another important advantage is the internet linkage ability of GIS for online sharing of data and ideas.

Sustainability assessment at regional scale simply involves geographic area usually away from desire targeted features and GIS links multiple spatial and temporal scales of biodiversity with human uses and socio-economic imperatives. Therefore, GIS can be seen as a tool for planning with the people and not just for the people.

The use of GIS is increasing for storing data and producing maps and thus data accuracy is imperative for accurate results that aid decision making process.

2.9.4. Operational Efficiency:

One of the issues of waste management is the waste collection process. In fact, large portions of waste management budget go to waste collection, as the waste trucks are fuelled and maintained to be able to carry out the needed tasks. However, despite the huge amount consumed by the transport unit of the waste management sector, its service delivery is the not efficient (Ogwueleka 2009; Taiwo, 2009). This makes the use of GIS very useful in route analysis which helps to identify the best route for waste collection at the shortest time possible. Its use in this area has been utilised in the developed countries and it can be of help to minimise the cost of waste collection and transportation. Lella *et al.,* (2017) who investigated optimization of waste collection and transportation routes, showed a 59.12% reduction in travel distance along the routine collection road network followed which potentially reduced the time it could take to carry out such tasks and the fuel consumption too. This shows how operational efficiency could be enhanced with the use of GIS.

2.9.5. GIS in Risks Assessment:

Waste management continues to be a huge challenge for municipal planners. The need to account for local conditions has led to an increasing use of spatial decision tools based on GIS to model base line waste conditions, identify potential facility locations, estimate transport impacts and areas that could potentially affect some features (Mennecke, 2001; Boulos, 2004; Woo *et al.,* 2018). The major agenda here is to give land use planners ideas on how to define and use analytical tools for GIS processing. GIS analysis for identifying areas of risks or choosing a suitability area for sitting a waste treatment facility can be said to consist of three major phases namely:

1. First Phase: Here a layer of areas for the targeted features are defined such as areas a facility should be, must be outside/ within certain criteria e.g. urban settlement. The same applies to the risk of exposure to population, which could emphasis that people must live at least 3 km away from a waste management facility e.g. landfill, considering the health issues associated with living closing to a landfill site.
2. Second Phase: These defined layers that are used to select a subset of units that are in a suitable location.
3. Third Phase: Additional criteria that define highly suitable units are defined. Suitable units are given distance parameters from major roads, residential areas,

urban areas that are densely populated. These values are tagged with appropriate codes for easy identification on the map. Also selected unit should be large enough for the construction of the facility. Same applies when choosing other features of interest.

The selection of suitable areas from available land resources has always been challenging bearing in mind different criteria/ factors required to meet the interest of the project. For example, when siting a suitable area for non-hazardous landfill sites, it is better to site the landfill more than 250 m away from residential areas (Environmental Agency, 2012) due to residential concerns like odour, noise, dust etc. that may arise because of activities from such landfill sites. While for a hazardous landfill site, residential buildings must be more than 500 m from the site due to health concerns e.g. birth defects (Vrijheid *et al*., 2002), which may arise because of emissions from such sites. Proximity as a consideration factor in relation to landfill sites depends on the type of solid waste that is received in the site, which also affects the level of risk exposure, hence, the need in the good management of the waste facility (landfill sites). GIS application can bring about objective aggregation of all sustainability indicators for more accurate assessment of either land use strategy or risk assessment or exposure evaluation, rather than looking at individual indicator while ignoring their apparent interactions and been suitable for evaluation and precision during proximity analysis (Baiocchi *et al.,* 2014). Due to the health impact of emissions from landfill sites, there are specific criteria to consider when sitting a waste management facility like a landfill, of which GIS can be applied for such analysis. Factors that can influence the decision in using GIS include:

Hydrological factors: Surface and ground water aquifers play a vital role in human survival. Humans may survive a long time in the absence of food, but not in the absence of good quality water, this makes protection of the surface and ground water aquifers from contamination vital. To prevent the pollution of the ground water and surface water sources, landfill sites should be located more than 50 meters away from water sources (distance from river networks). This will mitigate contaminated fluids from landfill sites leaching into water networks in proximity or percolating and polluting the underground water (Arukwe *et al*., 2012; Broomfield and Davies 2010; Yazdani *et al.,* 2015).

Land use/ cover factors: Land cover refers to the human and natural landscapes that are likely to be exposed to risks if in proximity with a hazardous waste dumping site. It is often recommended to site landfill on bare lands. Roads as a land use factor, serves as a wide way for movement of goods and services. Environmental pollution resulting from emissions from landfill sites can directly affect road users. This makes inhalations a route for direct transmission of contaminated air. Therefore, distance of road from landfill site is considered one of the major criteria in siting a hazardous landfill site (Josimovic and Maric 2012)

Residential building factors: When siting a landfill site, consideration must be given to residential areas and urban settlement. Proximity of residential buildings or urban settlements should be more than 500 meters from hazardous landfill sites, due to potential emissions of public health concern (Jarup *et al*., 2002; Josimovic and Maric 2012; Yazdani *et al*., 2015).

Geographical factors: Topography and slope require consider in landfill site selection. Selecting highly sloped areas will escalate pollution downstream with leachate (Arukwe *et al.,* 2012).

Geological factor: Distance from faults and poor soil quality must be considered when selecting a site for landfill. Faults and poor soil quality will intensify the contamination of ground water sources through leaching of the landfill leachate down to underground water (Yazdani *et al.,* 2015).

2.10. Sustainable Waste Management System (SWMS):

A Sustainable Waste Management System (SWMS) is an integrated approach that requires understanding of specific waste management problems of any given location, which are determined by working with the relevant waste management stakeholders, an integrated approach to problem solving can then be implemented. Some of the approaches involved include interviewing individuals knowledgeable about the waste management operations (which includes the collection and treatment technique used), qualitative assessment in the form of questionnaire in order to gain broader knowledge of the waste issues enabling quantification of the problems associated with the waste management practices, while focusing on behaviours, attitudes and other defined variables (Bailey *et al.*, 2015). This approach has been validated in the past to understand and identify waste management problems caused by the poor waste management policies and practices in other to solve or produce recommendations for sustainable waste management (Bailey *et al.*, 2015; Yoada *et al.,* 2014).

When contributions from stakeholders are collated, and analysed, it gives a holistic understanding of an existing problem and with other waste management measures, such as the compositional analysis of waste and cost-effective waste treatment options, the problem of waste management can be solved.

CHAPTER 3

LANDFILL AND ASSOCIATED RISKS TO HUMAN AND ENVIRONMENTAL HEALTH: CASE STUDIES IN NIGERIA AND SCOTLAND.

3.1. Overview:

In comparison to developed countries, developing countries dispose of MSW primarily by landfill, with minimal recovery of materials, which hinders environmental sustainability (Abubarkar et al., 2022). One of the main concerns with landfill sites are chemical emissions, of which, the non-methane volatile organic compounds (NMVOCs) and hazardous air pollutants (HAP) generated during the decomposition of biodegradable wastes have been suggested as causes of cancer, congenital abnormalities, and respiratory tract irritations *etc. (*Elliott *et. al.,* 2001; Porta *et al.,* 2009; IARC, 2010; Kah *et al.,* 2012). This assertion is confirmed by epidemiological research literature, the EUROHAZCON that established the baseline risks, showing that landfill sites do pose risks to nearby populations. According to Dolk *et al.* (1998), in the EUROHAZCON study of solid waste landfill sites, where over 1080 health issues were studied in populations near 21 landfill sites in Europe, demonstrated an increased risk of congenital defects for populations within 3 km proximity to hazardous landfill sites. This finding was further supported by Elliott *et al.* (2001) and Vrijheid *et al.* (2002), from whose findings showed higher risks of birth defects with residence within 3km of a landfill site compared to residence that are more than 3 km from such sites. However, these health concerns have not stopped people from living close to landfill sites, despite the potential risks; particularly so in developing countries where there is limited regulation/policy regarding the use of landfill sites.

The concern regarding health led to a publication by Olawoye *et al*., (2019), which evaluated the socio-economic and environmental implications of residential buildings in close proximity to the landfill site in Olushosun, Nigeria. Eighty-five questionnaires were sampled from buildings within 200 to 500 metres (0.2 -0.5 km) from the landfill site, however, the details of these building structures that are exposed to the site were not captured as it did not fall within the scope of the research. More so, due to residential concerns like dust, odour, noise, pollution, etc., it is recommended that a landfill is sited more than 0.25 km (250 m) away from residential areas (Environmental Agency, 2012), while hazardous landfill sites must be more than 500 m away due to health issues like birth defects (Vrijheid et al., 2002).

Meanwhile, one of the challenges for proper risk assessment of landfill sites in developing countries is lack of sufficient data for comprehensive evaluation from source of potential hazards (like landfill) to the receptor (Nwosu *et al*., 2016; Ajibade *et al*., 2019). While risk assessment of landfill sites through air quality monitoring and investigations of human health problems around landfill sites have been largely explored, the research conducted on potential risk of exposure to landfill, based on proximity of residential buildings to sites is unexplored.

Historically, landfill has been used for solid waste disposal in developed countries, but the introduction of environmental laws has helped minimised the amount of biodegradable wastes disposed of by landfill. For example, the EU Waste Framework Directive (2006/12/EC) and Landfill Directive (European Directive 99/31/EC) are based on the waste hierarchy principle that ensures waste is prevented, reused, recycled, and recovered, before its final disposal by controlled landfill. However, such environmental laws, if they exist, are poorly enforced in developing countries which increases potential risk from landfill sites. In this regard, developing nations face higher exposure due to informal settlements and unlined landfill sites that do not capture emissions (Olawoye *et al*., 2019; Aralu et al., 2025).

The aim of this chapter is to assess human exposure to potential risks from landfill sites using a geospatial technique of analysis; case studies were made of Olusosun and Patersons of Greenoakhill landfill sites, in Nigeria and Scotland, respectively. The risk assessment used consists of identification of hazards and the evaluation of risk associated with exposure to those hazards (WHO 2012). Proximity analysis was used to conduct the evaluation by identifying potential hazards and the structures at risk with the help of GIS, a spatial tool that helps identify areas of potential human and environmental risk (Bien *et al.,* 2005).

3.2. Methodology:

3.2.1. Case Study A, Area Description: Olushosun Landfill site:

Olushosun landfill site is situated in the City of Lagos, a city of 17.5 million people (Lagos Population, 2019). The site falls into Ikeja local government area, in the northern part of Lagos State (Figure 3.1). The 43-hectare site, which has an estimated 35-year life span, was established on Friday 19th November 1992 (Olorunfemi, 2011), and is managed by Lagos Waste Management Agency (LAWMA). Built on a laterite-based sub-soil, the site is 18m deep and 800m wide. It was designed as a semi sanitary landfill site, as such, there is covering on the top of the waste, although it is not regular due to lack of sufficient funds in providing all the necessary earth-moving equipment, hence, the deposited wastes are not covered daily. The site is one of the largest landfills in West Africa and receives about 40% of the total waste deposits from the State. It receives 5,000 metric tonnes of waste daily and approximately 1,000,000 tonnes annually (Olorunfemi, 2011). More so, the site is characterized by lateritic sandy and permeable clay sub-soil, with the hydrogeology of the area showing a shallow water table aquifer with about 8m depth and as a dumpsite, does not have composite linen to prevent pollutant leaching (Longe et al., 1987; Adelana et al., 2008; Oyebode et al., 2023).

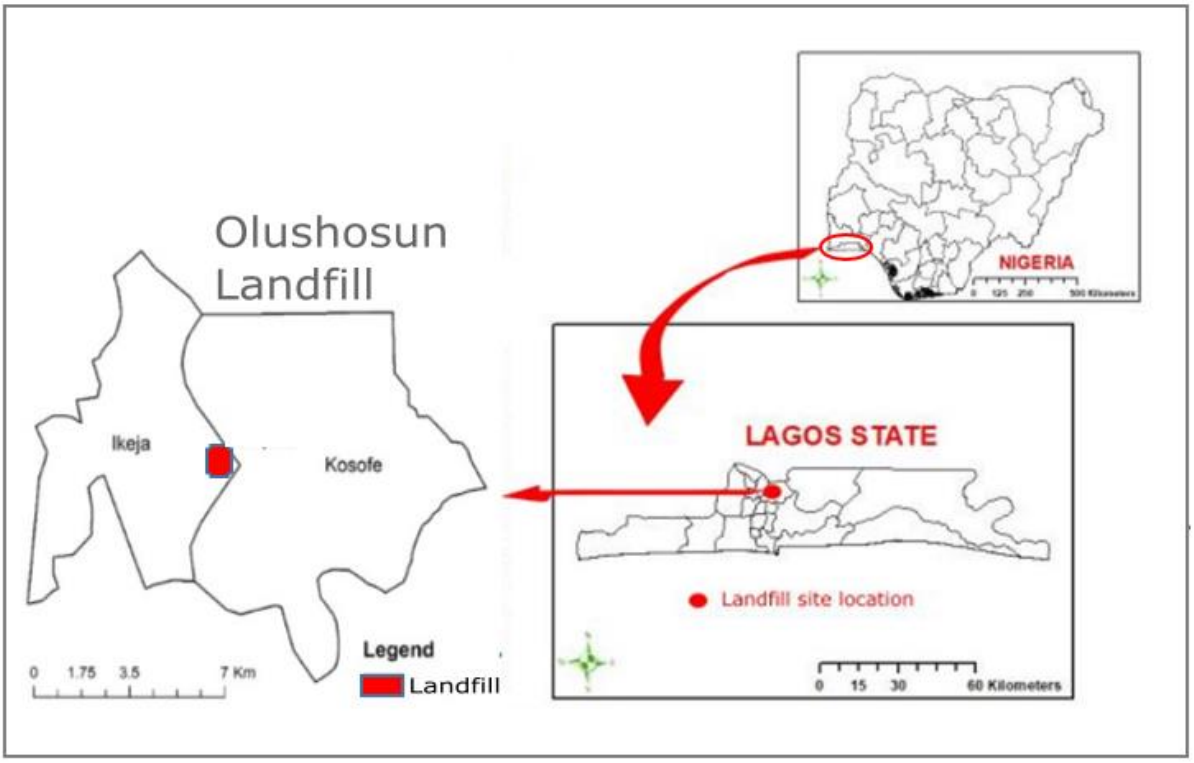

Figure 3.1: Map of Olushosun landfill site in Lagos State, Nigeria.

3.2.2. Case Study B Area Description: Patersons of Greenoakhill Landfill site:

Located in the Mount Vernon area of the city, the site is managed by Patersons of Greenoakhill Limited (Figure 3.2), and covers an area of 175 km^2. The site services the City of Glasgow, which has a population of 635,000, and is the most populated city in Scotland (Scottish Fire Service Inspectorate, 2024). The Glasgow site has standard engineered landfill design with a composite liner which has about a 1m depth of compacted clay and a 2mm HDPE geomembrane to contained generated leachate (SEPA, 2015; Giroud, 2016; Muralikrishna and Manickam 2017). The gas management entails methane capture through extraction wells which feed a rotary generator, providing enough energy (40,000mw of green electricity per year) via the National Grid to power between 3,000 - 4,000 homes (Paterson, 2024).

Although the Glasgow landfill site has a capacity of 1,800,000 tonnes in total, it is only licenced to receive 500,000 tonnes of municipal solid waste annually (SEPA, 2015).

There have been difficulties comparing these two sites, as they are different, for example, the data analysed for each site was at a different time due to the inability to assess data from from LAWMA. However, the assessment of the waste management processes in the two case study areas is important to understand better ways to manage the potential risks associated with waste disposal to landfill and its environment, especially for Lagos State, Nigeria, based on the lesson learned from Glasgow, Scotland.

Figure 3.2: Map of Patersons landfill in Glasgow, Scotland.

3.2.3. Waste Generation and Disposal:

Waste generation data for Lagos State and Olushosun landfill waste disposal data were sourced from Lagos State Waste Management Agency (LAWMA). The total waste generated in Lagos State was assumed to be the total waste deposited to the five landfill sites in Lagos (Olushosun, Solous II, Solous III, Ewu Elepe and Epe). However, the total waste landfilled at only Olushosun was used for further evaluation in the study. The waste generation in Glasgow, and the Patersons of Greenoakhill landfill waste disposal data, was sourced from the Scottish Environment Protection

Agency (SEPA) database (SEPA, 2015). The waste generating data was used to estimation the emission rate at the landfill sites, which helped in understanding how potentially risky the emissions are from the sites based on the knowledge of the characteristics of the individual emissions. Approval for data collection and granting of interview was done by communicating with the LAWMA and SEPA offices in writing to seek their permission and request data, which was granted. More so, an ethical approval for the research was granted by the University of Strathclyde (see Appendix 3.1). A visit to the LAWMA office in December 2016 and SEPA's office in July 2016, as well as to the two landfill sites enabled the observation and discussion of their waste management process by interview with one of their management staff, and collection of data to get first-hand information including an interview with two scavengers working at Olushosun site, and also the site waste operators. The list of questions on their solid waste management plan, policy, communication, treatment among others can be seen in Appendix 3.2.

3.2.4. Landfill Emissions:

To evaluate the potential effects of residential exposure to hazardous emissions from the landfill sites, quantitative assessments were undertaken with emphasis on the gaseous chemical emissions from the landfills, in particular carbon dioxide, methane and non-methane hydrocarbons (NMHCs), including the volatile organic compounds (VOCs), due to their environmental and health risks (details on the effects of these substances is given in Chapter 2).

In quantifying the chemical emissions from a typical landfill site, two models have been commonly used:

1 the stoichiometric model which involves the chemical reactions that occurs during the decomposition of waste material to produce methane (CH_4) and carbon dioxide (CO_2) and represent the sum of volatilization processes of the reaction (Paraskaki and Lazaridis 2005, Chalvatzaki *et. al.,* 2010);
2 the LandGEM model which is based on the first order decomposition rate reaction used to determine the total methane generation rate. This uses a simple model with an Excel software interface and was developed by the Office of Research and Development, United States Environmental Protection Agency (Alexander et al., 2005).

The advantages of the LandGEM model are that it is used to quantify uncontrolled landfill emissions, create landfill pollutants inventories, and it determines more representative landfill gas emissions (Alexander *et al.,* 2005; Kalantarifard and Su 2012; Keelson 2013). The LandGEM model which is available in the public domain requires a set of input data for the quantification of the landfill emissions, which includes, the amount of waste generated by the landfill (waste acceptance rate), waste design capacity, and open and anticipated closure year (when the landfill commenced operation and when it will be closed). Although, Cho *et al*., (2012) noted that the LandGEM frequently overestimates the annual methane potential, it remains more reliable compared to the stoichiometric model (Chalvatzaki et. al., 2010).

The first order decomposition rate equation used by LandGEM (Alexander *et al.,* 2005) is shown mathematically below:

$$Q_{CH_4} = \sum_{i=1}^{n} \sum_{j=0.1}^{10} kL_0 \left(\frac{M_i}{10}\right)\left(e^{-kt_{i,j}}\right)$$

Where
QCH_4= annual methane generation in the year of the calculation (m^3/year)
i = 1 year time increment
n = (year of the calculation) - (initial year of waste acceptance)
j = 0.1 year time increment
k= methane generation rate ($year^{-1}$)
Lo= potential methane generation capacity (m^3/Mg)
Mi= mass of waste accepted in the i^{th} year (Mg)
tij= age of the j^{th} section of waste mass Mi accepted in the i^{th} year (decimal years, e.g., 3.2 years).

3.2.5. The LandGEM model:

This model was used to assess the chemical emissions from Olushosun landfill; waste generation data, waste design capacity, open and anticipated closure year from this site were obtained from Lagos State Waste Management Agency. The data was input into the LandGEM model which has an excel interface that automatically calculates the emission estimates (the full report can be seen in Appendix 3.3). While for the Glasgow landfill, emission estimation data was obtained from SEPA's database via the Scottish Pollutant Release Inventory (SPRI), including the waste generation/ landfilled data. Annual emissions for each of the chemical pollutants generated from the two landfill sites were also checked against the Scottish Pollution Release Inventory Reporting Threshold (SPRI RT; SEPA 2015). The SPRI RT guide is used for the basis of emission evaluation of the two case studies because there is no available guideline for landfill emission management in Nigeria. The SPRI is the database of annual specified pollutant release to air and water from SEPA regulated facilities, and the thresholds are set by European Reporting Regulation (SEPA 2015). Operators of sites that perform certain operations or activities including landfill beyond set capacity criteria must submit an annual report to SPRI, however, some reporting thresholds have been decreased to make them more relevant to pollutant discharges in Scotland and the wider UK (SEPA, 2015), which conforms to international best practices for landfill regulation. There are temperature differences between Lagos and Glasgow. Lagos has an average temperature of 26.7°C - 28°C and 1783 mm annual rainfall (Fallahizadeh et al., 2019; Climate Data, 2024), while Glasgow has an average temperature of 8.1°C and 1228 mm annual rainfall (Climate Data, 2025**)**, which increases moisture content of the waste composition that speeds up the decomposition of organic matters (Chalvatzaki *et. al.,* 2010; Saveyn and Eder, 2014) and these decomposition or decay rate as well as the estimated emissions in the LandGEM model is also temperature dependent (Alexander et al., 2005). Higher temperature area tends to break organic matters faster which potentially increases emission rates especially in landfill (Srivastava et al., 2023).

3.2.5.1. Data Disparity:

It is also worthy to note there is slight data disparities stem from Nigeria's available data compared to Scotland's digital SPRI system. Temporal misalignment of the Nigeria manual data was mitigated by normalizing emissions per tonne of waste from the available recorded data set (Intergovernmental Panel on Climate Change (IPCC), (2006).

3.2.6. Proximity Analysis:

Health and environmental risk from landfill chemical emissions could potentially be observed within populations and surface water bodies close to such waste facilities, especially close to hazardous sites, hence, the level of exposure from these landfill sites based on the proximity of residential buildings to the waste facility was also studied. Proximity analysis allows buffer zones to be assigned around the landfill site. A buffer is one of the functional features in GIS software which enables a radial area of a desired distance around spatial data points or polygons to establish a relation among given data with regards to distance (Min *et al.,* 2016). For this Chapter, spatial data points and polygons were manually digitized and collected based on their coordinates/ GPS (Global Positioning Systems) to represent the landfill site area of the two case studies. However, only residential buildings within the Olushosun landfill sites were digitised to represent building polygons for the analysis, as the data available for that area were not wholesome (it was incomplete). The digitization of building polygons was carried out using GoogleEARTH software and further analysed in ArcGIS 12.0 software. However, the building structures within Patersons landfill site were extracted from DigiMap (an online academic data support services from a world-class centre for data and digital experts called EDINA). For this study, the following data points and polygons were considered: landfill sites and residential houses.

Furthermore, the census data showing the population of the areas of study were sourced from appropriate authorities, for example, the 2006 Nigeria census data was further sourced from DivaGIS data services, while the data for Scotland were sourced from DigiMap, including the 2011 Scotland census data; the data were sourced from the UK Data Services (2018) via its online database, which is funded by the Economic and Social Research Council (ESRC). This enabled for the spatial analysis to help in determining the population at risk of exposure within the case study areas using GIS. One limitation for the data collection was that the Lagos State census data was limited to the local government area, when compared to the Glasgow census data that is detailed to building count level.

Over 5,000 vector data which represented building polygons of the study areas where sourced for Glasgow city, while the site areas were digitised to show the polygon vector data of the waste facilities. The digitisation of each site vector polygons was done using GoogleEarth software with high resolution for precision. Using the methodology of Sharma *et at.,*(2006), each of the two landfill sites which were digitised as polygon vector data originally in Keyhole Markup Language (KML) file format on GoodgleEarth, which were later converted to shapefiles in ArcGIS 10.2 software for further analysis, while for Lagos data, over 38,235 building polygons were manually digitised as KML on GoogleEarth software and then converted to shapefiles using ArcGIS 10.2 software.

Using the methodology of Chakraborty and Manntay (2011), proximity analysis using multiple buffering rings, was conducted in ArcGIS 10.2 Software. A buffer is one of the functional features in GIS software which enables a radial area of a desired distance around spatial data points, lines, or polygons to establish a relationship based on proximity amongst given data features with regards to distance (Min *et al.,* 2016). Buffer zones were assigned around the landfill sites using a scale of 0.25, 0.5, 1 and 2 km to assess exposed structures and populations at potential risk. The above proximity scale was used to characterise risks on very high, high, medium, and low risk area respectively within the potential risk of exposure based on distance from landfill sites (Environmental Management, 2012). The above scales were considered appropriate as epidemiological studies have shown that most health issues associated with landfill operation occur within such proximities (Dolk *et al.*, 1998; Elliot *et al.*, 2001;

Vrijheid *et al.*, 2002). More so, the boundary data of the two case studies were also collected; Nigeria boundary data was collected from DivaGIS data services, while Scotland boundary data was collected from DigiMap. More so, the evaluation of the estimated emission per capita were based on the population within 0.25 km proximity to landfill sites and emission estimate based on only carbon dioxide and methane emissions expressed in tonnes of CO_2 equivalent (CO_2e) (Our World in Data, 2024).

The boundary data (with demographic records) for each case study including building polygons were unionised for each case study, which combined both features of the boundary data and building polygons to create a new feature having the two individual features in one output. Polygons representing the geometric union of all the inputs, as well as all the fields from all the input feature classes, were included in the output feature class. This new feature class for each case study was intercepted with the multi ring buffer zones using the Geoprocessing tool of ArcGis to create another new shapefile where input features of the building polygon and each of the multi ring buffer zones overlaps. The statistics of the overlaps captures the number of the exposed building polygon on each of the multi ring buffers for each case study which represent building structures within the classified risk area based on proximity of the building structures to the landfill sites for the two case studies, while population at risk within each of the exposed buffered zone were interpolated. The interpolation of the population within each buffer zone was done for the Glasgow case study as its population data captured down to the house count level. There was no building structure in the southern area of the Glasgow landfill, as it is part of the green belt categorized area of the Glasgow council, which is purposely designed to protect open space and preventing public encroachment (Glasgow City Council, 2024).

For the Lagos state case study, there was no data down to the house count level, hence, an inability to analyse the population within the classified risk area. However, using the demographic and household survey data for the Nigerian population (Thomas et al., 2021), the estimated population within the buffer zones was calculated. . This was done by multiplying the average number of household population with average number of household per building and then with the total number of building within a buffer zone or the desired proximity scale (Smith and Lewis 1980; Smith et al., 2002).

3.3. Results:

3.3.1. Solid Waste Generation and Disposal Analysis:

The information regarding the solid waste generation data and management procedures were sourced from the appropriate agencies; Lagos State Waste Management Agency (LAWMA) for the Lagos waste data, and Scottish Environment Protection Agency (SEPA) for Glasgow data; these agencies oversee the regulation of waste in the two case studies respectively.

Based on the interview of the waste management agencies, it was noted that wastes are transported to various waste management facilities, where they are weighed and screened to extract recyclables, and the remaining waste is disposed of in landfills. General waste, which includes hazardous and non-hazardous material, is disposed of in Olushosun landfill, while in the Patersons, only non-hazardous waste is received. Both case studies' waste management agencies ensure that waste management data is collected, including keeping up-to-date records of waste management activities (daily generation and disposal rates) and monitoring the waste contractors' activities to ensure that wastes are disposed of safely and without endangering the public.

Waste generation and disposal are important to understanding the waste management options. To control the level of risk associated with both volume and hazardous material of the Olushosun landfill, it is good to look at other forms of waste management like incineration, as this can enable the minimization of risk as well as reduction of the volume of waste (Lee et al, 2020). The annual waste generation and landfilling data is shown in Figure 3.3 and Figure 3.4, obtained for the two case studies; Olushosun and Patersons landfill sites, respectively.

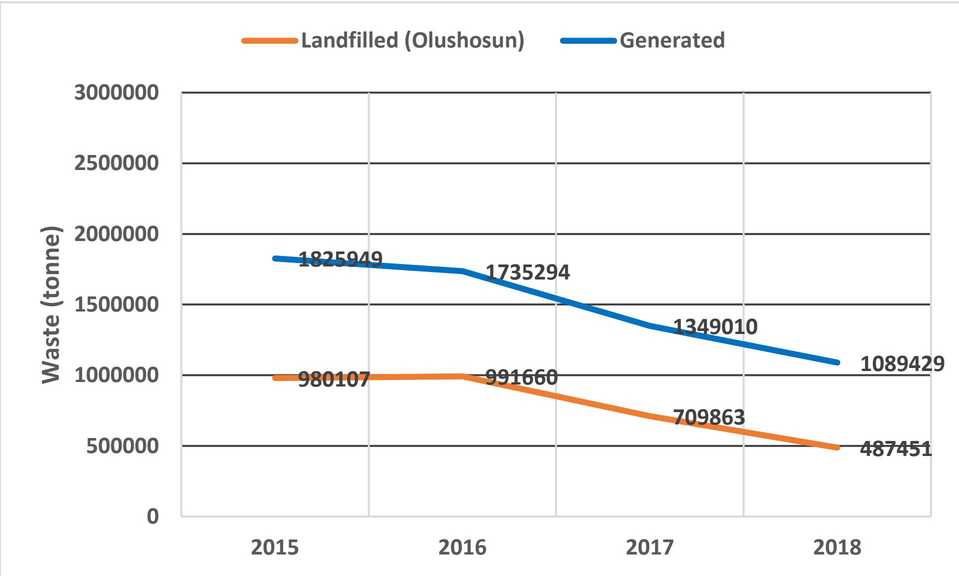

Figure 3.3: Waste generated (in tonnes) and landfilled at Olushosun landfill site from 2015 – 2018 (source: LAWMA 2018)

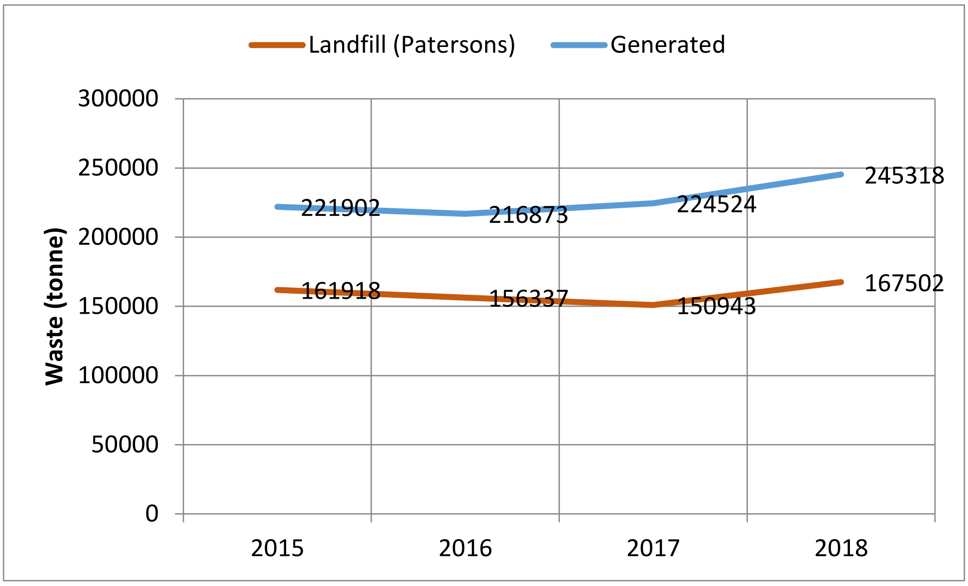

Figure 3.4: Waste generated (tonnes) and landfilled at Pattersons of Greenoakhill landfill site, Glasgow from 2015 to 2018 (source: SEPA, 2018).

The overall trend in Nigeria is a reduction in both generation and landfilling, while in Glasgow there was a reduction until 2017 after which there has been an increase. As the Olushosun landfill site services a larger population it is only to be expected that more waste was deposited than in the Glasgow site, however during the time under investigation the amount of landfill material more than halfed, dropping from 980,106 tonnes in 2015, to 487,450 tonnes in 2018, Patersons had more waste landfill in 2018, 167,502 tonnes compared with 2017, as 150,943 tonnes.

3.3.2. Landfill Emission:

Waste received in landfill degrades to generate emissions of environmental and health concern. Even an engineered landfill site does not capture all the chemical emissions from the site and while this is a concern, the un-engineered, unsanitary landfill site poses even more of a risk to the public, especially in the developing countries. The landfill emission estimated for Patersons of Greenoakhill landfill was sourced from the Scottish Pollution Inventory via the Scottish Environment Protection Agency (SEPA) website. The SEPA regulation mandates waste operators to submit an annual pollution inventory which is done by direct monitoring of pollutions in their waste facilities. While the Olushosun landfill estimated emission result was calculated using the LandGEM model, and the data used for the calculation was collected from the Lagos State Environmental Agency (LAWMA) website. Although, the two sites generated some gases that are above the SEPA reporting threshold (RT) like the methane, carbon dioxide, carbon monoxide, chloroform etc. (see Table 3.1 below), the Patersons site is less of a concern as it is an engineered and controlled site which captures its chemical emissions as one of its risk mitigation measure; the emissions are used to generate energy. There are temperature differences between Lagos and Glasgow. Lagos has an average temperature of 26.7°C and 1783 mm annual rainfall (Climate Data, 2024), while Glasgow has an average temperature of 8.1°C and 1228 mm annual rainfall (Climate Data, 2025), which increases moisture content of the waste composition that speeds up the decomposition of organic matters (Chalvatzaki *et. al.,* 2010; Saveyn and Eder, 2014). It is also worthy to note there is slight data disparities stem from Nigeria's available data compared to Scotland's digital SPRI system. Temporal misalignment of the Nigeria manual data was mitigated by normalizing emissions per tonne of waste from the available recorded data set (Intergovernmental Panel on Climate Change (IPCC) (2006).

While the Olushosun site is not engineered hence, the high emission from the site is of greater concern. The emission rate result shows some important environmental issues and need for compliance. For instance, methane and carbon dioxide, both of which are greenhouse gases, exceeding the reporting threshold of 10,000 kg indicates a major issue for greenhouse gas emissions. Some of the hazardous air pollutants (HAP) and volatile organic compounds (VOC) including 1,1,1-Trichloroethane, 1,2-Dichloroethane, and Chloroform were found at Olushosun, and even carbon monoxide in both case studies; that exceeded their respective reporting threshold, also raise cause for concern too. Result however, showed the absence of emission rate data for some contaminants of HAP/VOC as they were below the reporting value, and there is still need for comprehensive emissions rate monitoring to enhance efficient environmental management and compliance.

Table 3.1: Olushosun and Patersons Landfill Chemical pollutants inventory and the reporting threshold. See full report in Appendix 3.4.

Landfill Gas Pollutants Emission Rate (Kg per year)	Olushosun (2017)	Patersons (2017)	Reporting Threshold (kg)
Methane	15,495,141,000	1,730,000	10,000
Carbon dioxide	15,495,141,000	31,900,000	10,000,000
NMVOC	18,589,851	-	10,000
1,1,1-Trichloroethane (methyl chloroform) - HAP	14,876.199	-	10
Carbon monoxide	4,337,631.9	110,000	100,000
1,2-Dichloroethane (ethylene dichloride) - HAP/VOC	12,702.705	-	1,000
Chloroform - HAP/VOC	929.8524	-	5
1,1,2,2-Tetrachloroethane - HAP/VOC	34,084.992	-	-
1,1-Dichloroethane (ethylidene dichloride) - HAP/VOC	74,345.01	-	-

1,1-Dichloroethene (vinylidene chloride) - HAP/VOC	6,197.3367	-	-
Carbonyl sulfide - HAP/VOC	15,185.67	-	-
Chlorobenzene - HAP/VOC	7,743.97	-	-
Chloroethane (ethyl chloride) - HAP/VOC	40,281.609	-	-

Note: the blank data were below the reporting value for Patersons, and some reporting threshold were also not specified for some pollutants in the SEPA reporting threshold (RT).

3.3.3. Proximity Analysis:

Applying demographic and household survey data for the Nigerian population gives an average of 4.9 people per urban household, and 1.1 households per building (Thomas et al., 2021), therefore estimating a population of 89,393 within 2 km of the Olushosun landfill site as shown in Table 3.2, compared to 28712 population within 2 km of Patersons landfill site. The estimated emission per capita within 0.25 km proximity to landfill sites were Olushosun - 16,199 tonnes (16,199,833 kg) of CO_2 equivalent (CO_2e), and Patersons - 295 tonnes (295,000 kg) of CO_2e.

Research has often discussed about people that live close to landfill sites and the effect of potential environmental and health risk associated with such cannot be over emphasised. This practice has occurred more in developing countries when compared to developed countries. Table 3.2 shows the proximity analysis demonstrating the fact that building structures are within Olushosun and Paterson of Greenoakhill landfill sites.

Table 3.2: Building structures and population within each buffer-zone classified risk area based on proximity to Olushosun landfill site and Patersons landfill site (Scotland household data is based on UK Data Service (2018) of 2011 Scotland census data from ESRC for Scotland Data and household data for Nigeria is based on Thomas et al., (2021)..

Buffer Zone (distance in kilometres)	Residential Buildings within Buffer Zone at Olushosun	Population within Buffer Zone at Olushosun	Residential Buildings within Buffer Zone at Patersons	Population within Buffer Zone at Patersons
0-0.25	355	1913	28	114
0.25-0.5	856	4614	255	1072
0.5-1.0	3790	20428	1468	6158
1.0-2.0	11584	62438	4259	21368

Table 3.2 shows that more residential structures are seen within the classified potential risk area at Olushosun landfill site when compared to the Patersons landfill site. The number of the structures within the sites increases with distance away from the sites at both case studies. This also applies to the population at Patersons where there is an estimated population of 28,712 within 2 km of the site.

The surface water network around the Olushosun site is more than 2km and thus more than the 500 meters' safe distance (Figure 3.5) as suggested by the Environmental Agency (2015). Similarly, the Patersons site is also a safe distance from the water network (Figure 3.6). Figure 3.5 and 3.6 shows the extrapolation processes within each classified buffer distances to extract and know the number of structures within each proximity scale for the Nigerian and Scottish site, respectively.

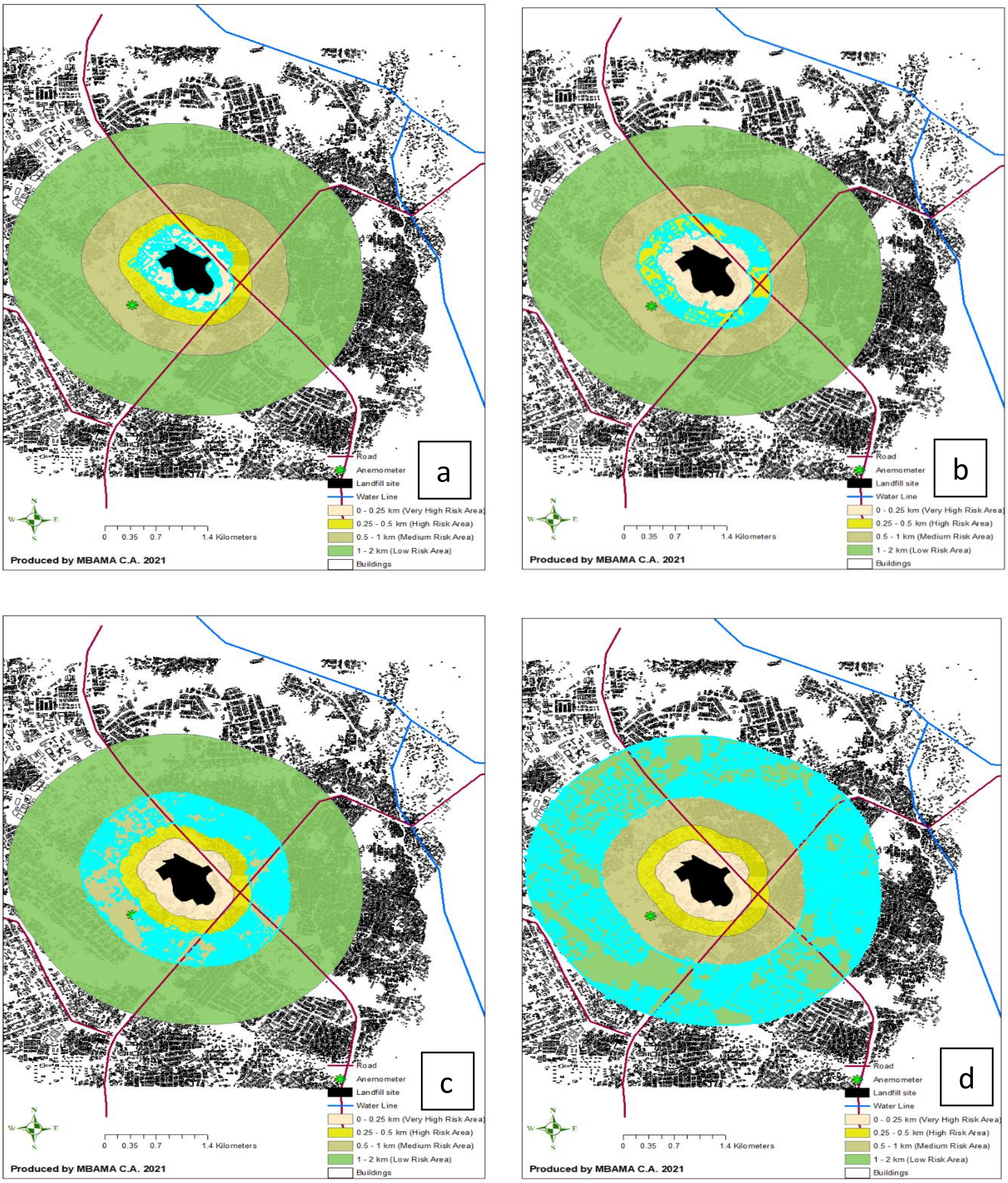

Figure 3.5: Each buffer area showing intercepted building polygon within classified risk area based on proximity scale of (a) 0.25 km, (b) 0.5 km, (c) 1.0 km and (d) 2.0 km from Olushosun landfill site and the dark blue water line represents surface water, a river flowing outside the buffer zones, the brown line represent the road network, while the green asterisk symbol is usually the spot for aneamometer to record the wind speed/direction

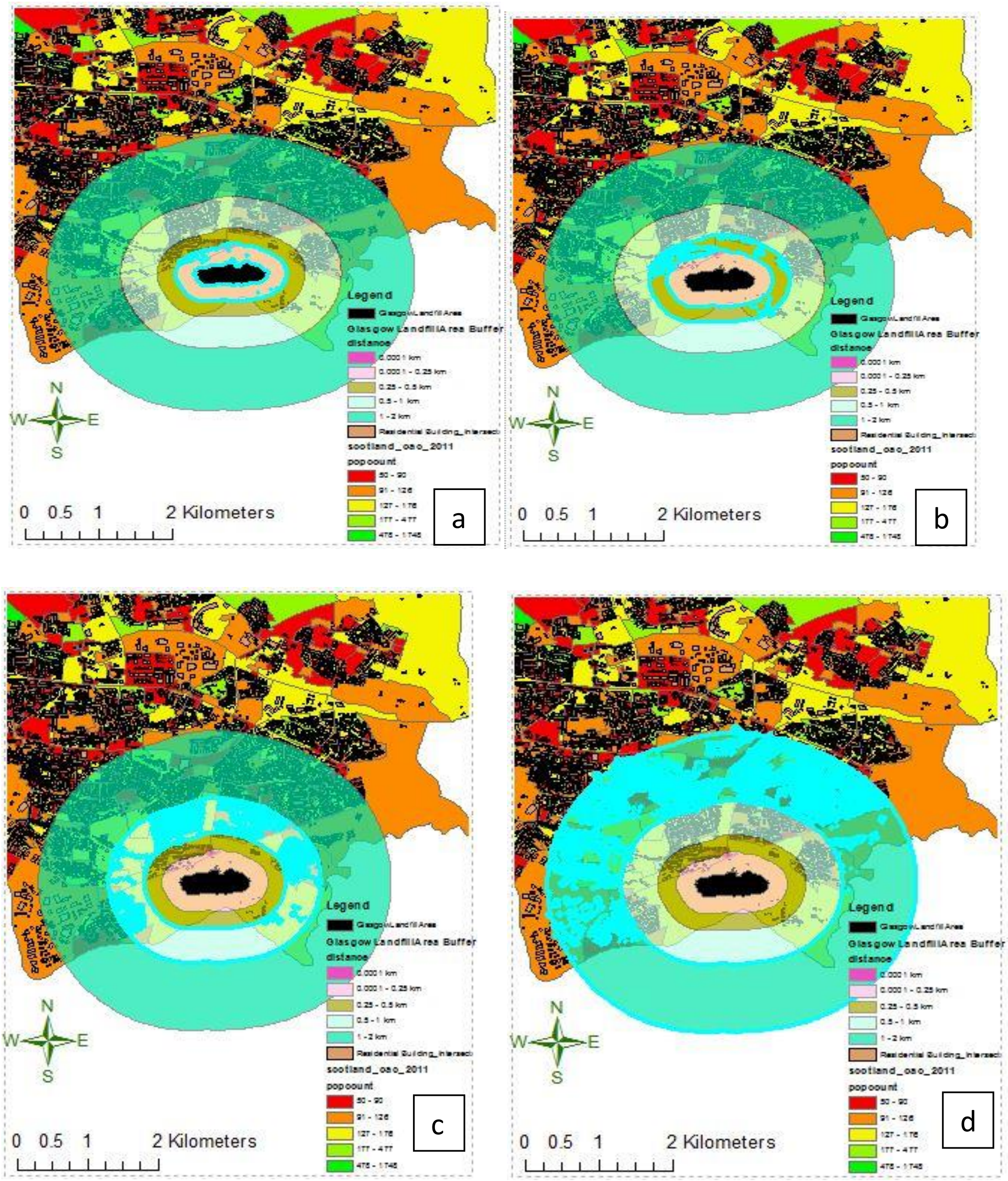

Figure 3.6: Area showing intercepted building polygon within classified risk area based on proximity scale of (a) 0.25 km, (b) 0.5 km, (c) 1.0 km and (d) 2.0 km from Patersons landfill site. The map shows population counts on the buffer zones proximity scale, but, does not show building in the south as the scope of study was limited to the boundaries of the study area, more so, no surface water (river flow) within the study area.

3.3.4. Leachate:

According to Ameloko and Ayolabi, (2018) which conducted the geophysical assessment for vertical leachate migration profile and physicochemical study of groundwater around the Olusosun dumpsite Lagos, south-west Nigeria, shows the lithology of Olushosun is composed of loose sediment ranging from silt, clay and fine to coarse grained sand, referred to coastal plain sand. It is also characterise by exposed surface which consists of poorly sorted sands with lenses of clays and the sands are in part cross-bedded (Ameloko and Ayolabi, 2018). Meanwhile, when compared with Patersons, it’s highly engineered liner reduces leakage and minimises community risk (Patersons, 2024).

Every landfill site generates leachate which results from the breakdown of the organic component of waste. The leachate must be managed effectively to mitigate pollution of the environment. Figure 3.7 shows leachate generated from Olushosun landfill; there is a high risk of this leachate contaminating the surrounding environment as the base of the landfill was not lined, allowing the leachate plume (which is not properly managed) to leak into groundwater (Sanusi 2013). The site does not have an environmental management plan (EMP) or environmental management system (EMS) in place to evaluate and address any possible threats to the environment or to human health (Sanusi, 2013). Although, Patersons landfill leachate was not accessed, it was confirmed through interview with management staff that the leachate is usually collected and treated before disposal as set under the SEPA landfill operational guideline, as seen at the Linwood Moss landfill site under Renfrewshire Council (Figure 3.8).

Figure 3.7: shows landfill leachate that poses potential risk of contamination to groundwater and the environment at Olushosun site (source: site visit in 2018).

Figure 3.8: Linwood Moss Landfill leachate, being managed in Scotland (source: site visit in 2019).

3.3.5. Scavengers:

The informal sector, i.e. the scavengers, play a key role in waste management in developing countries. This is seen at the Olushosun site where scavengers sort most recyclable materials from the landfill. This is done daily to be able to raise income from the waste when it is separated and eventually sold. Figure 3.9 shows scavengers in the Olushosun landfill site, Lagos State. One of the key challenges seen on site is that none of the scavengers had any personal protective equipment (PPE), hence, had potential to be exposed to risk on site. The scavengers interviewed said they pay to enter Olushosun landfill site and most of them sleep at the landfill site when they are tired. The Olushosun landfill contains unsegregated wastes and sharp objects that can potentially cause harm to the scavengers. For the Patersons, however, there is no such thing as a scavenger, as the site is controlled and secured by a private firm.

Figure 3.9: Scavengers on site without any form of personal protective equipment (PPE) at Olushosun landfill site (source: site visit in 2018).

3.3.6. Tents:

Lack of sufficient finance is one factor preventing low-income earners from having a permanent place to live. The same is true for scavengers, who frequently choose to sleep near dump sites to save money on rent and to be close to the site if fresh waste is placed there. At the Olushosun dump site, scavengers constructed hundreds of tents, as shown in Figure 3.10. The scavengers are more at risk of breathing in chemical emissions from the landfill because of the tents. There is also the potential that the rubbish heaps at the dump could collapse, exposing the scavengers to serious injury or death.

Figure 3.10: Those working in the informal sector often live onsite in tents, where they are exposed to landfill emissions and risk from potential waste collapse (source: site visit in 2018).

3.4. Discussion:

3.4.1. Waste generation and Disposal:

From Figure 3.3 a downward trend exists in both the amount of waste generated in Lagos State and the amount landfilled at Olushosun. For example, from 2015 to 2018, there was a 40% decrease (from 1825948 to 1089428 tonnes) of waste generated in Lagos State, at the same time there was also a 50% decrease (from 980106 to 487450 tonnes) of waste sent to the landfill site. The decrease of waste generation in Lagos between the year 2015 - 2017 is considered a genuine decrease in waste production due to the efforts of the waste management authorities towards creating awareness and trainings for stakeholders in waste management (Awodele et al., 2016). Additionally, waste recycling and reuse, which is known to promote stakeholder participation in efficient waste management is increasingly promoted for more efficient waste management (Desa et al., 2012; Mamady, 2016; Olawoye et al., 2019). A downward trend in waste generation and landfilling was also seen at the Glasgow site from 2015-2016 (Figure 3.4) falling around 2.3% (from 221902 to 216873 tonnes) generated, and 3.5% landfilled at the Greenoakhill site (from 161,918 to 156,337 tonnes). This is attributed to the increased recycling and re-using of waste in Scotland which increased by half a million tonnes in 2016 (BBC News, 2018). However, there was an increase of waste generation of 13% (216,873 to 245,318 tonnes) and landfilling of 7% (156,337 to 167,502 tonnes) between 2016 to 2018, this kind of increase is seen when there is partly more waste being generated and more waste being sent to landfill (SEPA 2019). The waste management strategy in Glasgow leans more on recycling and recovery, which aligns well with the waste hierarchy. The reduction could be as a result of greater public awareness and participation. However, this does not necessarily mean more consumption, because true volume reduction requires more importance on preventionand reuse (Glasgow City Council, 2023). Research also associate increase of waste generation with economic growth and urbanization (Shershneva, 2022). These reductions in waste generation and landfilled at the two case studies could be because of the effort of their Waste Management Agency to create awareness and training programmes for stakeholders in waste management (Awodele *et al*., 2016). A significant proportion of waste management efforts, particularly in recycling, is driven by the informal sector. This sector's contribution is operationalized through the collection of recyclable materials directly from households and by scavenging at landfill sites. The scale of this workforce is substantial; for instance, the International Labour Organization (ILO) estimates that informal sector comprises millions of workers globally. Despite their critical role in the waste management value chain, these informal workers frequently operate without the benefit of legal recognition or protection, a situation exemplified by the case of Nigeria (Solaja et al., 2024). Approximately 5,000 scavengers work daily at Olushosun landfill to recover recyclables from over 10,000 tones of waste which are delivered to the site daily, however, no record of exact amount of recovered materials from site (Adewuyi, 2025), hence, reducing LandGEM inputs but increases exposure risks as they work without personal protective equipment such as masks, gloves, safety boots etc (Ogwueleka and Naveen, 2021; Solaja et al., 2024).

Glasgow City Council encourages the public through their waste management policy to source segregate waste especially foods, recyclable and general waste (Glasgow City Council, 2020). For more efficient waste management, including waste minimization, reusing, recycling and segregation at source, there is need to promote more awareness programmes by the waste management authority to educate the public, and this awareness campaign has seen the recycling rate increased in Scotland. For example, in 2018, the amount of recycled plastic increased by 8,163 tonnes (5%) to 56,586 tonnes, maintaining a seven-year pattern of annual growth. According to the longer-term trend, glass has increased its recycling rate by 832 tonnes (0.8%) to 107,380 tonnes, remaining the second most recycled commodity (SEPA 2019). Raising awareness on the benefits of efficient waste management using the above approach is known to serve as a tool to increase stakeholders’ participation in efficient waste management. Desa, *et al*., (2012) looked at environmental awareness and education as a key approach to solid waste management and found that awareness campaigns on inefficient recycling and communication strategy have proved to be beneficial and enhances wider participation in reuse and recycling, which can reduce waste generation (Desa, *et al*., 2012). Although, municipal solid waste generation is known to be on the increase in urban cities, the results of the case studies shows the need for more efforts in waste management approach to manage the waste in a way to minimise its environmental impact. The efforts of Glasgow, Scotland to manage its waste through the development of modern waste management facilities like their engineered landfill site, plays a key role in reducing waste that can cause less environmental and health risk. However, Nigeria is known to lack efficient and modern technology for the management of its municipal solid waste (Babayemi and Dauda 2009; Ogwueleka, 2009), hence, the potential risks its landfill site poses cannot be over emphasized.

3.4.2. Landfill Emissions:

When biodegradable waste decomposes, it releases gaseous pollutants which have environmental and health risk. The result of the LANDGEM model for Olushosun site (Table 3.1) showed high carbon dioxide and methane emission rates of equal value of 15,495,141,000 kg per year when compared to other resultant pollutants. Carbon dioxide and methane causes climate change (Sahin *et al.,* 2013; Li and Chen 2016). The lack of waste segregation at the source critically undermines accurate emissions calculations and significantly increases the carbon footprint of waste management in two primary ways:

Firstly, it increases Landfill Methane Emissions. This is because without segregation, organic waste (like food waste, garden trimmings) is co-disposed with other refuse in landfills, which creates ideal anaerobic conditions for methane (CH_4) generation, a greenhouse gas with a global warming potential 28-34 times greater than CO_2 over 100 years (Intergovernmental Panel on Climate Change (IPCC), 2022). In situation like Lagos with high organic waste composition and tropical climates, this effect is magnified, leading to significantly higher methane yields per tonne of waste than in temperate regions (Saveyn and Eder, 2014).

Secondly, emissions savings from recycling is foregone. This is because the absence of effective recycling prevents the recovery of materials like plastics, paper and metals. Afterward, the system relies more heavily on new/ virgin material extraction, manufacturing and processes that are far more energy intensive and higher emission than using recycled feedstocks. The emission savings from avoiding virgin production, which is a core benefit of recycling, are then, thus lost from the calculation entirely (Laurent et al., 2014). Therefore, calculations based on an unsegregated waste system will essentially show higher net emissions due to unchecked methane release and the omission of the substantial carbon offsets provided by closed - loop material recycling.Carbon dioxide has an adverse environmental and health impact when produced in large quantities (Sahin *et al.,* 2013; Xu and Lin 2016), and in a global basis causes climate change, as it is one of the greenhouse gases that contribute to global warming (Li and Chen2016; Ritchie and Roser 2020). According to Li and Chen (2016), methane's high global warming potential makes it one of the highest contributors to the effect of greenhouse gases. In addition to the fact that methane is known to have environmental impact, it can cause explosions when exposed to high temperature. Methane can however be harnessed to produce heat and in the generation of electricity, as it constitutes a major component of the gases for such processes, making it useful for domestic and commercial applications. Occasional reports of fire breaking out at Olushosun landfill site is attributed to estimated high methane emission rate (Kalu, 2018).

The emission rate of non-methane organic compounds (NMOC) at the Olushosun site was 18,589,851 kg per year (see Table 3.1). NMOC are an important group of polluting compounds used to assess compliance with landfill gas emission regulations by the United States Environmental Protection Agency (Saquing *et al*., 2014). According to Ofungwu and Eget (2009), NMOCs include odorous compounds (*e.g*., hydrogen sulfide), volatile organic compounds (VOCs), and hazardous air pollutants (HAPs), some of which can cause carcinogenic and non-carcinogenic adverse health effects as discussed in Section 2.6.3 of Chapter 2.

The LandGem model results also present some VOCs such as Chloroform, 1,1-Dichloroethene (vinylidene chloride), Carbonyl sulphide, Chlorobenzene etc. (see Table 3.1 and Appendix 3.2) that are of concern. This is in-line with the results of

Majumdar and Srivastava (2012), who assessed the VOC emissions from open dumpsites in the Indian metro city of Dhapa. These authors identified 13 VOCs listed as hazardous air pollutants (HAP) which is shown to put dumpsite worker's health at risk. VOCs remain a big problem from uncontrolled dumpsites due to the damaging effect they have on the ozone layer and the human carcinogenic effect especially in occupational health and people close to the source of release (Majumdar and and Srivastava 2012; Majumdar et al., 2014; Laurent and Hauschild 2014; Qiu *et al.,* 2014; Montero-Montoya *et al.,* 2018).

Furthermore, the result of the landfill assessment, showed that any typical landfill site contains chemical contaminants which could potentially cause serious human health risks as seen in Table 3.1. The Scottish Pollutant Release Inventory (SPRI) for the Patersons site showed that seven chemical compounds were reported to have exceeded the SPRI reporting threshold, this included carbon dioxide, which was the largest pollutant release from the landfill site, followed by methane, while methylene chloroform was the lowest release to breach the reporting threshold (see Table 3.1.). Meanwhile, the activity of informal waste pickers (or reclaimers) do introduce significant variable that can lead to substantial inaccuracies in LandGEM model projections. This would primarily affect the model's calculations by altering the key input parameters upon which LandGEM's methane generation estimates are based. For instance, the model (a first-order decay model) relies on critical input parameters such as the Methane Generation Potential (L_0), which shows the total amount of methane a tonne of waste can produce. The waste composition, which shows the fraction of bio-degradable organic carbon in the waste stream, and the mass of waste in place could potentially show the accurate tonnage of waste deposited in the landfill.

Therefore, the work of informal pickers would directly compromise the accuracy of the above inputs.

Moreso, the alteration of waste composition by scavengers would systematically remove high-value recyclables – the plastics (PET, HDPE), papers and cardboard, and metals, thereby increasing the relative amount of readily biodegradable organic component (like food waste) which remains in place (Gutberlet, 2015). Since LandGEM's L_0 value is often based on an assumed initial waste composition, the model will overestimate methane generation if the default values are used without accounting for this removal of non-biodegradable components. LandGEM calculations are highly sensitive to the total mass input. Using the official "tipped tonnage" data without subtracting the informally reclaimed fraction (reduced effective mass of waste) will therefore overestimate the mass of waste available for decay, leading to a proportional overestimation of biogas generation (Kaartinen et al., 2013). Finally, the removal of certain waste materials can indirectly affect the decay rate (k). For example, the removal of paper and cardboard, which decomposes more slowly than food waste, hence, could further skews the waste mix towards rapidly decomposing organics. Therefore, potentially leading to a higher initial peak in methane generation that may not be captured if standard kinetic values are used.

Therefore, the unquantified activity of informal sector creates a divergence between the hypothetical waste composition used in the LandGEM model and the actual waste undergoing decomposition. Therefore, the inability to conduct site-specific waste characterization studies that also account for informal recycling could result in a systematic under or overestimation of landfill methane (CH_4) emissions by the model (Mou et al., 2015; Jens et al., 2019). To enhance accuracy of the LandGEM model, the model inputs must be calibrated using empirical data on post scavenging and waste composition and adjusted mass balances (Scheinberg et al., 2016; Chandra and Ganguly 2023; Malmir et al., 2023).

While none of the chemical emissions from the Patersons of Greenoakhill landfill site are expected to cause health risks such as an increase in the incidence of cancer, birth defects, or congenital anomalies in newborns living in close proximity to landfill sites, as suggested by Dolk et al., (1998), Eliot et al., (2001), and Vrijheid et al., (2002) on typical landfill sites in developed countries, there may be an increased risk of greenhouse gas effect due to methane generation, as only 85% of the gases could be captured from landfill sites in general (SEPA, 2016).

The environmental effects of such chemical emissions are the reasons for various legislative drivers such as the EU Packaging Directive and the EU Landfill Directive (Rudden 2007), implemented to reduce the volume of MSW that goes to landfill with resultant reduction in such chemical emission rate. Methylene chloroform, also known as Trichloroethane 1,1,1 (TCE), is found to be about 148,660% above the reporting threshold at Olushosun landfill site against what was reported at Paterson of Greenoakhill landfill site. Methylene chloroform is a hazardous air pollutant (HAP), hence, potential risk to the environment and human health (Chiu, et al., 2013). More so, its presence in the atmosphere damages the stratospheric ozone layer which protects the earth from the harmful effects of UV from the sun. Exposure to high atmospheric concentrations of TCE, for example, through accidental release, can cause damage to the kidneys, heart, and central nervous system among others; long term exposure to lower concentrations can also cause liver failure (Chiu et al., 2013; SEPA 2015).

The emission estimation results from the two case studies shows that landfill sites have components of carbon dioxide, methane, and non-methane organic compounds. Although, the collected data are not over the same period and not directly relatable as they are different sized sites, in different sized cities with different economies, the pollutant compositions from Olushosun landfill site are seen to be very high, while the emission from Patersons was low. This is because of the very high disposed waste received at the Olushosun landfill waste which is 398% higher than the waste received at Paterson of Greenoakhill landfill site within the 4-year research data period (2015 to 2018). This is in line with the result of Ndanguza *et al*, (2020), which looked at modelling the effects of toxic wastes on population dynamics and noted that high waste generation has its corresponding high toxic emissions that potentially cause harm to the public.

This potential risks from landfill emission necessitate that engineered landfill site be encouraged which will not only help to capture some of these chemical emissions, but can also help to develop energy processes from the system. Even though Glasgow's landfill sets a good example by having one, Nigeria has not yet built an engineered landfill site, so it is very important for the Nigeria to build one.

3.4.3. Proximity Analysis:

Individual features of our man-made and natural land scape can be analysed using Geographical information system (GIS) for environmental assessments, which helps us to understand the nature of these features and their interrelationships or connections. This makes GIS application a very useful analytical tool for siting landfill sites and other environmental assessment including proximity analysis, which is of interest to policy makers, researchers, and developers. Proximity analysis was conducted using multi ring buffer scales of 0.25 km, 0.5 km, 1 km, and 2 km that was used to characterise risks on very high, high, medium, and low risk areas, respectively (Environmental Management, 2012). These scales are areas where residents might readily be exposed to different levels of potential risk from landfill emissions. The result of the landfill assessment which included observation during dumping of the waste on site and interview with waste operators and scavengers, showed that unsegregated municipal solid waste was dumped at Olushosun landfill, which potentially pose major threats to the environment and public health. As a result, the risk of exposure was divided into the four buffer distance categories above according to how far each buffer zone was from the landfill. Out of 16,585 building structures within two kilometres of the Olushosun landfill site, the proximity analysis result shows that 355 buildings are in the area designated as "Very High Risk" exposure (0.25 km). This area fails inside the 250 m (0.25 km) buffer from the landfill site, which is the suggested distance between a residential neighbourhood and a landfill site, according to Environmental Agency (2012).

Many scavengers who work on the landfill site collecting recyclable material also live on the waste dump in tents they have built on top of the waste (see Figure 3.10), and this poses indirect risk of occupational health effect through inhalation of chemical pollutants over time, and directly through the handling of waste material by scavengers without the use of personal protective equipment (PPE) during their activities on the site (see Figure 3.9).

The proximity areas to the landfill site shows concern especially for the residential buildings within the 1000 m (1 km) buffer zone from the landfill site because research has shown there are health risk associated with living in such proximity especially within a hazardous landfill site. As a result, if the landfill is classed as a very high-risk region for receptor within a 1 km buffer zone, there could be serious consequences such as birth defects, or congenital anomalies in newborns (Dolk et al., 1998).

The presence of residential structures with this buffer zone may indicate that people live within this area, by choice, or have no alternative, but may be doing so without knowing the dangers of living so close to a landfill site. According to Jonsson (2019), people who reside close to landfill site are not aware of dangers associated with living near such sites. However, for Olawoye *et al*., (2019), who studied the socio-economic and environmental implications of residential buildings in proximate distance to the same case study area, noted that residents of the area are knowledgeable on the potential risk associated with their living close to the site. The study found that haphazard construction within the case study area has various socioeconomic, environmental, and health consequences, including thermal discomfort, illnesses, low rental value of residential buildings, poor aesthetic value, and water contamination (Olawoye *et al*., 2019), These authors advise effective monitoring, social inclusion in waste management, promoting health and safety, using alternative waste disposal techniques, creating legislative frameworks for waste management and mitigating climate change. Low rental cost could be the reason to have over 16,585 building structures within 2km close proximity of risk classified area from the site. Olawoye *et al*., (2019), who, as mentioned previously surveyed people residing within 200 to 500 m (0.2 to 0.5 km) of the site, also noted the need to increase education and awareness of the dangers of improper waste disposal by the public.

These results suggest that health issues stemming from landfill sites will continue to be a serious problem if adequate measures are not considered to mitigate inefficient waste management, most especially in Nigeria as with other developing countries.

Although, Lagos State has town planning policy, there is limited enforcement by the local planning authority (Oduwaye 2009; Ogisi and MRABURE 2020). Siting landfills away from residential buildings helps to minimise the rate of exposure of the population to potential hazards from the sites (Irvine, 2001; Porta et al., 2009; Olawoye *et al*., 2019). Figure 3.5 shows that the surface water (river network) was over 500 m (0.5 km) away from the landfill sites, which according to the Environmental Agency and other authors, is more than the safe recommended distance to consider when sitting landfill sites (Arukwe *et al.,* 2012; Environmental Agency, 2012; Yazdani *et al*., 2015); such a distance helps to control the contamination of the surface water from potential pollutants through leaching. Leachate, a poisonous by-product formed by landfills and a primary source of concern for public health, can seep through the ground, contaminate surface, and ground water in landfill sites (Amano *et al*., 2021; Parvin and Tareq 2021).

Due to the uncontrolled leachate from the Olushosun landfill site (Sanusi 2013), there could potentially be contamination of underground water and further, the contamination of surface water through the drainage works or runoff. Hence, there is potential risk from landfill leachate and air pollution especially within residences in close proximity to the sites, for instance, among the 1000 m (1 km) high risk classified buffer area which has about 5001 residential structures, therefore, there is need for further study of health issues within the exposed classified risk areas, to see if there could be establishment of correlation between living within the exposed areas and health issue. More so, some literature has identified some health issues like cancer, birth defects, *etc*. that occurs when residence are near hazardous landfill sites, further modelling of these pollutants and monitoring of the underground water source within these areas should further be investigated. Studies have shown that leachate from landfill is highly toxic with potential to cause harm or even death (Ademola *et al*., 2020; Ndanguza *et al.*, 2020; Parvin and Tareq 2021). It is hoped that further study will be done to model pollutants from the source of hazard, landfill, to the residential buildings within the given proximity scale to understand the potential direction of such risks and furthermore, the physio-chemical monitoring of the water sources to understand the level of contamination and risk from leachate.

In the second landfill case study, the Patersons landfill, the proximity analysis result indicates that 28 buildings fall within the “Very High Risk” of exposure area, with a population of 114 residents within these buildings, and therefore at potentially “very high” risk of exposure to Pattersons site. Patersons' very high-risk zone showing the 28 buildings, houses facility staff, including the security officers and operators, confirmed via site interviews and spatial data exploration. This area fails within the 250 m (0.25 km) exclusion from a landfill site as recommended by the Environment Agency (2012). The population at risk is assumed to be the workers within the waste management facility, hence, there could be very high risk of occupational exposure via direct inhalation of chemical pollutant over time. The population within 0.25 km at Olushosun landfill site has a higher emission per capita, which is 16,199 tonnes of CO_2e (16,199,833) compared to Paterson landfill that has 295 tonnes (295,000 kg) CO_2e per capita. This implies that, when landfill emissions are distributed per capita within a 0.25 km proximity, the population near the Olushosun landfill bears a disproportionately higher burden of potential exposure compared to those near the Petersons landfill. Therefore, the proximity-based analysis reveals higher environmental stress on population close to the Olushosun landfill. The Patersons site is seen to have followed the recommended distance scale when sitting the landfill site based on how the residential structures are sited over 250 m (0.25 km) away from the site. More so, Figure 3.5 demonstrated that surface water (the river network) was over 500 m (0.5 km) away from the landfill site, which is a good measure to mitigate any potential risk of contamination of the surface water from potential landfill emissions (Arukwe *et al.,* 2012; Environmental Agency, 2012; Yazdani *et al*., 2015). Siting landfill sites away from residential buildings helps to minimise the rate of exposure of the population to potential hazards from the sites.

The case studies showed exposure to risks from landfill sites based on proximity, as informal workers like the scavengers are always on site to sort waste, hence, the need for occupational health and safety to be taken serious at this workplace. When compared to Glasgow, which has about 18 building structures, high exposure to dangers was observed in the Olushosun landfill site within 0.25 km (250 metres), which has 355 residential buildings. Based on their proximity to the landfill site, Olushosun and Patersons of Greenoakhill sites have exposure to building structures that differs by around 95%, indicating that the latter has a far lower risk of exposure than Olushosun waste site.

For proximity of 0.5 km (500 m), there were 856 residential buildings within the buffer distance for Olushosun landfill, while for Patersons of Greenoakhill landfill, 255 building structures were found within it. It is recommended that landfill is sited more than 0.25 km (250 m) away from residential areas (Environmental Agency, 2012) due to residential concerns like odour, dust, noise, *etc.* that may arise as a result of activities from such landfill sites, while for hazardous landfill site, residential buildings have to be above 500 m in close proximity to sites due to health issues *e.g.* birth defect (Vrijheid *et al.,* 2002), which may arise as a result of emissions from such sites. Greenoakhill site receives only non-hazardous waste (SEPA, 2015), while Olushosun sites receives even hazardous waste as wastes are not usually segregated before collection and disposal.

As a result of the high sanitary state of the Patersons of Greenoakhill engineered landfill site and the risk management measures like emission capture at the site, the level of risk of exposure of the site is low compared to the level of exposure from Olushosun site which is not properly managed. Hence, it could be recommended that the later site be aimed at closing soon and closed due to residential encroachment to the unsafe areas within the site, as exposure to the potential chemicals from the landfill can cause potential risk of environmental and health effects, as evident in literatures.

The findings further supports that people are still living on the landfill site especially the scavengers in developing countries. Some literature supports that people living close to such landfill sites is as a result of the low cost of renting properties, and not that they are unaware of the dangers associated with such practice (Olawoye *et al*., 2019)**,** others argue that it's the lack of knowledge on the potential dangers of residing in proximity of such site that makes people to reside close to such waste facilities especially in developing countries (Jonsson 2019).

While the Glasgow landfill site is managed properly, that of Olushosun pose great risk to the underground and surface water as its not properly managed. Although, some literature has identified some health issues like cancer, birth defects, *etc*. that occurs when residence are in close proximity to hazardous landfill sites, further modelling of these pollutants and monitoring of the underground waste source should further be investigated and siting a new sanitary landfill site for Lagos state in area that is outside urban settlement as done in developed nations, will mitigate the potential risk of landfill sites.

3.5. Conclusion:

Municipal solid waste sent to Olushosun landfill site in Lagos, Nigeria is largely not segregated from source to distinguish it from hazardous waste, which pose more occupational risk to the scavenger, and public health risk to residents very close to the site when compared with that of Patersons of Greenoakhill landfill site in Glasgow Scotland, that handles only non-hazardous waste. The presence of estimated emissions of non-methane volatile organic compounds (NMVOCs), carbon dioxide, methane etc in both case studies shows that landfill are contributors to global warming which exacerbate climate change most especially carbon dioxide, methane, etc.

It is paramount to understand the effects of NMVOCs, which are suggested as possible causes of cancer, congenital abnormalities and respiratory tract irritation when exposed to the public especially people living close to landfill sites, to enable such risks to be managed. The case study showed high level of exposure to risks from landfill sites based on proximity at Olushosun site when compared with Patersons site, hence, the need for occupational health and safety to be taken serious especially for scavengers at the Olushosun site and possible working towards closure of the Olushosun site due to residential encroachment to the unsafe areas within the site, as exposure to the potential chemicals from the landfill can be deleterious.

Although occupational exposure to chemicals is potentially unavoidable at Olushosun site as it is not an engineered landfill site, there is need to consider personal protective equipment (PPE) especially for the scavengers that are the most vulnerable on site. This could be achieved by formalization of the scavengers through cooperatives and also providing them with PPE and regular assessment of their health.

In order to address other health issues emanating from the improper landfill management, there is need to work towards a phased relocation to an engineered landfill outside residential areas. The application of GIS to determine a suitable landfill location is importantly needed, as the current Olushosun site presents significant environmental and public health risks. Siting a new landfill outside of urban settlements, which is a standard practice in developing countries, would mitigate these concerns. Furthermore, this must be reinforced with the enforcement of stringent town planning policies. Such policies would include restricting residential development within designated zones proximal to the landfill site, thereby helping to address the current risk of exposure. Hence, safeguarding and protecting the public and the environment, through safety buffer zones within landfill sites. The Lagos State Urban and Regional Planning and Development Law, 2010 could further mandate no commencement of building project without obtaining necessary permits and approvals.

CHAPTER 4

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TEMPORAL MSW GENERATION PATTERNS AT HIGHER EDUCATIONAL INSTITUTIONS (HEIs): WASTE MANAGEMENT PROCESS IN NIGERIA AND SCOTLAND.

4.1. Overview:

Municipal solid waste (MSW) recycling as a waste management option is the systematic recovery of unwanted or discarded materials and their conversion into new products of benefit to the end user (Hopewell et al., 2009). Recycling schemes foster the idea of minimising the use of virgin resources, and effective recycling, in addition to waste reduction and reuse, remains key to sustainable waste management (Ferreira et al., 2012; Baharum et al., 2016). The concept of sustainable waste management has been advocated over the last few decades, and regions have developed waste policies to manage increasing waste generation and conserve scarce natural resources. The Waste Framework Directive (2006/12/EC) and the Landfill Directive (European Directive 99/31/EC), for example, are founded on the waste hierarchy principle, which prioritises waste prevention, reuse, recycling, and recovery before final disposal in a regulated landfill. Similarly, the Landfill (Scotland) Regulations 2003 mandate that waste of various classifications be disposed of in appropriate treatment facilities under Scottish law. Consequently, in Nigeria, the Solid Waste Management

Policy Guideline (NSWMPG) was designed to ensure that waste is handled in such a way that more materials are recovered or recycled, reducing the risk of landfill disposal to the environment and public health (FMoEnv, 2015).

Waste characterization has been used in research to support sustainable waste management by identifying recoverable materials and setting targets to reduce the amount of biodegradable waste going to landfills, thereby reducing potential disposal concerns (Hoang, 2005; Byer et al., 2006; Coggins, 2009; Mbeng et al., 2012; Ishak et al., 2015). However, studies are often limited to the characterization of MSW based on the estimation of such wastes without a proper waste audit because of the cost implications of conducting such audits (Sharma and MCBean2007). While research on solid waste characterization at the household level is common, such studies at Higher Educational Institutions (HEIs) have been largely unexplored. HEIs, have similar issues to municipalities in terms of waste management and play an important part in building a sustainable society; they might be compared to towns and cities. These institutions, like municipalities, contribute to high solid waste generation due to their population size and complexity of activities (Acurio et al., 1997; Schmieder, 2012; Ezeah et al., 2015; Ishak et al., 2015).

The focus of this chapter was to assess the temporal pattern of waste generation and composition to evaluate the solid waste recycling policy within HEIs in both developing and developed countries; the University of Lagos and the University of Strathclyde were used as case studies. Solid wastes from different coloured recycling bins were sampled and audited, where the weight and volume of each waste type was measured to assess the extent of contamination across the coloured bins in the three main waste-generating activity areas on each campus (administrative, commercial, and residential areas). The effectiveness of current policies was assessed in both case studies, and where necessary, a sustainable waste management approach that will improve the university's waste management operational efficiency will be recommended in both case studies.

4.2. Methodology:

4.2.1. Case Study A: University of Lagos Area Description:

Established in 1962, the University of Lagos (UoL) is one of the oldest higher educational institutions in Nigeria. With an estimated day population of 87,000**,** the university generates on average 32.2 tons of waste daily (Adreniran *et al*., 2017). The main campus, located at Akoka, in the western part of Lagos State is divided into 4 zones, A-D (Figure 4.1). Within these zones waste generation originates from administrative, commercial, residential areas. The nature of activities in the administrative areas include administrative offices and academic work, the commercial areas include marketplaces e.g. photocopy centre, restaurants, motor parks, worship centres *etc,* while the residential areas include the staff quarters and student hostels.

Waste management in the university is coordinated by the Department of Works and Physical Planning (DWPP), who contract two private waste contractors to manage the University's wastes. The wastes are collected and dumped at the university's recycling centre, where the contractors sort the recyclables manually. The coordinating department monitors the activities of these waste contractors and manages the university's waste management data. UoL's waste recycling policy aims to prioritise material recovery over landfilling and has appropriate infrastructure to capture different waste streams for recycling, *i.e.* colour coded bins to capture different waste streams

(DWPP, Personal communication, 14 December 2016). During the data collection phase of the research, the DWPP assigned the researcher to the contractor responsible for Zones A and B and permitted access to these areas for waste sampling. Zones A and B, which contribute to over 70% of the total waste generated daily, contain administrative, commercial, and residential areas; both zones are dominated by residential structures (60 and 84%, respectively), but have structures dedicated to administration (27% and 7%, respectively) and commerce (13 and 9%, respectively) (Adeniran *et al*., 2017).

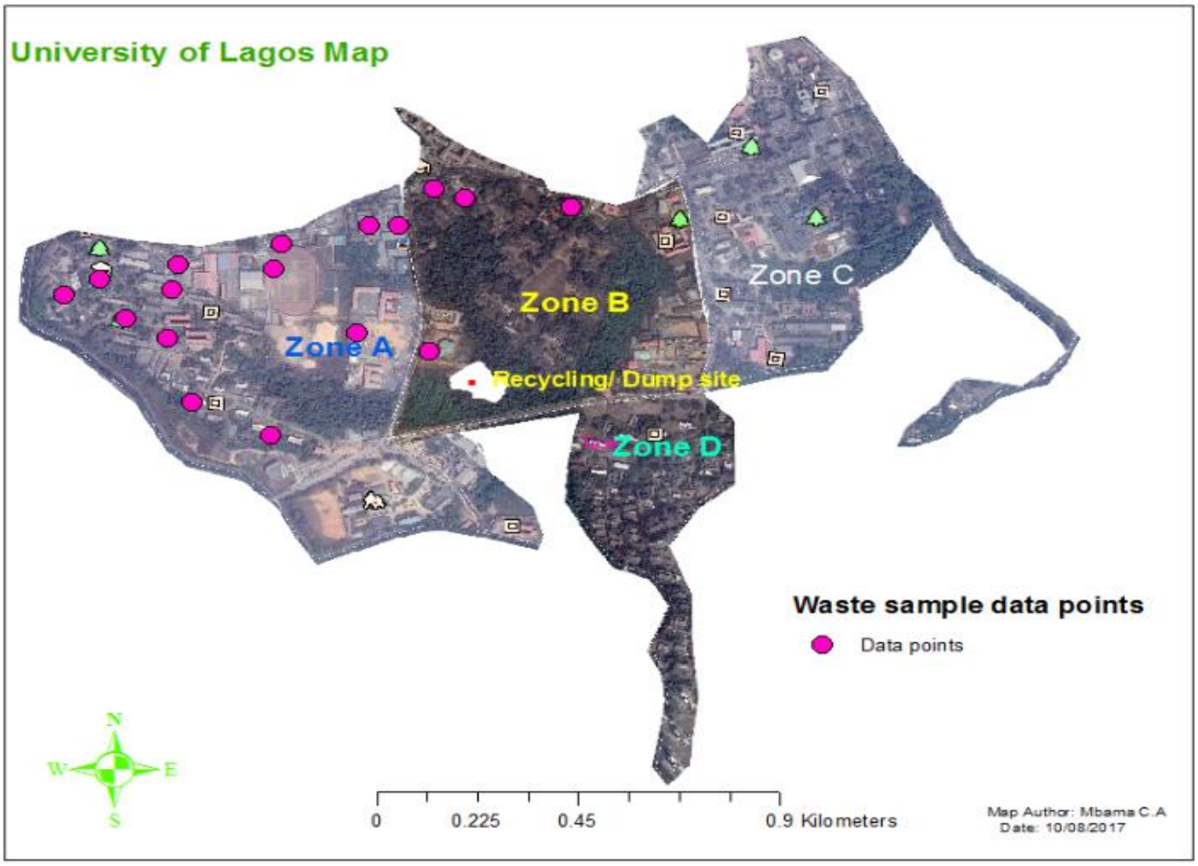


Figure 4. 1: Map of University of Lagos, Akoka Campus, showing the location of the four campus zones (A–D) and the waste collection points (pink markers) within Zones A and B.

4.2.2. Case Study B Area: University of Strathclyde Area Description:

The University of Strathclyde (UoS) gained its University Status in 1964, although established as the Andersonian Institute in 1796. The main campus is in the centre of Glasgow – the largest city in Scotland. The University has five faculties within which waste generated originates from administrative, commercial, and residential areas. The nature of activities in the administrative areas include administrative offices and academic work, the commercial areas include marketplaces e.g. restaurants, library *etc.* while the residential areas include the student accommodation. The University has a population of about 26,000 including staff and students (UoS, 2022; UoS 2023). The waste management at the university is handled by the Estates Services unit, which contracted it to Biffa, a waste management company that sees to the daily collection, transportation, and treatment of the waste to their facility that is outside the university's environment in line with the University's waste management policy.

At Biffa, waste is sorted mechanically for recycling of the waste material. The Estate Services of UoS overseas the activities of the waste contracts and keeps records of the waste management data. UoS waste recycling strategy is centred on the university's waste management policy (Sustainability and Environmental Management, 2021) which prioritises material recovery over landfilling and provides adequate infrastructure to capture different waste streams for recycling, such as colour labelled recycling bins. Estate Services assigned the researcher to one of their staff to enable easy access to the locations for data collection. The location includes the administrative area and commercial area, while the residential area was not considered as it is outside the school environment.The study did not include the residential area because it is situated outside the school premises, outside the areas assigned to cover, and which is mostly managed by third party accommodation providers, outside the UoS operational cover. This omission may contradict results by separating the core waste generating sector (students residing outside the campus), possibly resulting in the underestimation of the total recyclable contamination, which will potentially misrepresent the behavioural patterns in such area of the population (Keeping Britain Tidy, 2022).

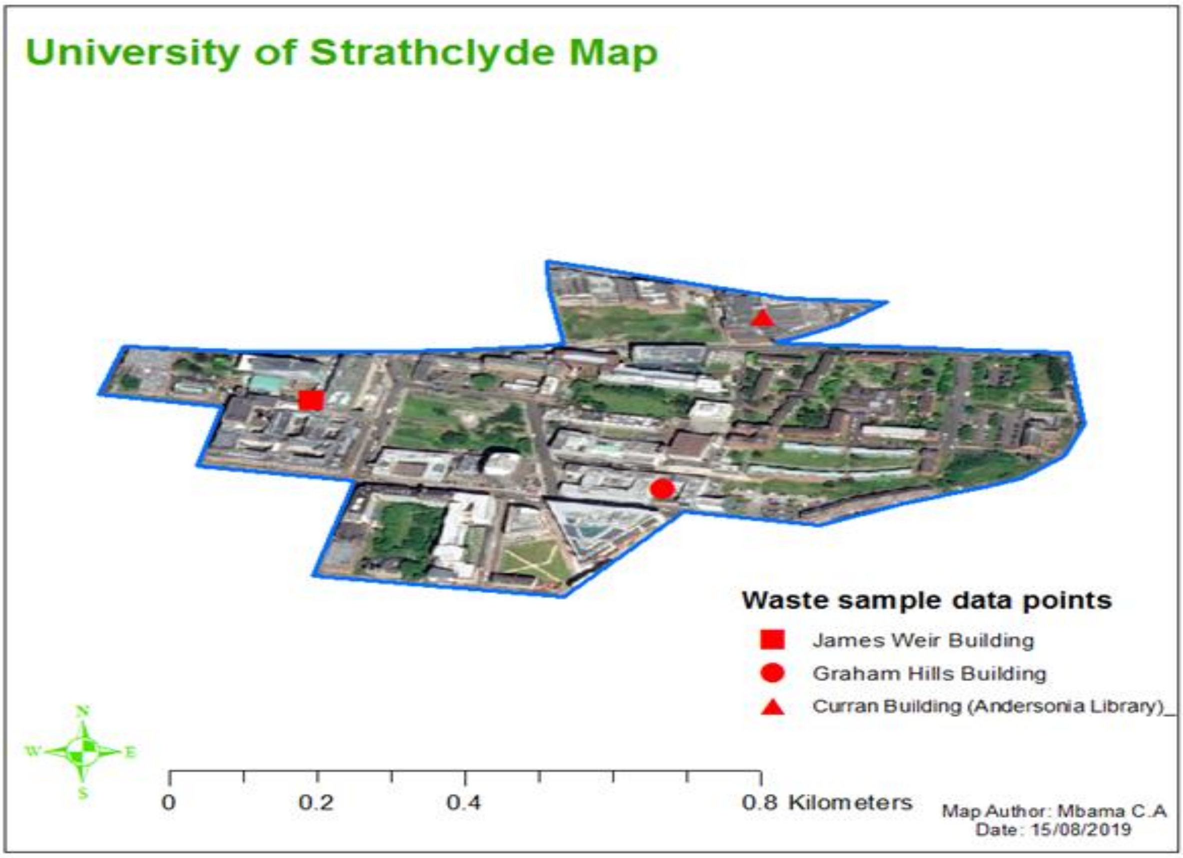


Figure 4.2: Map of University of Strathclyde, Glasgow, showing the waste sampling points at James Weir, Graham Hills, and Curran Building (Source: Mbama C).

4.2.2. Waste Audit Sample Collection:

An audit was conducted to establish composition of the waste in the different coloured recycling bins located in the waste generating areas on each campus to determine if the universities recycling policies were being effectively implemented. Waste samples were transferred to the specified university facilities (the UoL's recycling centre and UoS's Estate Services unit), where sampled bags were opened and manually sorted on a plastic sheet on the floor. Each waste material was put into appropriate waste category (e.g. mixed paper, mixed plastics, mixed glass and organic waste) to evaluate contamination (Mbama et al., (2022). The output method of analysis was used for the waste audit (Tchobanoglous et al., 1993 cited in Sharma and MCBean 2007). This method examines solid waste composition from already disposed of waste. An 'activities approach,' as outlined in the Waste Audit User Manual: A Comprehensive Guide to the Waste Audit Process by the Canadian Council of Ministers of the Environment (CCME, 1996), was also utilised. These methods track waste and recyclables within activity areas in institutions and separately audit the waste from each area.

The audit at UoL involved sampling waste from different coloured bins in the administrative, commercial, and residential areas. Once collected, the waste samples from each coloured bin in each area were segregated into six different waste types: mixed paper and card; mixed plastic (with subsections for water sachets, single use plastic bags and plastic bottles); cans; organic waste (with subsections for food and non-food waste); mixed glass; and non-recyclables. Glass and food waste, both of which were sampled independently since they contained only pure waste materials, were included in the recyclable waste. The weight and volume of each waste type was measured to assess the extent of contaminants in the coloured bins.

For the UoS, upon discussion of data collection with the university's Estates Services, the waste audit team (Table 4.1) comprising the researcher, Spela Raposa, Environmental Recycling and Awareness Officer at Estates Services and Natasha

Rapkin, a Master's Degree Student working on waste management and four additional students, decided to access and collect waste samples from 3 different buildings on the campus: the Level 5 Teaching Cluster in the Graham Hills Building (GH); Level 3 Computer Cluster (LL3) and the main entrance to Nourish Cafe (LC) both in the Andersonian Library; and the staff kitchen (JWSK), offices (JWSO) and students zone (JWSZ) in the Department of Civil and Environmental Engineering, Level 5 of the James Weir Building, in order to represent the targeted administrative and commercial areas (Figure 4.2). As mentioned already the residential building area was not included.

As recommended by CCME (1996), representative waste samples were collected in a similar fashion to the quartering and dividing approach for representative sampling used by Tiew et al., (2010). For UoL, one third of the waste contained in each of 64 bins sampled across the three major waste generating areas was collected. The DWPP indicated that there were 800 coloured bins on the university campus, but coloured bins were officially only located in the administration and commercial areas for collection of general wastes and recyclable materials, not in the residential areas; people living in the residential areas are advised to dispose of their waste in black bin bags. However, during data collection, it was noted that some of the coloured bins (green (for mixed plastics) and blue (for mixed paper and cardboard)) were located within the residential areas, and therefore samples were also collected from these bins.

The CCME (1996) recommend sampling between 10-25% of the waste generated in any given area. However, it was not possible to reach the recommended minimum sample size of 80 bins, as the study was undertaken during university vacation in

December 2016, when not all bins were in use at UoL. For consistency, the waste audit was also carried out during similar vacation at University of Strathclyde, but in 2017.

The waste samples were collected at both case study sites (UoL and UoS) with the help of their University's waste haulage unit; the haulage units provided a waste truck for sampling and transportation of the samples to the university's recycling centre for storage until the audit was completed at UoL, while waste was stored until the audit was completed in an enclosed vacant space within the Estate Service unit of the UoS. The wastes were separated into six different waste components, like mixed paper and card, mixed plastic, cans, mixed glass, orgnic/food waste, and general/non-recyclables. The individual waste stream was weighed, and their weights recorded to understand its compositions in each coloured coded waste targeted category as well as understand the efficiency of the universities waste recycling policy. At each university, the researcher employed a team of assistants to audit the waste by separation and assessment; details on each team are given in Table 4.

Table 4.1: List of waste audit team at University of Lagos (UoL) and University of Strathclyde (UoS).

S/N	Team Members at UoL	Team Members at UoS
1	Charles Mbama	Charles Mbama
2	Staff 1	Spela Raposa
3	Staff 2	Natasha Rapkin

4	Staff 3	Chigozie Odumodu, a Naval Architecture PhD student, UoS
5	Staff 4	Student 2
6	Student 1	Student 3
7	Student 2	Student 4

Before completing the audits, a risk assessment for the case studies were completed e.g. from explaining the goal of the project to the waste audit assistants, presenting the risk assessment results and health and safety procedures, and providing PPE for the participants that conducted the audit. The risk assessments (Appendix 4.1) were completed to ensure the potential risk that could occur during the process was minimised, while the waste audit team labelled all waste bins from all specified locations within the categorised areas in the case studies. Plastic sheeting was placed on the floor to maintain cleanliness. There, the bags were separated by location, sorted, and recorded one bag at a time. The sorting was done by emptying the contents of each bag onto the floor, splitting them by item/ waste type and placing groups of items into other bags labelled with pre-determined waste characterisation categories in both case studies.

4.2.3. Data Analysis:

The result of the regression analysis for UoL was validated. In this case, the slope and intercept of the given Y and X variables were determined using Excel software to confirm the accuracy of the trend equation. The coefficient of determination (r^2) and the correlation coefficient were used to evaluate the expected data and the seasonally adjusted forecast. These have been utilised to confirm statistical findings in academic papers (Bryhn et al., 2011; Zaki et al., 2012) and the value of the better fit of the regression model was quantified. The r value is the coefficient of correlation that assesses the degree to which the data conforms to a linear connection and is a reliable measure of agreement (Zaki et al., 2012; Akoglu, 2018; Schober et al., 2018).

More so, One Way ANOVA in IBM SPSS Statistics V24.0 was used to further analyse the waste stream/ data in both case studies. This was done to explore any significant difference in the mean of the targeted waste stream when compared with the contaminants in each coloured waste bins across the different waste generating areas on campus; the software can be used to analyse and compare the mean variance between more than two groups (Brown, 2005). Levene's statistical test was conducted to test the homogeneity of the variance across the 3 activity areas. Reinard (2006) indicated that this test better analyses the equality of error variance. In this investigation, appropriate analytical guidelines in the use of statistical software were used (Mishra et al., 2019).

4.2.4. Key Interviewee Discussion:

A visit to the university's waste management facility (recycling centre) and the Estate Services were made at UoL and UoS respectively, in addition to formal and informal discussions with university staff who have key roles with respect to waste management. The DWPP was initially contacted in September 2016 via email before the commencement of research work in December 2016, while the Estate services was contacted in January 2016. The initial e-mail contact was to inform the university about the key research aims, request assistance, and get approval to conduct the waste audit in the university. The formal discussion posed structured questions (see

Appendix 4.2) to the waste management coordinators to gain insight into the universities' waste management approach. At UoL, informal discussions also took place with waste haulage drivers, members of the cleaning staff, and member of staff from the waste contractor involved in the manual sorting of recyclable at the university's recycling centre. At UoS informal discussions took place with a member of staff from the company contracted to treat the university's waste, Biffa, and a formal discussion with the waste management staff. Open-ended formal questions included in the discussion covered how the university's waste management system works, how much waste is generated, recycled, and landfilled monthly, and how often waste haulage is completed. The Universities provided waste generation data from October 2014 - October 2016 (UoL) and February 2011- June 2015 (UoS). In order to build up data for more than the 2-year period for UoL (as that was the only data released for the research), when compared to the 4-year data period collected from UoS, a forecast was done for UoL to allows for the development of additional data, using a time series moving average in the Excel advanced analytical tool, for a more data-driven strategy, as well as the ability to make data-driven decisions for better waste management.

4.3. Results**:**

4.3.1. Solid Waste Management:

Unless stated otherwise, all information regarding the University of Lagos and University of Strathclyde's waste management procedures came from the Department of Works and Physical Planning (A. O. Adelopo, personal communication, 14^{th} December 2016) and Estate Services Department (D. Dean, personal communication, 16^{th} May 2016), respectively.

UoL's Waste Management Policy, established in 2014, is in-line with the Nigerian Solid Waste Management Policy Guidelines that aims at minimising the risk associated with waste generation (FMoEnv, 2015). The UoL through DWPP, contracts waste management to two commercial processing companies to ensure that wastes generated within the campus are efficiently managed. The wastes are hauled to the university recycling centre where they are manually sorted to extract some recyclables, and the residues are disposed of on-site at UoL, where the waste is expected to be lifted for land reclamation. Similarly, the University of Strathclyde's waste policy aims is to reduce the negative environmental impacts arising from generation of waste, through prevention, reuse, and repurposing, in accordance with environmental legislation compliance (Sustainability and Environmental Management (2021). According to the UoS waste management policy, the "*University is committed to implementing an effective and responsible waste resource management process that meets and ideally exceeds legislative, regulatory, and best practice legislation and guidance… The University implements processes, procedures and initiatives that ensure compliance with environmental legislation and best practice, and which encourage waste producers to reduce the overall waste that they produce and prevent waste production wherever possible"* (Sustainability and Environmental Management, 2021).

The UoL produces hazardous, non-hazardous, and inert waste. Most hazardous waste is clinical waste generated by the university's health clinic; this material is normally incinerated safely within the health centre. The inert waste is primarily generated during construction or demolition within UoL, while the non-hazardous waste, material other than clinical or inert waste, is generated across the university, and is the focus of this research.

Officially, the UoL practice waste recycling and has over 800 colour-coded solid waste bins provided at different locations across the campus: blue bins for mixed paper and cards; green bins for mixed plastics; red bins for cans; and black bins for residual/other waste. Upon implementation of the waste management policy in 2014, UoL ran a waste management campaign which included: waste and environmental management orientation for new students; regular awareness jingles on the university's radio station; display of color-coded waste bins and signage of what should be disposed in each colored bin at strategic locations throughout the campus (Figure 4.3); and waste management awareness lectures with faculty officers and commercial operators. Unofficially, some university staff also engage in their own recycling by collecting recyclable materials within their reach, to sell and make extra income, and the informal sector (scavengers and waste pickers) enter the campus to pick-up recyclable wastes to sell for profit.

Figure 4.3: Simplified waste segregation signage to aid source segregation at the University of Lagos.

The DWPP at UoL and the Estate Services at UoS, ensures collation of waste management data, which includes keeping up-to-date records of waste management activities like daily generation, recycling, and disposal rates etc, and the monitoring of the waste contractor's activities, to ensure that recyclable wastes are recovered, and residues disposed of safely without posing risk to the public. For the UoL, its solid waste data was provided for the years 2014-2016 (Figure 4.4); and for UoS, the waste data was provided for the year 2011-2015 (Figure 4.5), and using the moving average, the trend pattern of the waste generation for both case studies were determined. The trend patterns were analysed using the moving average in the Excel statistical data analysis tool; moving average is a time series model used to smooth values to understand and highlight important trends or patterns (Hyndman 2009 cited in Lovric, 2011). The mean monthly waste generation was 877.5 tonnes, with the minimum 494.9 and maximum of 1243.6 tonnes at UoL. The moving average result shown in Figure 4.4 indicates a seasonal pattern in the data. Results show a slight negative circular trend in seasonality, with the peak generation observed in March - May, while nadir is observed in July over time. For the UoS, the moving average result shown in Figure 4.5 also indicates a seasonal pattern in the data trend. The result shows a slight negative circular trend in seasonality, with the peak generation observed in March - June, while the lowest generation is observed in July – August over time.

Despite commitment and efforts by both university's waste management team, the data provided by the DWPP shows that less than 1% of the waste material is recycled, while about 99% is either used for land reclamation or sent to a landfill site. Land reclamation of residual waste at UoL involves filling up water areas or excavated sites with waste to create new land (Stauber et al., 2016), a process that could cause environmental and/or health risks, including the contamination of the groundwater through leaching, and potential fire outbreak from methane gas generation (Figure 4.23), and does not support waste hierarchy (Gregson *et al.,* 2013; Efraimsson *et al*., 2014). On the other hand, UoS does not use landfills at all, instead, it recycles everything, including energy recovery or through anaerobic digestion which is confirmed through the data provided by the Estate service.

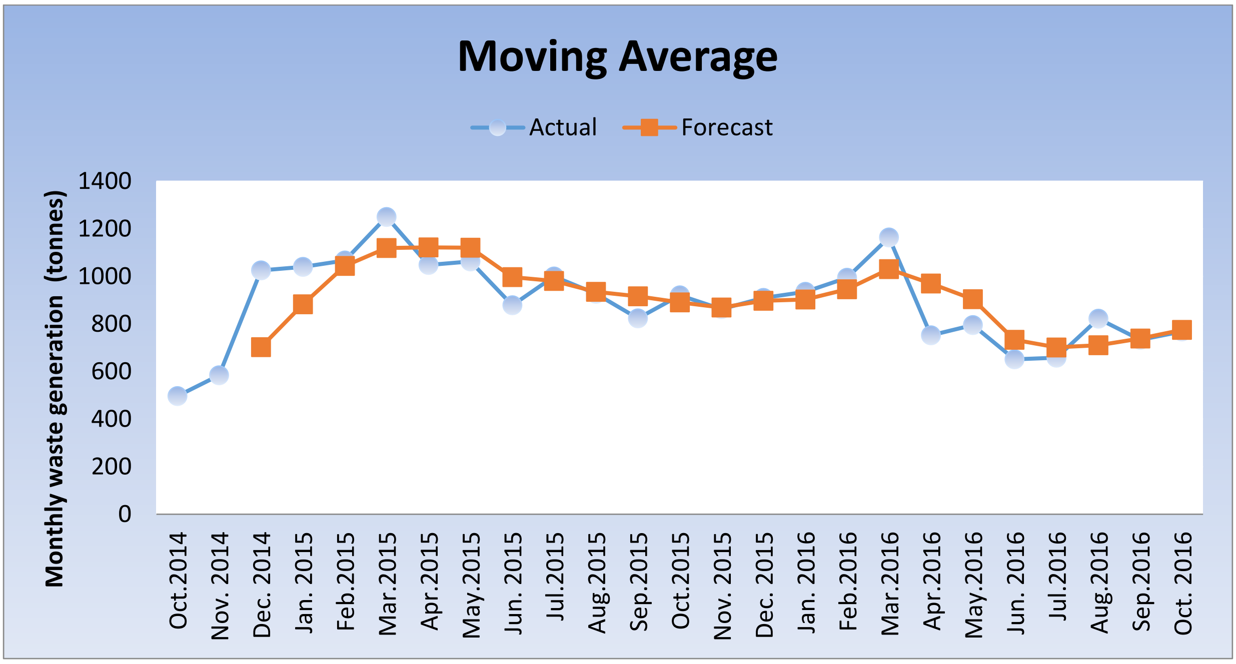


Figure 4.4: Monthly waste generation and quarterly moving average showing trend pattern from October 2014 to October 2016 in Akoka Campus, University of Lagos.

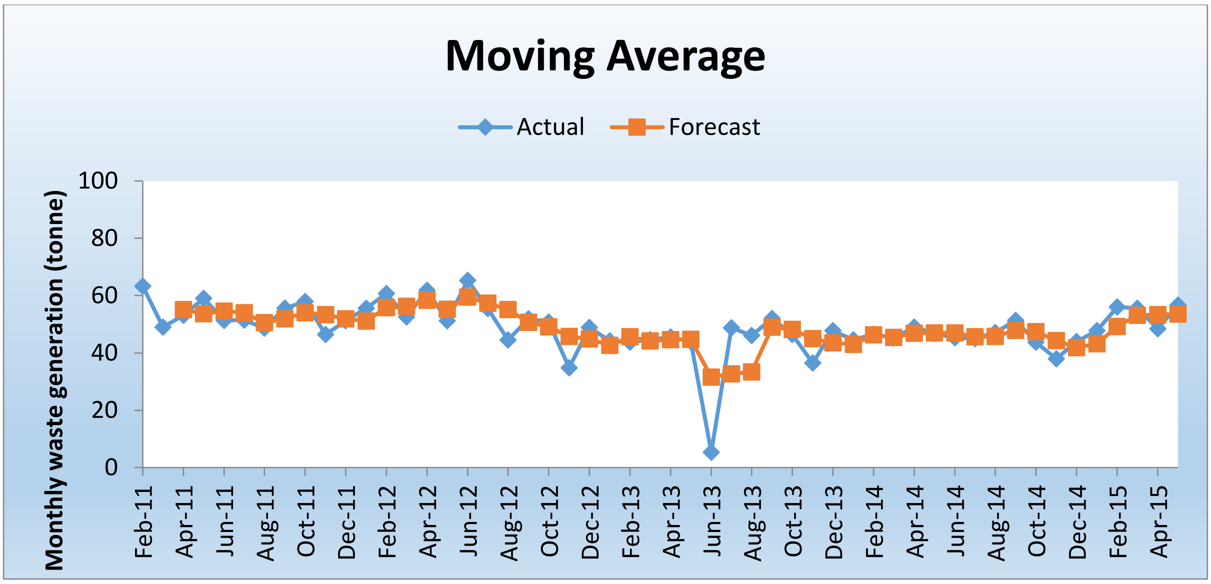


Figure 4.5: Monthly waste generation pattern from February 2011 to June 2015 at University of Strathclyde.

UoS's solid waste data collected for the years February 2011 to October 2015, shown in Figure 4.5, demonstrated that about 583 tonnes of waste were generated on an annual basis (calculated by finding the average annual generation from 2012 to 2014), while the average monthly waste generation was about 48.58 tonnes. The Estates Service Department ensures that waste management data are analysed to understand the progress made towards waste management policy implementation and to monitor their performance and that of their waste contractors. The waste data also shows that none of the university's waste goes to landfill as they are either recycled, sent to anaerobic digester (for the organic wastes), or incinerated for energy recovery.

More so, the UoS waste management policy forms part of the university's sustainability framework and supports the University's Social Responsibility and Climate Change Policy, which encourages that waste generated at source is segregated into different colour code bins. The university has simplified its waste segregation signage to help communicate to staff and students what is expected of them in terms of recycling

(Figure 4.6). The idea here is to produce a higher level of pure, uncontaminated waste streams, which can provide a discount for the university in terms of the cost of handling waste for the next payment period (Raposa, 2018, personal communication 28/2/2018). In updating signage, the word ‘only’ was removed from ‘only paper’ and ‘only plastic bottles’ labels, and changed to simpler ‘paper,’ ‘plastic,’ ‘cans’ ‘general waste’ and ‘food waste.’ More so, their regular enlightenment programmes aimed at encouraging students and staff to recycle as shown in Figure 4.6.

Figure 4.6: Simplified waste signage to aid source segregation at the University of Strathclyde (Sustainability and Waste Management 2021).

The UoS contracts their waste management to Biffa for recycling at Biffa’s semi-automated Material Recovery Facility, while organic wastes are contracted to Energen Biogas, a waste management company which uses Anaerobic Digestion to process the waste and generate energy and fertilizer. Figure 4.7 shows the journey taken by UoS waste. Despite the UoS recycling efforts with no waste going to landfill, there is still no significant waste reduction, which demonstrate a gap in their waste prevention efforts which is the main factor to consider in the waste hierarchy.

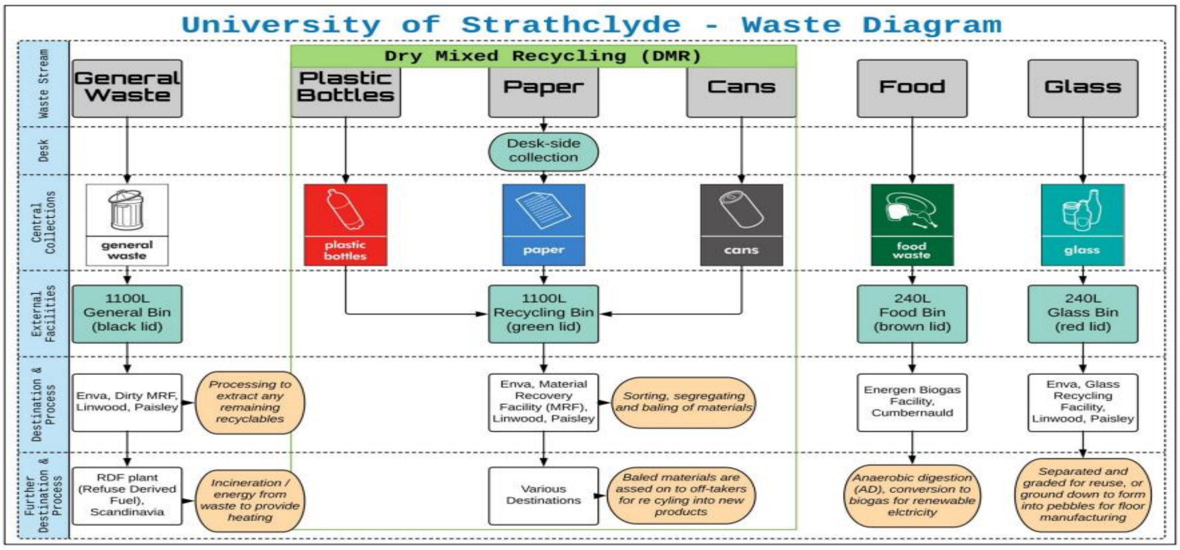


Figure 4.7: Waste flow chart at University of Strathclyde (Sustainability and Waste Management, 2021).

4.3.2. Temporal waste generation pattern:

From the UoL data (2014-2016), a time series analysis was conducted to understand better the temporal waste generation pattern which also showed the quarterly moving average for the waste generation and forecast in tonnes for the UoL from October 2014-December 2017 (Figure 4.8) in order to expand a little, the UoL waste data to understand more clearly the waste generation pattern as only two year data period was provided for UoL when compared to the UoS that has more than two year data period, for which no further forecast was conducted (see Appendix 4.3b for detailed result).

The time series analysis/trend using four quarterly moving average (4QMA) at UoL shows a seasonal pattern in the waste generation. It also shows a slight negative circular trend with seasonality with the highest peak observed in March, been the first quarter of the year. While the lowest is observed in June (towards the last second quarter) over time. The forecast could be extended to covered for 2018 monthly generation for which it is expected to repeat itself. However, UoL's slight increase in waste generation during university vacations (November – December) could be attributed to ongoing administrative projects and commercial operations, for example the campus markets, restaurants and motor park used by the public). At UoS, extra classes or programs/maintenance projects caused the high volumes of wastes during the survey period (University of Strathclyde, 2022; Sustainability Strathclyde 2024). Notwithstanding, the four quarterly moving average (4QMA) used for UoS data also showed a down-trend pattern as described by Watanapa et al., (2006).

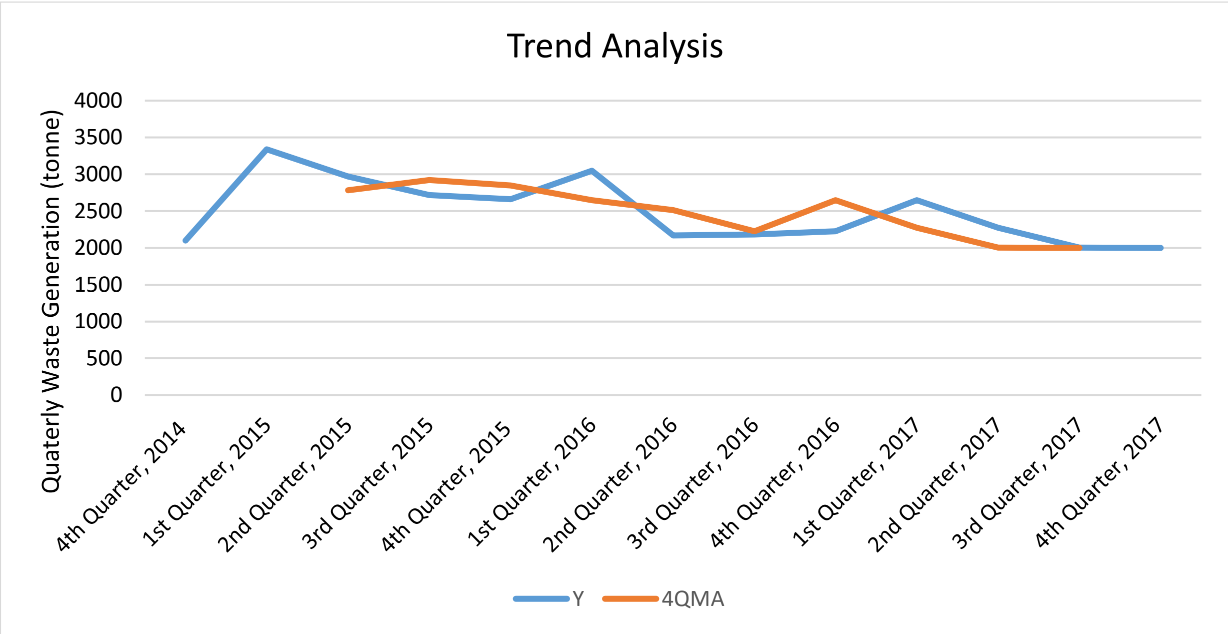


Figure 4.8a: Quarterly waste generation pattern from October 2014 to December 2017 at University of Lagos, where Y=Quarterly Waste Generation and 4QMA =Trend.

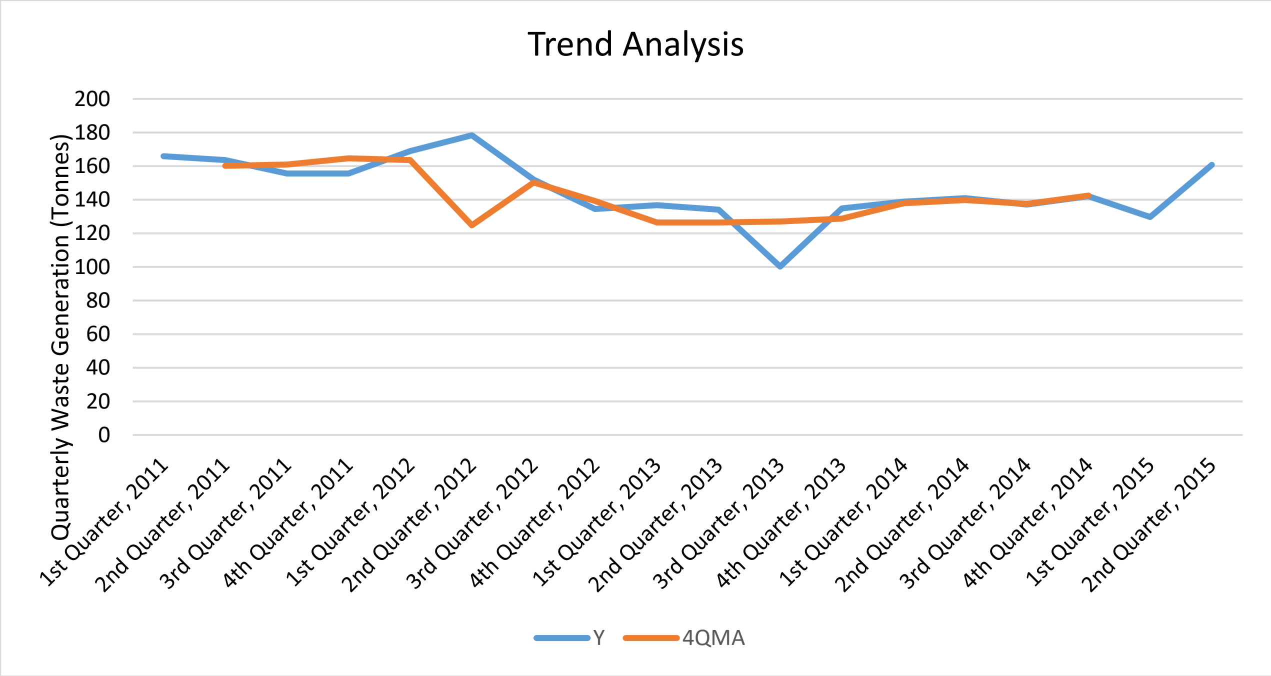


Figure 4.8b: Quarterly waste generation pattern from February 2011 to June 2015 at University of Strathclyde where Y=Quarterly Waste Generation and 4QMA =Trend.

An evaluation of the seasonal index was done to understand the waste generation capabilities at the case studies. And result, shows quarterly variations in the seasonal indices of the waste generated at the University of Lagos and University of Strathclyde as shown in Table 4.2.

Table 4.2: Quarterly seasonal indices for waste generation at University of Lagos (UoL) and University of Strathclyde (UoS).

Seasonal Index	UoL	UoS
First Quarter	114.3%	101.08%
Second Quarter	100.8%	108.00%
Third Quarter	91.2%	94.2%
Fourth Quarter	93.7%	96.7%

The seasonal index for the first quarter (114.3%) of UoL indicates that generation for that quarter is 14.3% above expectation based on average waste generation for the year. While the seasonal index for UoS (101.08%) shows the waste generation is 1.08% above expectation in the first quarter. For quarter two which has a seasonal index of 100.8% shows a slightly increase of 0.8% of the annual waste generation at UoL, while that of UoS is about 8% (seasonal index, 108.00%) above the annual waste generation expectation. Similarly, third quarter has the least seasonal index of 91.2% and 94.2% at UoL and UoS respectively, which indicates that the waste generation for the third quarter is 9% and 6% less at both UoL and UoS respectively than the expected annual average, which is followed by the fourth quarter that has seasonal index of 93.7% (at UoL), 96.7% (at UoS) that indicates the generation for that quarter are 6% (at UoL) and about 3.3% (at UoS) less expectation based on the average for the year. The full mathematical calculation can be seen in appendix 4.3a and appendix 4.3b.

4.3.2.1. Validation of Regression Result:

To validate the result, the slope and intercept of the known Y and X variables were calculated using Excel software. The results obtained were a slope of -60.46 and an intercept of 2919.66. The coefficient of determination (r^2) and correlation coefficient (r) for the initial trend forecast were both 1. The r^2 and r values of the trend estimate after seasonal adjustment were found to be 0.8728 and 0.93, respectively.

4.3.3. Waste Audit for UoL and UoS:

In the UoL campus, there are over eight hundred 300 L capacity coloured solid waste bins to capture 4 different waste streams as follows: mixed paper and cards in blue-coloured bins; mixed plastics in green-coloured bins; cans in red-coloured bins; and residual or other wastes in black-coloured bins. The bins are deployed at different locations within the campus. Sixty-four representative waste samples, amounting to approximately 254.5 kg/49 m^3 were collected from the 3 major waste generating areas. The mean, standard deviation and margin of error (which shows the variance on the quantity of the wastes sampled) for the 64 waste samples were calculated; a standard deviation of 2.8 shows that the representative sample data values are similar, so the data is shown to be closely clustered to the mean, 4.0 which indicates that the sample is standard and well distributed. This can be seen with the margin of error of 0.7 which shows a good sample size that is representative (see Supplementary 4.4).

The waste samples were collated in 2 categories: 1) general waste, *i.e*. waste collected from black bins (materials intended for landfill disposal), and 2) recyclable wastes, the materials collected from the coloured bins that support the university's recycling programmes, i.e. red, green and blue bins; all samples were sent to the university's recycling centre for sorting. Figure 4.8 shows the composition of the waste in these two categories, and the composition of all waste collected. Organic waste (food and non-food waste) at 30% was the largest component of all the waste collected; results from the sub-categories of the organic waste stream indicated that 22% of this was food waste, while the remainder was other organic material (78%) such as garden waste (leaves, plant branches *etc*). And while organic waste was the biggest component of the general waste stream at 39% (see Figure 4.9), this material was the third largest component of the recyclable stream (21%) behind mixed plastic (33%) and paper and card (28%). The second and third largest components of all waste analysed was mixed plastics at 28% and paper and card at 24%. Very little mixed glass (2% of all waste collected) or cans (4% of all waste collected) were found in either waste stream. The most common plastics found among all waste sampled were 'nylon' bags (51%, 36.5 kg – from subsection data), composed of Low-Density Poly Ethylene (LDPE) *i.e.* water sachets, bin liners, carrier bags, etc., the remainder was Polyethylene Terephthalate (PET) bottles (49%, 35.0 kg – from subsection data); this was also confirmed through visual inspection, an example of which can be seen in Figure 4.10. The high contribution from 'nylon' water sachets may be attributed to the low cost of this form of water, which is assumed to be safe for drinking.

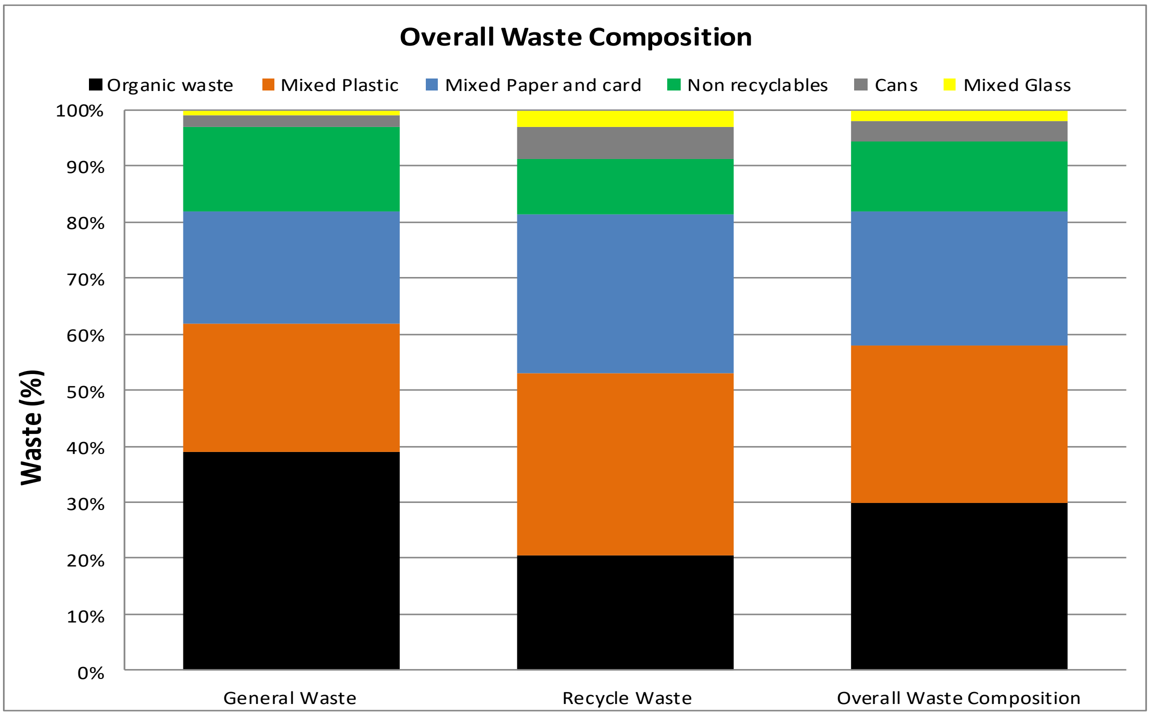


Figure 4. 9: Composition of the general waste samples from black bins (n=29, 124.0 kg) and recyclable waste samples from green, blue, and red bins (n=35, 130.5 kg) at Akoka Campus, University of Lagos.

Figure 4.10: High LDPE content found during waste analysis sorting process; of the 71.5 kg of plastic waste sampled, 36.5 kg was 'nylon' sachet water and 35.0 kg was PET plastic bottles.

For the University of Strathclyde, six distinct categories of waste collected in 6 different coloured bins, e.g. mixed paper and cards in blue bins; mixed plastics in red bins; cans in black bins; organic/food in dark green bins; glass in light green bins; and general wastes in white bins. The coloured bins, in 3 different capacities, *i.e.* 240, 660 and 1100 litre, are deployed at different location across the university. The inability to increase the sample size was because of low waste generation during the period of survey when the university experiences low student activities.

As with the audit at UoL, the waste samples were collated in 2 categories: 1) general waste, *i.e*. waste collected from white labelled bins (waste intended for incineration), and 2) recyclable wastes, the materials collected from the coloured bins that support the university's recycling programmes, *i.e*. red, blue, black, light, and dark green bins. The recyclable waste included the glass and food waste that were sampled separately as they contained pure waste materials.

Figure 4.11 shows the composition of waste from the general waste bins, the recycled material, and all waste collected. If all waste is considered, then mixed paper at 39% was the largest component. And while mixed paper was still the biggest component of the recyclable waste stream at 45%, this material was the third largest component of the general stream (14%) behind non-recyclable (53%) and food waste (16%). The second and third largest components of all waste analysed were non-recyclable at 31% and mixed plastic at 21%. A small quantity of food waste (7% of all waste collected) and cans (3% of all waste collected) were found in the overall waste composition.

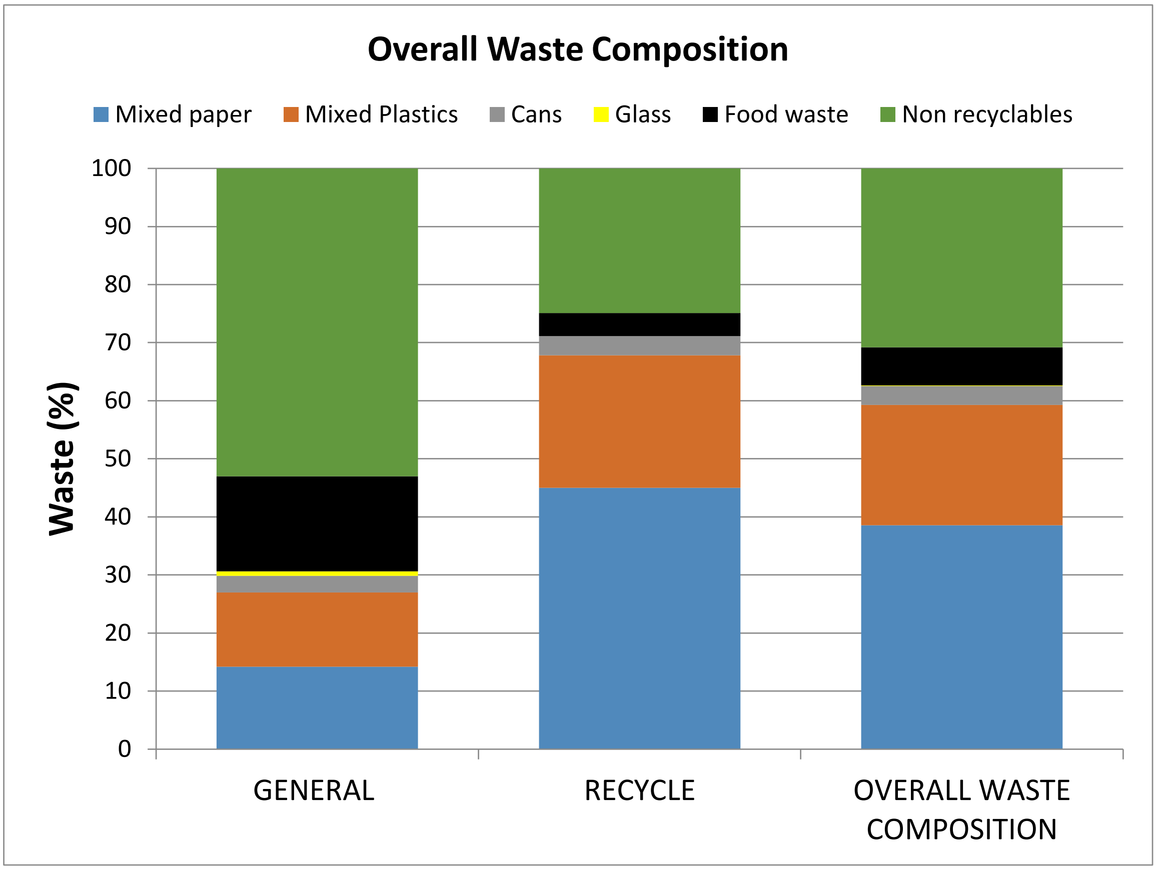


Figure 4.11: Composition of the general waste samples from white bins (n=5, 11.12 kg) and recyclable waste samples from light and dark green, blue, and red bins (n=25, 42.01 kg) at University of Strathclyde.

4.3.4. Waste by Area of Activity at UoL and UoS:

The percentage composition of the general waste stream from the different waste generating areas at UoL and UoS are shown in Figure 4.12. While organic waste was the major component of this stream in all areas at UoL, there were some differences between the areas, with the commercial area containing the highest level of organic waste at 45%, and similar, lower levels, in the administrative (35%) and residential (36%) areas. Mixed plastic made up 30% of the administrative waste stream and was around a fifth of both the residential and commercial streams. In the residential areas, just over a quarter of the general waste was composed of mixed paper and card (27%), while the commercial area waste had a much lower level of this material (11%). The other waste streams, *e.g.* cans and mixed glass materials, were poorly represented (1-3%), except the non-recyclable material that ranged between 9-20% of the general waste stream. However, for the UoS, the non-recyclable waste was the major component of the waste streams at the two waste generating areas. The commercial area had the highest level of non-recyclable waste, at 77%, while the administrative areas had comparable, lower levels (47%). Waste samples was not collected within the residential area at UoS. Meanwhile, within the administrative and commercial areas, the mixed glass and mixed plastic materials were poorly represented at 0-4% respectively.

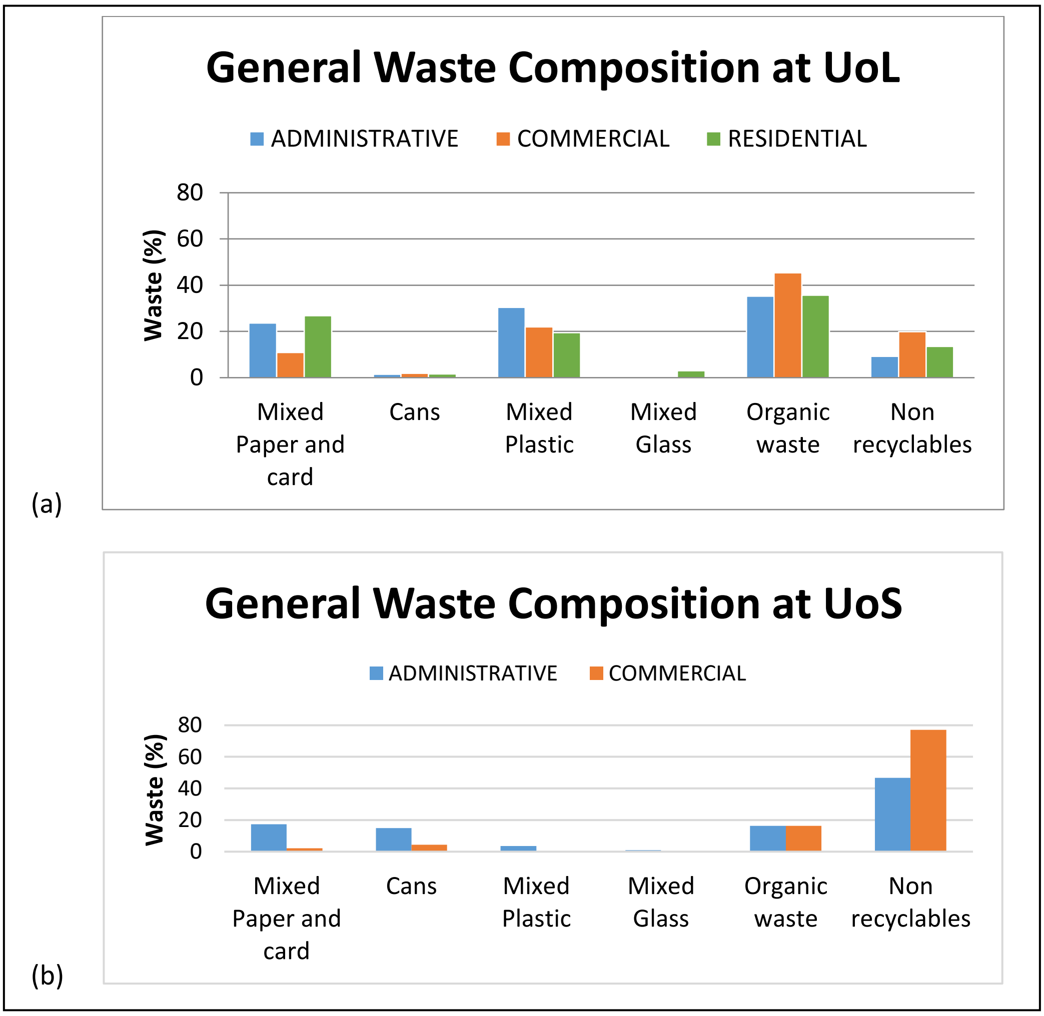


Figure 4.12: Composition of the general waste from black bins for the administrative (33.5 kg), commercial (50.0 kg) and residential (40.6 kg) waste generating areas of Akoka Campus, University of Lagos. While, for University of Strathclyde; the administrative (n=3, 8.80 kg) and commercial (n=2, 2.32 kg).

Differences in composition were also noted in the recyclable waste stream at UoL and UoS (Figure 4.13 and 4.14). The largest contributor to the recyclable waste stream in the administrative and residential areas at UoL was mixed paper and card, at 45% and 29%, respectively. The largest stream found in the commercial area was mixed plastic at 33%; the administrative area also had a similar level of mixed plastics (32%). Compared with the general waste, although a similar pattern was found in the organic material across the 3 waste generating areas at UoL, i.e. the commercial area had the most, there was much less of this material present (25% as opposed to 14/17% in the administrative/residential areas). Also like the general waste stream, there was poor representation from the cans, mixed glass, and non-recyclable materials (10-16%). However, for the UoS, the non-recyclable material made up the greatest portion of the recyclable waste stream in the commercial area, contributing 54%, followed by cans, which 33% in same area, while in the administration area, the mixed paper and card made up the highest proportion of waste accounting for 49% followed by cans and non-recyclable at 21%. One outstanding observation in the two case studies was that organic waste accounted for more at the commercial area in UoL (25%) when compared with other areas within UoL, while comparatively, organic waste accounted for more at the administrative area of UoS, although in a smaller proportion (4%) when compared to commercial area of same UoS (1%).

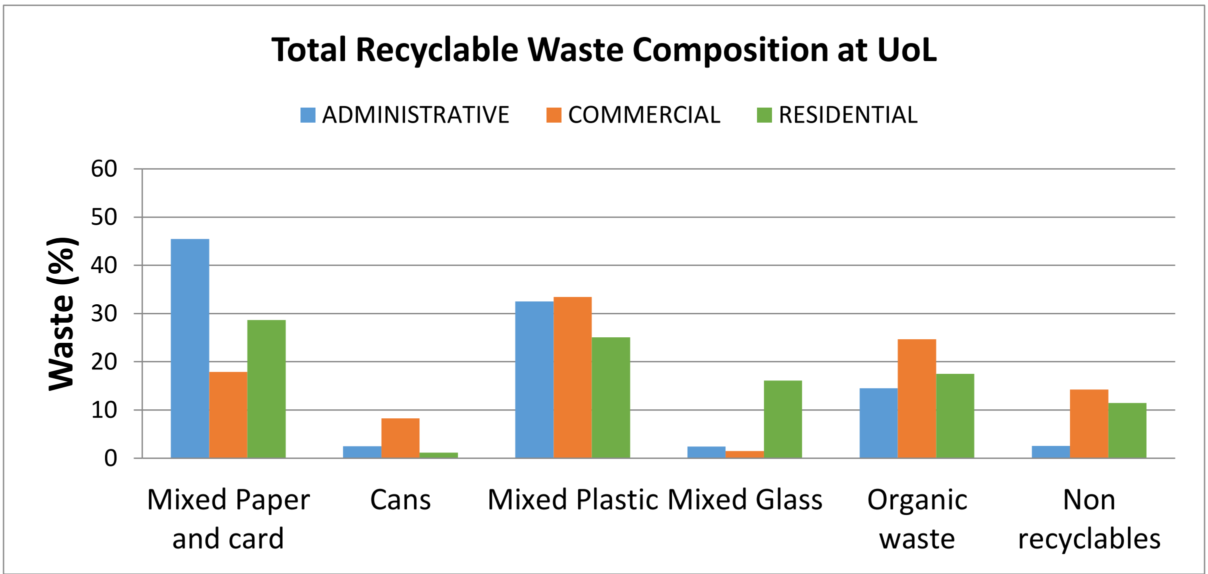


Figure 4.13: The total recyclable waste composition, i.e. waste collected from blue, red, and green coloured waste bins across the administrative (45.9 kg), commercial (75.2 kg) and residential (9.5 kg) waste generating areas in Akoka Campus, University of Lagos.

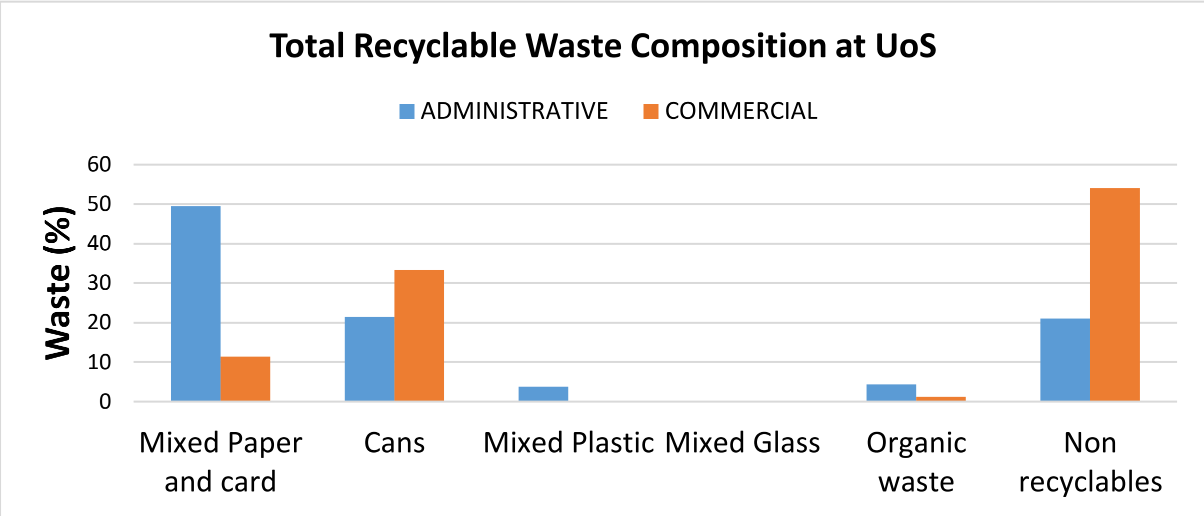


Figure 4.14: The total recyclable waste composition, i.e. waste collected from blue, red, and green coloured waste bins across the administrative (37.09 kg) and commercial (4.92 kg) waste generating areas of the University of Strathclyde.

4.3.5. The Contamination of recycling bins at UoL:

To investigate how efficient, the recycling program at the UoL, the contamination rate of the various targeted colour coded bins was observed. The result is discussed below:

4.3.5.1. Blue Bins designated for Mixed Paper and Card recycling at UoL:

Figure 4.15 shows the percentage of different waste components in the blue colour bins that are designed for the collection of mixed paper and card, in the three areas of activity; all non-paper and card components are considered as contaminants in this stream. Almost half the waste from the administrative (48%) and residential (49%) blue bins contained target material, however, only 11% of waste in the commercial blue bins contained paper and card waste. After target material, the next biggest component was mixed plastic in the commercial area (47%); just under a quarter of this stream was organic waste (26%), with some non-recyclable material (12%) and cans (3%). Among the administrative and residential waste, the second largest component was mixed plastic and mixed glass, respectively, both at 30%, with minimal contamination from the other waste streams; no organic waste was found in the residential blue bins.

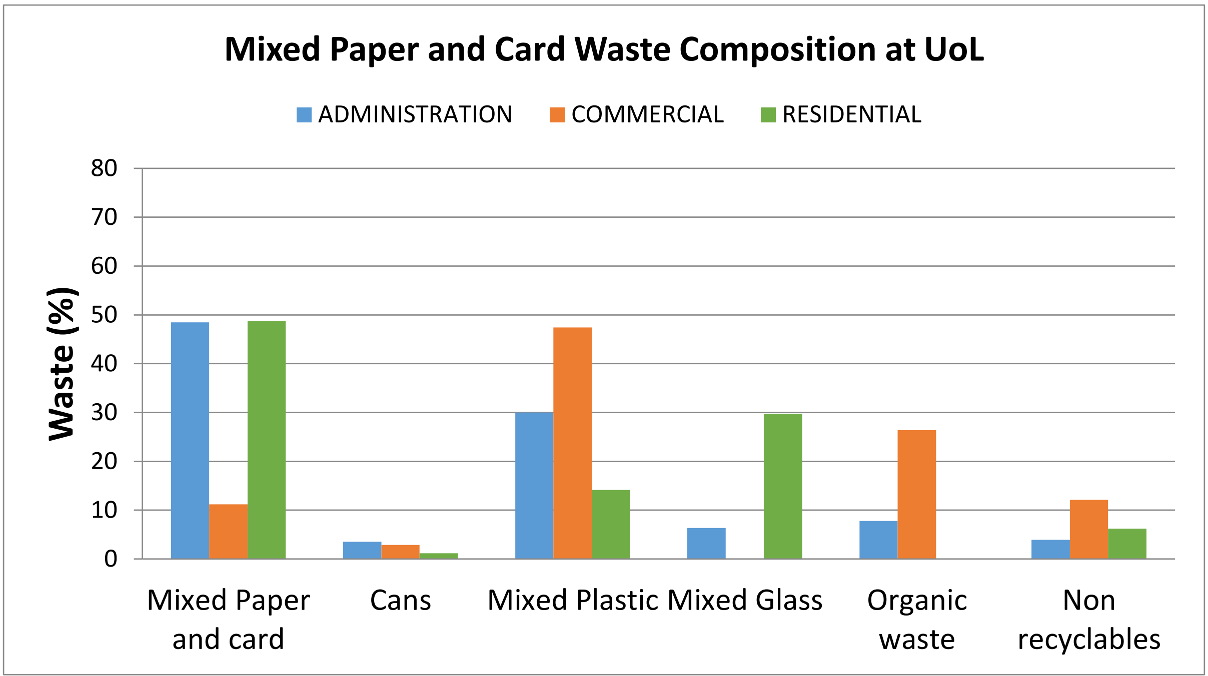


Figure 4.15: Waste composition of the blue bin (mixed paper and card waste) samples collected from the administrative (12.5 kg), commercial (33.5 kg) and residential (5.2 kg) waste generating areas in Akoka Campus, University of Lagos.

4.3.5.2. Green Bins designated for Mixed Plastics recycling at UoL:

The targeted waste captured from the administrative and commercial green bin samples, i.e. bins designated for recycling of mixed plastics, was only 25% each from the two areas and the highest contamination came from the administrative area that has 54% of contaminations from mixed paper and cards (Figure 4.16), while the residential green bin samples had a higher level of target material at 38%. The greatest contamination of the residential green bins came from organic waste (38%; mainly food waste) and non-recyclable material (18%). Mixed paper and card were the largest component of non-target material in the administrative green bin samples (54%), with 16% being organic waste. A similar level of mixed paper and card (26%), as plastic waste was found in the commercial green bins. Except for the commercial waste at 16% cans, minimal glass and can contamination be found in this stream.

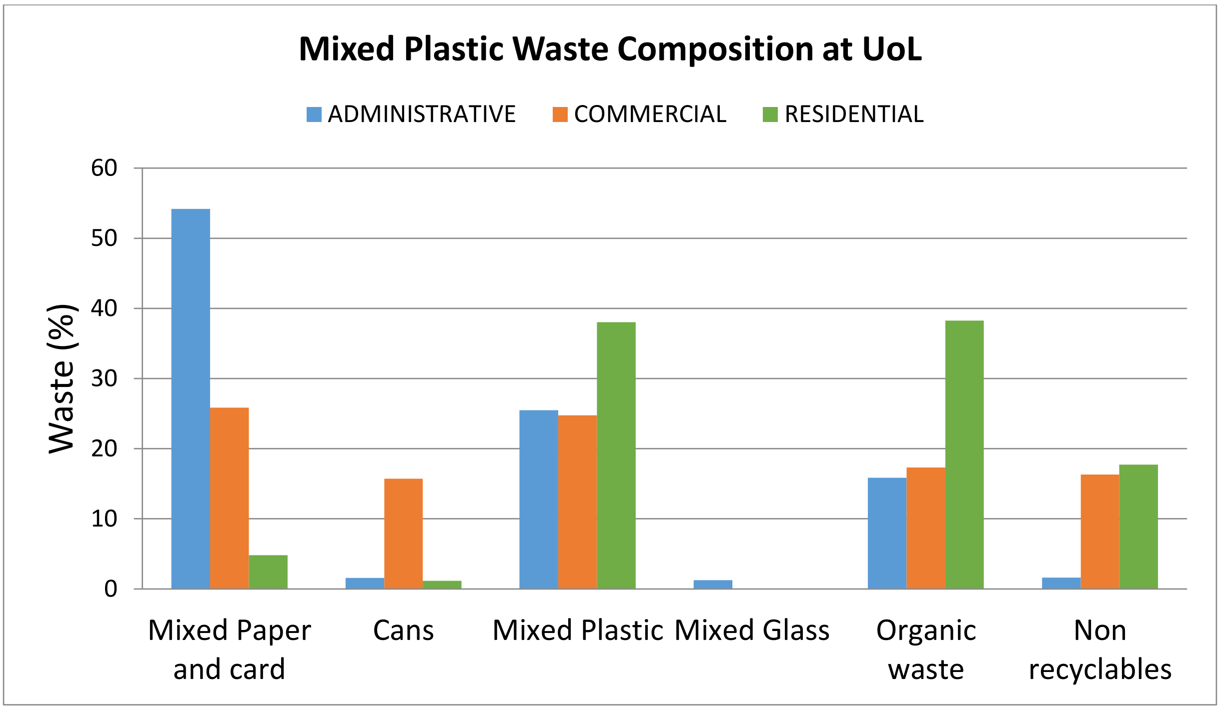


Figure 4.16: Waste composition of the green bin (mixed plastic) samples from the administrative (24.2 kg), commercial (33.1 kg) and residential (4.3 kg) waste generating areas in Akoka Campus, University of Lagos.

4.3.5.3. Red Bins designated for Can recycling at UoL:

As can be seen in Figure 4.17, very little target material was found in the red can waste bin samples from the administrative and commercial areas (1% and 2% respectively);

there were no red bins present in the residential area because this area is expected to dispose of its wastes in black bin bags, hence, there were no results for the red bins. However, blue, and green bins were found in the residential area, there from the residents desired to have solid waste bins. The largest contaminant of the red bins in both the administrative and commercial areas was mixed plastic, at 93% and 33%, respectively. A sizeable constituent of the commercial red bin waste was mixed paper and card (24%) and organic (22%) waste; the administrative area had minimal organic waste (3%). As with the other recyclable streams, minimal glass and non-recyclable material was found (1-13%). Additionally, despite not being a waste stream under investigation, approximately 5 kg of electrical waste (primarily electrical wires) was found in a red bin from the commercial area during the waste audit.

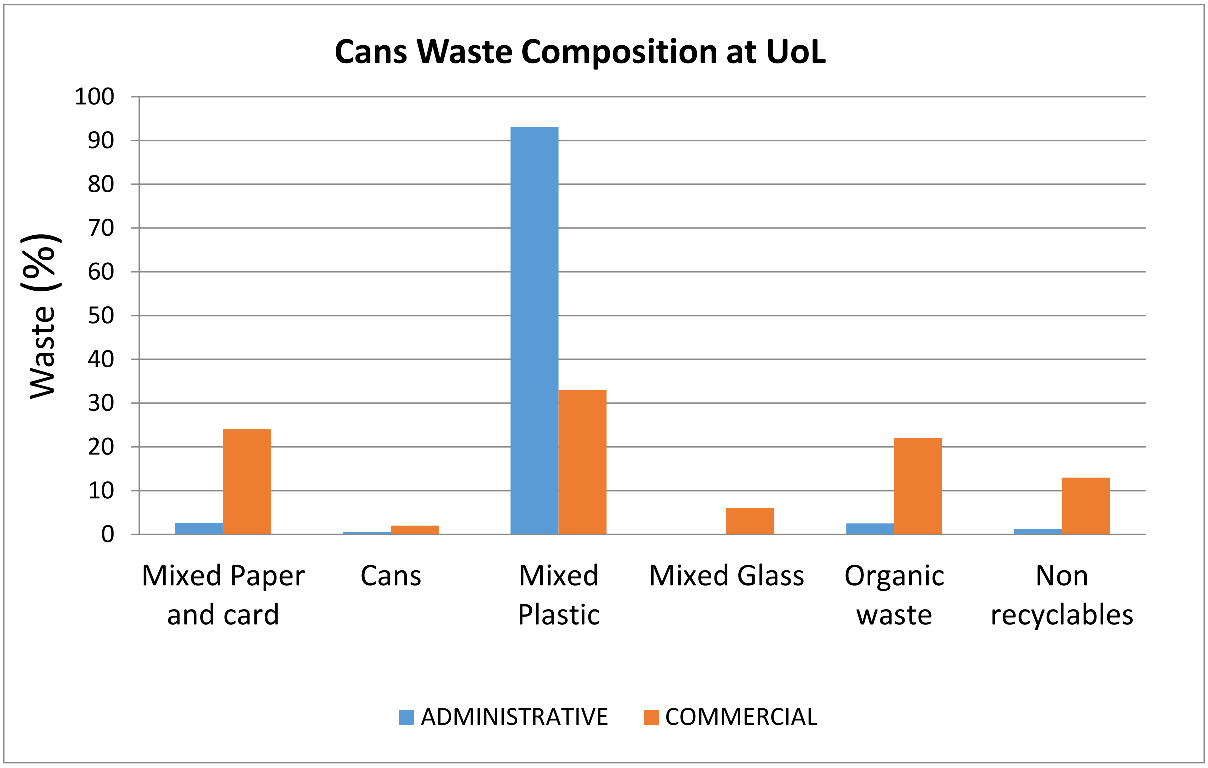


Figure 4.17: Waste composition of red colour bin (cans) samples from the administrative (9.2 kg) and commercial (8.6 kg) waste generating areas of Akoka Campus, University of Lagos; no red bins were present in the residential areas.

4.3.6. Contamination of the recycling program bins at UoS:

Like the investigation of the efficiency of the recycling system at UoL, an evaluation of UoS was also undertaken. While the UoL looked at 3 waste generating areas (administrative, commercial, and residential areas), the UoS only looked at two waste generating areas which are only the administrative and commercial areas. The residential area was not considered as it was outside the UoS vicinity, and permission was not given to cover that residential area.

4.3.6.1: Blue bins designated for mixed paper recycling at UoS:

The blue bins are for collecting mixed paper, anything that was not paper was a contaminant in this stream. After segregating the target materials from the administrative area, the largest contaminant category found was non-recyclable waste, at 15%, while the smallest contaminant in this stream was organic waste (3%). Similar to the above, in the commercial area, the biggest contamination issue came from non-recyclable material that made up 63% of the waste, while mixed paper, being the targeted waste category, only made up 37% of the waste composition in the commercial area, but was 77% at the administrative area; there was no contamination from other waste categories as shown Figure 4.18. The non-recyclables in blue bins (Figure 4.18) included non-paper and recyclable materials, for example foils, coffee cups, tissues, laminated films, food waste etc., suggesting poor user awareness which further implies people do not know what goes where, so, there is clear need for targeted recycling education on mixed paper recycling.

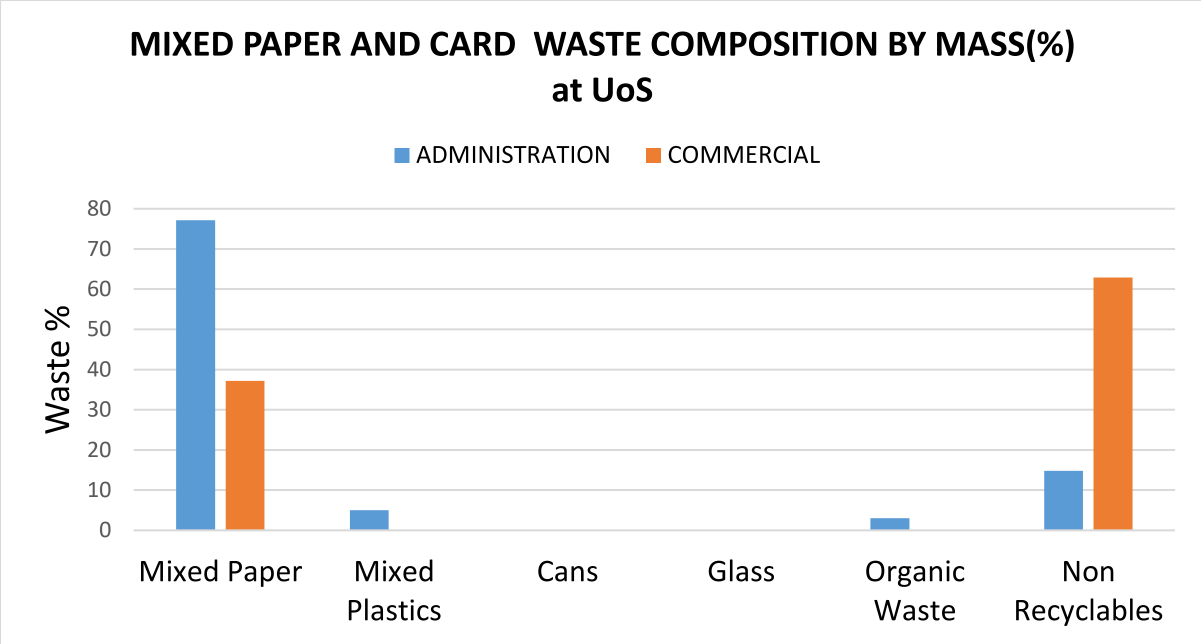


Figure 4.18: Waste composition of blue colour bin (mixed paper and cards) samples from the administrative (10.8 kg) and commercial (0.7 kg) waste generating areas of University of Strathclyde.

4.3.6.2. Green bins designated for mixed plastic recycling at UoS:

More than half of the waste collected from the administrative and commercial green bin samples, which are bins for recycling mixed plastic, was target material. Fifty-three percent of the material in the green bins from either area was plastic. Most of the contaminated waste in the administrative and commercial green bins was from non-recyclable material, at 32% and 44%, respectively. Mixed paper made up 12% of the non-target material in the administrative green bin samples. Organic waste made up 2% of the contaminants from the two areas. The amount of mixed paper in the green bin at the commercial area was only 1%.

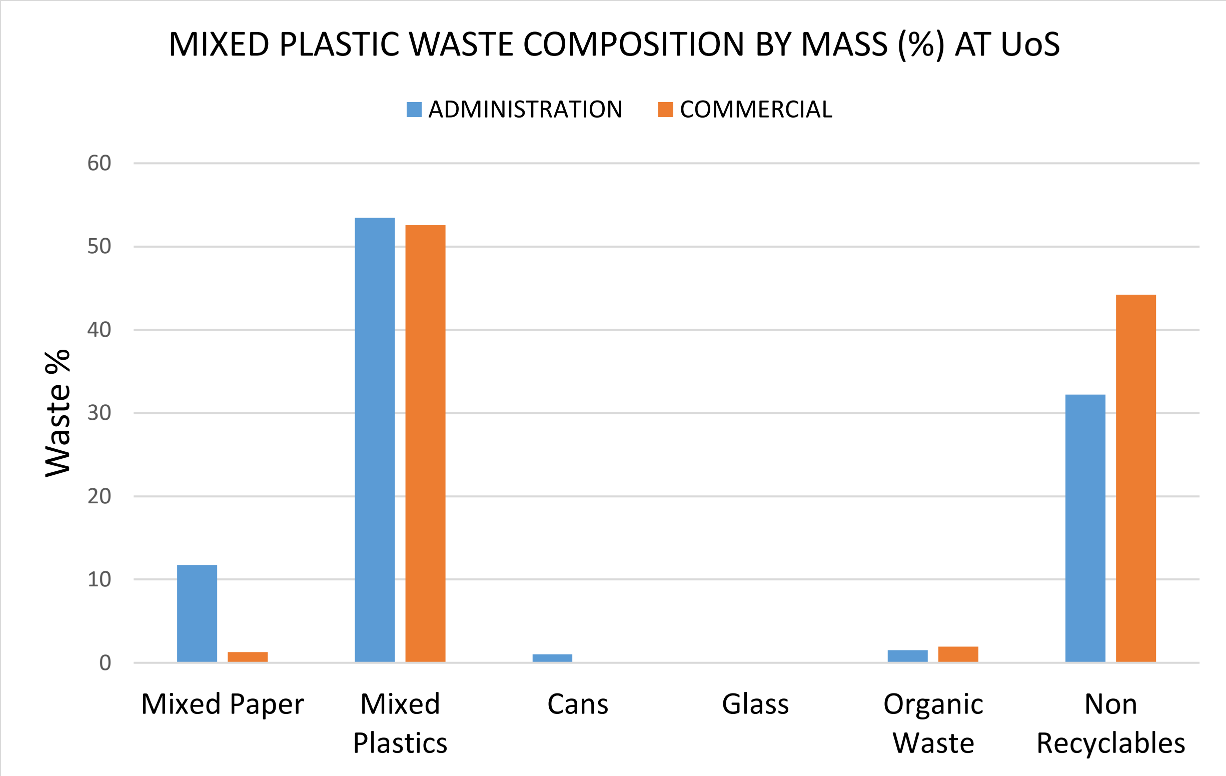


Figure 4.19: Waste composition of green colour bin (mixed plastic) samples from the administrative (5.9 kg) and commercial (1.6 kg) waste generating areas of University of Strathclyde.

4.3.6.1. Red bins designated for recycling Cans at UoS.

The biggest contaminant in the red bin waste samples, which is expected to receive only cans from the administrative area was mixed paper, which made up 46% of the waste (Figure 4.20), while mixed plastic and non-recyclables made up about a fifth of this stream. In the commercial area, the biggest contaminant was non-recyclables, which made up 58% of the waste (Figure 4.20) while mixed plastic made up a further 31%, and mixed paper made up the rest (11%) in the same commercial area. During the waste audit, no glass was found, but there was 6% of organic waste in the administrative area.

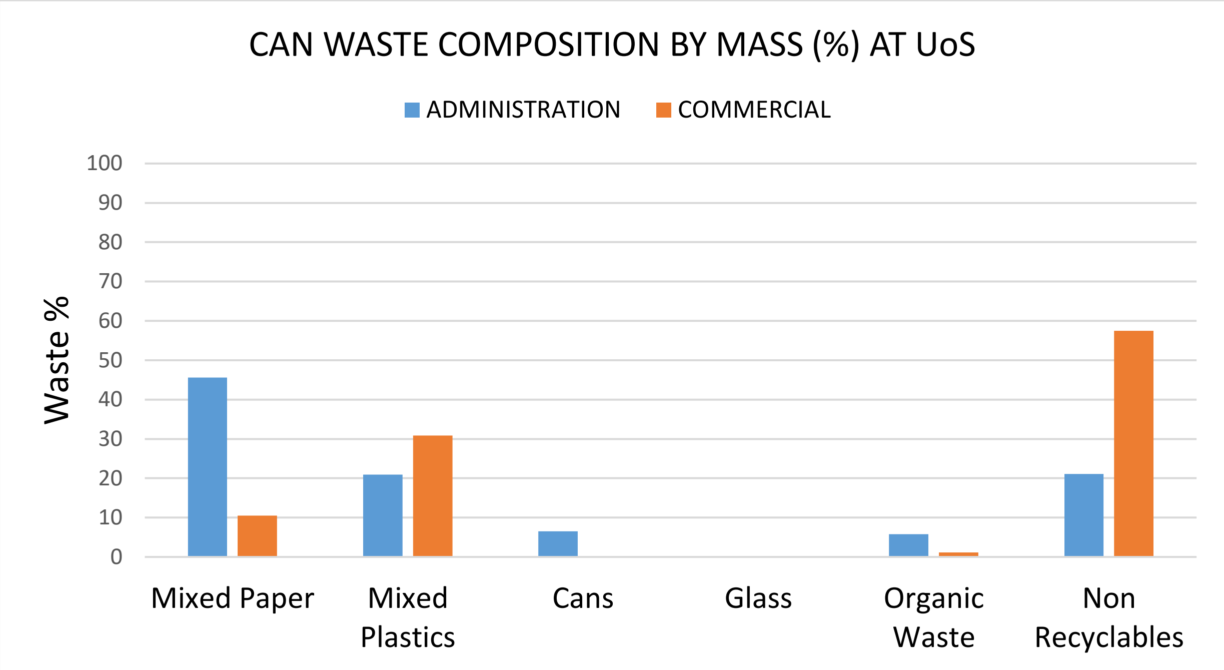


Figure 4.20: Waste composition of blue colour bin (mixed paper and cards) samples from the administrative (20.4 kg) and commercial (2.7 kg) waste generating areas of University of Strathclyde.

4.4. Data Analysis:

For the UoL data, the One Way ANOVA result showed that across the 3 waste generating areas (administrative, commercial and residential areas) no significant difference was found in the waste composition in the blue mixed paper bin samples ($p=0.507$), when the mean of the mixed paper composition was compared to the mean of the five classified contaminants in the blue mixed paper bin. Same goes for the green mixed plastic bin ($p=0.539$), when the mean of the mixed plastic composition was compared to the mean of other contaminants in the mixed plastic bin. More so, the same applies to the red cans bin samples ($p=0.474$), when the mean of the red cans was compared to the mean of other contaminants in the red cans bin across the waste generating area, respectively. This suggests people on campus are using all bins regardless of colour as general waste bins, and they are not segregating their waste properly, resulting in low material recovery from the waste (see Supplementary 4.5).

Similarly, the One Way ANOVA result for UoS showed that across the 2 waste generating areas (administrative and commercial areas) no significant difference was found in the waste composition of the blue mixed paper bin samples (p=0.218), when the mean of the mixed paper composition was compared to the mean of the five classified contaminants in the blue mixed paper bin. Same applies to the red cans bin samples (p=0.611), when the mean of the red cans was compared to the mean of other contaminants in the red cans bin across the waste generating area respectively (Supplementary 4.6). However, the green bin samples had p value of 0.000 hence, showing a significant difference when the mean was compared to that of the mean of other contaminants in the mixed plastic bin. This suggests that the green bin is being utilised as it should.

4.5. Discussion:

As part of the implementation of the 2014 waste management policy, the UoL introduced a recycling scheme, providing more than 800 coloured bins throughout the campus; blue, green, red, and black bins for collection of mixed paper, mixed plastic, cans, and general waste, respectively. Despite some success with waste infrastructure, *e.g.* the recycling centre, provision of waste bins, introduction of haulage trucks to transport wastes, etc., the university still faces challenges. Key challenges include the lack of efficient waste management that explores economic, as well as environmental benefits, from the waste generated; less than 1% of waste materials generated are being recovered at the university's recycling centre, while the rest is landfilled.

4.5.1. Temporal Waste Generation Pattern

The moving average helped to demonstrate the universities waste generation trend and capacity. In UoL, the moving average result shows a slight downward trending circular pattern over time, with the highest generation occurring between the months of March and May and the lowest occurring in July. This indicated a slight seasonal reduction in the university's waste generation (seasonality of university life) which may be because of the university's waste minimization campaign after the university introduced their waste management policy in 2014. Similarly, the UoS's moving average result also showed slightly negative trend in waste generation which indicates a slight reduction in waste generation over the period of the data collection (Figure 4.7). The highest waste generation occurred between the months of March and June, and the lowest generation often occurred between July and August within the data collection period. The periods of high waste generation are at times when there are more student activities on campus, *e.g.* during matriculation and graduation ceremonies, while the low waste generation periods are known to be the periods of low student activities. This concurs with Hoang (2005), who believes waste generation depends on external factor such as season. Taghizadeh *et al.,* (2012), on the other hand indicated that such seasonal variation is affected most during vacations in the university.

Furthermore, the forecast of the UoL also showed a downward trend of the waste generation for the forecasted period (2016 -2017). Forecasting the generation of waste is crucial for strategic planning and cost-effective budget allocation. Chalkias Lasaridi (2009) and O'Connor et al. (2013) found that more than 60% of waste management budgets are dedicated to waste collection and transportation. Thus, predicting waste generation allows for the optimisation of waste management systems, potentially resulting in reduced waste generation and lower waste collection and disposal costs. Furthermore, predicting waste generation helps in long-term infrastructure planning and resource allocation, especially during emergencies like disease outbreaks. Understanding waste capacity and predicting waste generation allow for proper planning in waste management (Ghysels, et al., 2006; Ghinea, et al., 2016; Kulisz, et al., 2020). More so, educational institutions are at the frontline of adopting strategies toward 'a greener campus' such as waste minimization and recycling (Ramachandra and Bachamanda 2007; Sharma and MCBean 2007; Ezeah *et al.,* 2015). This can be seen in the universities' demonstrations to implement their waste management policy where the universities have made provisions for waste segregation at source through their colour-coded waste bins placed at strategic places at the institutions, which ensures that waste is recycled other than been sent to landfill. There are simplified waste management campaigns during student inductions, via email that encourages staff and student to minimize printing of hard copies, minimizing the use of plastic water containers through the provision of water fountains within the university environment, especially at UoS (Figure 4.21), as well as providing coloured labelled waste bins across the universities to encourage recycling of waste material. However, more effort is still needed to sustain the downward trend to encourage environmental sustainability.

Figure 4.21: Water fountain at the University of Strathclyde.

4.5.1.2. Validation of Regression Result

The slope and intercept of the known Y and X variables were assessed using Excel software, resulting in the same values, confirming the regression model. The coefficient of determination was applied to the predicted data to assess the proportion of total variance in the dataset. This method has been utilised in previous studies to validate statistical findings (Bryhn et al., 2011), and the better fit of the regression model was determined. If the R-square is equal to or greater than 0.6 ($r^2 \geq 0.65$), the outcome is considered relevant (Bryhn et al., 2011). However, relying solely on this criterion may obscure the understanding of the relationship's direction (Akoglu, 2018; Schober et al., 2018). The initial prediction of y yielded a coefficient of determination r^2 of 1 and a correlation coefficient, r of 1, indicating a perfect correlation of 100%.

The seasonally adjusted trend estimate displayed a coefficient of determination (r^2) of 0.9 and a correlation coefficient I of 0.9. The results show a significant correlation for both the R and R^2 values. The r value indicates the strength of the linear relationship in the data, showing a strong positive correlation as interpreted by Akoglu (2018). However, obtaining additional real-time data over a period can improve the robustness of data evaluation for the seasonal index, thereby enhancing the accuracy of predictions. The results are important for implementing sustainable waste management strategies by using them to improve waste management plans, develop infrastructure, and enhance recycling efforts. They can be combined with the findings of Adeniran *et al* (2017) and Mbama *et al*, (2023), and potentially used to allocate resources effectively for sustainable waste management practices in the case study area and similar institutions.

4.5.2. Waste Audit

The results from the waste characterisation study suggest that 88% of the UoL waste could be diverted from landfill; 30% is organic material that could be composted, and the rest has the potential to be recycled (Figure 4.8). At UoS, the results indicate that 69% of waste could be diverted from landfill (Figure 4.10), of which 7% of its organic waste could be diverted to anaerobic digestion and the rest recycled. In actuality all of UoS's waste is diverted from landfill, whereas UoL still sends 99% of its waste to landfill. These waste audit findings are similar to those of Adeniran *et al,* (2017) who also investigated waste management at UoL, and showed recycling potential in 75% of the waste generated, and in-line with similar studies on waste streams at HEIs. Smyth et al., (2010) found that about 70% by weight of the University of Northern British Columbia (UNBC) waste stream could potentially diverted from landfill to recycling, composting, anaerobic digestion, or incineration for energy recovery. Furthermore, Ezeah *et at*., (2015) and Taghizadeh et al., (2012) confirmed that over 80% of waste from University of Wolverhampton and University of Tabriz, respectively, could be managed through other waste management approaches rather than landfilling of such waste.

Organic (30%), mixed plastic (28%), and mixed paper (24%) wastes represented the highest proportion of compostable and recyclable materials of all waste sampled at UoL (Figure 4.8), whereas mixed paper (39%), non-recyclable (31%), and mixed plastic (21%), waste represented the highest proportion of all waste sampled at UoS. (Figure 4.10).

These results varied from the findings of Smyth et al., (2010), of which mixed paper and card at 29% represented the highest proportion of the UNBC campus waste, followed by non-recyclables (28%), and organic materials (22%). This could be due to geographical and cultural differences, as both have been found to be factors influencing waste composition (Mihai, 2012). The current findings highlight the three major waste streams that could be recovered from the UoL are plastics, paper, and organic waste, as they show their prevalence among the waste stream, but the UoS should focus on paper, plastics, and non-recyclables for sustainable waste management, as the above are prevalent among the university's waste streams. These streams have also been highlighted in the literature as being the main waste streams identified in Higher Education Institutions (Armijo de Vege *et al*., 2008; Smyth *et al.,* 2010; Taghizadeh *et al.,* 2012).

Non-recyclable material, to be disposed of either through incineration or landfilling, made up about 12% of the waste across the case study at, UoL, a value almost half that was found by Adeniran et al (2017) at the same campus. While this study only sampled waste from Zones A and B on campus, Adeniran and colleagues (2017) sampled from all 4 campus zones, which will have increased the number of samples from residential structures, and may explain the difference found in residual waste material, as residential areas, under the current official recycling policy, these areas have no coloured recycling bins. Meanwhile, non-recyclable materials made up about 31% of the waste across the UoS case study area, a value like that found by Adeniran et al., (2017) at UoL. This waste stream is the second largest waste stream in UoS campus probably because of the students' dependence on packaged food items and food containers which are stained with oil, hence, hard to be recycled. There was a high volume of organic waste generated in all three areas of activity on campus at UoL; of this 43% came from the commercial area which can be attributed to the nature of business in that area, for example, this is where many cafeterias and canteens are located. While the organic waste was 7% in the overall waste composition (Figure 4.10) at UoS, the majority of which also came from the commercial area. Organic material has the potential to generate methane when deposited long term, for example as it is in the UoL recycling centre before sorting, as opposed to UoS that has its waste processed at the contractor's waste facility outside the university environment. When organic waste accumulates for a time, it begins to produce methane, which raises environmental risks like the possibility of a fire during hot weather. It is common for accidental fires to start at the UOL site. Such fires can affect waste materials at the recycling centre which are yet to be sorted, destroying any economic value that could be extracted from these materials.

Mixed plastic waste accounted for approximately 28% of the total waste stream, making it the second largest stream in the study areas at UoL (Figure 4.8), while 21% accounted for same at UoS, making it the third largest waste stream in the study area. The high proportion of mixed plastic could be attributed to the high dependence of staff and students on plastic packaged food and drinks, especially sachet water at UoL which is seen by students as an affordable and good source of portable water. At UoL, there was a lower composition of paper (24%) as compared with plastic, which may be attributed to the study being carried out during vacation period when learning activities are reduced. However, at UoS, mixed paper at 39% was the highest waste composition, this shows that there is need to intensify the university efforts to creating awareness on waste reduction, reuse, and recycling. Although, UoS has been putting effort to reduce the use of hard copy paper printed materials, by reusing single side printed papers for notes as well as to-do lists, returning junk mails using return to sender stickers etc (UoS, 2022), in order to enhance environmental sustainability, it is expected that the university will experience a reduction in the level of mixed paper in the waste stream at UoS. More so, the high level of mixed paper and plastic agreed to the values which were suggested from other literature. For example, research shows that 50 to 90% of solid waste generated within HEIs are mostly mixed paper, mixes plastic and food waste which could be recycled and/or composted (Armijo de Vega *et al*., 2008; Baldwin and Dripps 2012), Mixed glass and cans made up the lowest portion of the waste stream (less than 5%) at the two case study sites, suggesting low usage of such materials within each campus.

Although not an official category used in this study, 5 kg of electrical waste (e-waste) was identified during the audit at UoL, this was not mirrored at UoS. The presence of e-waste in the waste stream is dangerous due to the environmental and health impact of such waste (Orlin and Guan 2016). For example, if e-waste is burnt, it can release carcinogenic by-products such as polyhalogenated dioxin and furan chemicals because of incomplete combustion of the e-waste *e.g*. incineration of electric wires, computer monitors, phones *etc.* under low temperature produce such by-products (Wong *et al*., 2007; Perkins *et al.,* 2014).

Contamination (non-target material) in coloured recycling bins across the two campuses remains a big challenge. The high level of contamination found indicates that staff and students are not engaging with the recycling system at both UoL and UoS. This investigation has shown that the University of Lagos has a recycling policy that should encourage more waste material recovery from the major waste streams, yet waste is collected together by the haulage unit, irrespective of the waste streams, and stakeholder's (staff, students, and visitors) engagement in recycling does not align with the university's overall recycling strategy. Same is applicable to UoS that has good recycling policy which is not adequately followed or observed by the staff and students at the university, resulting to contamination of the targeted waste streams.

The output method and activities approach were used in the current study for the waste audit with seven auditors at both UoL and UoS (Figure 4.22 and Table 4.1). However, another method that could be used for an audit is the back-end approach (CCME, 1996; Ramachandra and Bachamanda 2007), which measures organisational waste, without considering how such waste or recyclable materials are generated within institutional activity areas. Such methodology is good for assessing general waste, hence, may be more applicable to waste audits at landfill sites, conversion facilities, waste processing centres or transfer stations (Abylkhani et al., 2021). The activities approach methodology was used in this research due to its effectiveness in understanding the variation of waste across activity areas, which could ultimately be targeted individually for waste reduction and enhancing efficiency in material recovery (Ramachandra and Bachamanda 2007; Smyth, 2008, Smyth *et al.,* 2010), and has been commonly used previously for waste composition assessment in HEIs (Felder *et al* 2001; Smyth *et al.,* 2010; Baldwin and Dripps 2012; Ezeah *et al.,* 2015).

Figure 4.22. Cross section of waste auditors during waste characterization exercise at University of Lagos.

Based on the waste composition analysis, the two universities can not only recover/recycle waste, *e.g*. the volume of mixed plastic and paper has high recycling potential, but also to reduce and reuse (the 3 Rs of waste management) more waste. Although the 3Rs are a voluntary approach to the waste management (Siwaporn et al., 2017), they would encourage efficient waste minimization at the UoL e.g. if drinking quality water fountains were installed by the UoL, this would minimise the use of 'nylon' sachet water and plastic bottled water, thus preventing generation of these waste materials. Also, a charge for single-use plastic bags would be another way to cut down on the amount of plastic waste, especially carrier bags in Nigeria, as this is already the case in Scotland. This could be implemented on campus to minimise such usage in favour of re-useable bags. Schemes such as this have been successful in western countries like the United Kingdom, resulting in an 81% reduction in the volume of single-use bags distributed between 2010 to 2012, also bag usage per capita per month decreased from 9.7 plastic bags in 2010, to 1.8 bags in 2012 (Thomas *et al.,* 2016; Poortinga *et al.,* 2016). Such measures could be adopted nationwide in developing countries to enhance behavioural change (Siwaporn *et al.,* 2017). There is potential compromise of the accuracy in data and collection through informal recycling by staff, students and scavengers which diverts waste. While this informal recycling helps to generate revenue for them, it creates problem of inaccuracy in data collection. More so, is the safety risks whereby the scavengers are exposing themselves to hazardous waste when they pick some of these waste without personal protective equipment. Furthermore, when there is potential financial losses due to the informal recycling (as they normally crash prices of the material just to quickly get money to feed) that potentially affect the recyclable pricing for the formal sector unless prices are subsidized for the formal system (Hinchliffe et al., 2011; Williams et al., 2013).

Meanwhile, the UoS incineration reduces waste volume and most importantly diverts landfill waste, however, such a treatment approach emits CO2, NO2 and other particulates. Nowadays, modern waste facilities like in Glasgow, come with flu-gas cleaning which potentially reduce pollutants when compared to the uncontrolled burning of waste, which further ensures that final emission comply with environmental regulations, hence, reducing it's negative impacts on climate change (Guendehou, et al., 2006; Lee et al, 2020).

4.5.3. Data Analysis and Contamination:

The One Way ANOVA shows no significant difference in the waste samples from the blue, green and red bins across the waste generating areas at UoL when the mean of the targeted waste stream is compared to the mean of the five contaminant waste streams in the bins across the 3 waste generating area, indicating that there was no proper segregation of materials in these coloured bins. This suggests that people on campus uses all bins regardless of colour as general waste bins, and they are not segregating their waste properly, resulting in low material recovery from the waste. This will increase the environmental and economic cost of the management process, for example in the UoL, 99% of the total waste generated is never recovered but sent to landfill. Also, revenue that could be generated through marketing of high-quality recovered waste materials is lost. However, when this was compared with UoS in the same way, the One Way ANOVA result for UoS showed that there was no significant difference between the waste composition of the waste bins (blue paper bin, red can bin), except for the green plastic waste bin, when the mean of the waste bin composition were compared to the mean of the five classified contaminants on each of the waste bin, which suggests that only the green bin is properly used, which could be that it is easier just to dispose of plastic bottles which is probably the bulk of the waste, however, more effort is needed to enhance proper bin use. The high level of contamination found at UoS still indicates that staff and students are not fully engaging with the recycling system. This investigation has shown that the UoS has a good recycling policy, but stakeholder's (staff, students, and visitors) engagement in recycling does not still align with the university's overall recycling strategy. Further comparison of the two cases, shows that UoL landfill practice has a distinctive impact, as landfill is known as the major waste management practice that enhances the emission of greenhouse gases which exacerbates climate change. According to research, waste management contributes to about 5% of the global greenhouse emission, of which its deleterious effect cannot be overemphasized (Turner *et al.,* 2015; Kristanto et al., 2020).

To enhance the quality of the recyclable material that could be recovered, it is imperative to increase awareness of proper usage of coloured bins to enable segregation of organic waste (Dana, 2011), thereby minimizing contamination of other waste streams, i.e. paper, plastics, with organic material which would reduce quality. There is potential to increase the recycling rate through source segregation by staff and students, which would also reduce the amount of time and man-power used to separate waste at the UoL recycling centre. More so, it could help the university re-negotiate with the waste management contractors, as the amount of their time and labour could also be reduced, thus providing the university with further economic savings.

Recycling policy must be enforced to ensure high-quality recyclable materials of economic value are recovered, as suggested by Armijo de Vega, et al., (2008). Currently, the research finding shows that less than 1% of materials are still recovered at UoL, which could potentially be due to the lack of engagement with the recycling policy. The materials that are recovered are often manually sorted at the university's recycling centre after collection and having less than 10 staff at the UoL recycling centre results in poor material recovery rate. If source segregation is enhanced, more revenue could potentially be generated, saving time and more productive target met. An effective campaigns strategy should include the simplification of bin-signages, feedback-based interventions like tagging educational or awareness note on contaminated bins (Kaufman et al., 2020). The use of waste apps could provide real time disposal guidance, which has been used to increase more awareness and recycling participation (Jane, 2025).

At UoS, 100% of their materials are recovered either through recycling, anaerobic digestion, and incineration.

Research has found that some staff members of the UoL are engaged in unauthorized waste recycling on campus (Adeniran *et al*., 2017), while waste pickers/scavangers also enter the campus and undertake unofficial recycling from university waste. To ensure that revenue potential from waste materials is returned to the university, there not only needs to be enforcement of the recycling policy, but control mechanisms in place to prevent unoffical recycling of campus waste materials both at individual or departmental level *i.e.* recycling of waste by individuals or department other than university's authorized waste contractors. Recycling can enhance environmental sustainability as it encourages resource longevity, while incineration can help to recover energy from waste which could be used to power homes, among others.

The waste audit results showed that organic wastes are the largest waste stream generated at the UoL, which suggests that biological treatment methods such as anaerobic digestion (AD) or composting may be viable management options for UoL. AD has the advantage of not only generating energy through production of methane, but also fertilizer could be created from relatively small-scale facilities (Intharathirat *et al.*, 2016). One ton of organic waste has the potential to generate between 100 – 150 kWh of electricity (Braber, 1995). However, composting remains a good option for treating organic waste in developing countries to produce organic fertilizer considering the cost-effectiveness of setting up simple composting system, in addition to having the temperature advantage the weather provides (Jara-Samaniego *et al.,* 2017).

Composting of organic waste has successfully been implemented by HEIs in the treatment of solid biodegradable waste. For instance, Kean University (KU) in New Jersey, USA has been successfully running a compost system. The university generates 50 tons of waste annually of which over 70% (food/ organic waste) is usually composted; this has helped the university in diverting its organic wastes from landfill (Mu *et al.,* 2017). At UoL, collection of segregated organic material should be enforced as part of the recycling policy, with particular focus on the commercial areas *i.e.* cafeteria, and residential areas *i.e.* staff quarters, as these areas generates more organic waste (33% and 32%) respectively; as composted materials can be used to enhance crop productivity, revenue could be generated by selling on the compost (Mu *et al.,* 2017). Additionally, considering the UoL generates a lot of organic waste from their commercial area, centralized composting may be ideal, or even applying the 'pay as you throw' principle, and more awareness education. Compositing has been effective at Kean University (KU) in New Jersey, USA where over 70% of waste is composted, hence diverting it from landfill (Mu et al., 2017). More so, increasing awareness and using an approach like 'pay-as-you-throw' in school cafeterias could help to reduce food wastages; such a scheme has been successful at Utrecht

University, in the Netherlands (Desa et al., 2012; Aseto, 2016; Yale, 2019). Other methods include food-sharing apps, which can help to redistribute leftover foods. This has also been successfully applied at Stranford University in with partnership of ShareMeals (Pak, 2020).

For the UoS, it was found that food waste collection bins are not placed in most of the strategic areas; hence, food waste was the second largest contributor to the general waste bins even in the administrative area. For example, in the Graham Hills Building which did not have a food bin, food waste was the second largest component in the general bin, at 44%, while at James Weir (level 2), 14% of the general waste bin contained food waste. More so, in James Weir (level 5) it was observed that mixed paper was being disposed of in the general bin instead of using the appropriate coloured bin. At James Weir (administrative area) mixed paper (22%) was the second largest waste component in the general waste bin, while 16% was recorded for food waste in the library (level 2) of the commercial area, making it the second largest waste stream in that area. It would therefore seem beneficial for a small food waste bin to be provided in those areas that recorded high levels of food waste, e.g. James Weir level 2 and Library level 2. Some of these critical areas where students stay for a long time are important because most students cannot stay a long time without eating food, hence, could potentially generate food waste which could contaminate the other waste streams if they are disposed of in bins other than food waste bin.

Further more, the UoL result shows that the non-recyclable waste category makes up a small portion of the waste stream (12%) compared to other waste categories. Some energy recovery may be possible from this material via incineration, but this is not really a viable option as construction of energy recovery incinerators is expensive –

unless it could be shipped to a pre-existing facility, but transportation has environmental cost (Hamad *et al.,* 2014). The incineration of non-recyclable waste by the university is really a good move to enhance energy recovery from waste and at the same time reduce the volume of waste, which is far better, when compared with landfilling of wastes. Although landfilling of waste can be seen as a cost-effective waste management option for developing countries, it is last to be considered in the waste management hierarchy due to its high environmental impact (DEFRA, 2011). The UoS is more efficiency in their waste management policy implementation than UoL, this is evident in the installation of water fountains at most building at UoS that help to minimise plastic wastes. More so, the management of waste is contracted to a waste management company that manages the waste outside the UoS premises, even when some part of the waste is incinerated at an incinerator to recover energy from the waste, as there is no incineration without energy recovery in the UK due to the EU Waste Framework Directive, but at the UoL, the management of waste by its contracted waste management company is done within the university environment. This enhances environmental risk and exposures of the workers as well as the people within the waste treatment centre to risk. However, despite the UoS recycling everything and sending no waste to landfill, there is still no significant waste reduction, hence, highlighting a gap in waste prevention which is the main factor to consider in the waste heirarchy. This further suggests its policy has focused more on recycling and energy recovery which is the downstream management, rather than upstream management of waste reduction (de Sadeleer et al., 2020; Herbst and Barner 2024).

When the waste is burned as a result of may be natural process, e.g. due to excess methane generated which potentially reacts with high temperature resulting to the burning of the waste most time (Figure 4.23), it could emit some dangerous gaseous chemicals which exposes the people within the areas to great risk as observed at university of Lagos.

Figure 4.23. Burning of waste inside the University of Lagos recycling centre.

Efficient waste collection plays a key role in waste management, and this is particularly relevant where segregated wastes require separate collections for each stream. Therefore, there is need to collect coloured waste bins for different waste categories separately by the haulage unit to maximize recovery efficiency and waste pickups should happen more regularly. Research has shown that over 60% of waste management budgets are used for waste collection and transportation (Chalkias Lasaridi 2009; O'Connor *et al*., 2013), however much of this cost ends up in the payment of salaries and fuel. To minimize the cost of waste collection, it is essential that GIS routing of the UoL's activity areas is completed to identify the shortest route during waste collection to plan waste collection of different coloured bins efficiently.

Routing using GIS has been found to be an efficient and cost-effective approach in waste collections and transportation. For instance, it has been used in the past to optimize waste collection/bins positions at Sfax City, Tunisia (Kallel *et al*., 2016). Kallel and colleagues (2016) developed three optimal scenarios using an ArcGIS Network Analyst tool to compare with the system's base-scenario in order to understand and improve the efficiency of waste collection; the findings showed that up to 57% of time could be reduced and 48% of fuel consumption could be saved when waste collection was optimised (Kallel *et al*., 2016). For the University of Lagos, this could potentially reduce the cost of waste collection and transportation.

Raising awareness on the benefits of waste recycling can serve as a tool to increase stakeholders (academic and non-academic staff, students, and visitors) participation at both universities, UoL and UoS. Desa, et al., (2012) looked at environmental awareness and education as a key approach to solid waste management and found that awareness campaigns on inefficient recycling and communication strategy such as focusing on environmental education *i.e*. recycling, have proved to be beneficial and enhances wider participation in recycling (Desa, et al., 2012). More so, increasing knowledge-based campaigns on waste-related environmental and health issues can foster positive attitudinal change towards safe waste management practice (Mamady, 2016).

4.6. Conclusion:

This study investigated how recycling was done at two higher education institutions in a developing country and a developed country. The goal was to improve knowledge, which is needed for good and effective (sustainable) waste management practices in both case studies.

Results showed a slightly negative trend in waste generation, which indicates a slight reduction in waste generation in the UoL and UoS over the duration of the study. More so, results indicate that in both case studies, material recovery of organic waste, mixed plastic, and mixed paper would be profitable in the management approach, indicating more opportunity from these three waste categories. The level of contamination across coloured waste bins remains a big challenge despite the university's recycling policy and efforts to provide recycling facilities across the campus. The source segregation of the above three waste streams (organic, paper, and plastic) could be maximised, potentially to generate income for the waste contractors, thereby getting rebates or subsidised charges from the waste contractors in both case studies. In the management approach, there is greater opportunity to optimise recovery from these three waste streams at both UoL and UoS.

Staff and students are not following university policy with respect to discarding their waste material properly, as no significant difference was found between the waste compositions of the blue, green, and red bins in the waste generating areas in both case studies. If source separation could be maximized and waste collection and transportation routes optimised especially at UoL, they could potentially reduce the high environmental and economic cost of waste management for the university, as more revenue could be generated through marketing of recovered waste materials with less time, and fuel consumption by haulage trucks, thereby saving time and cost of waste management at the university. There is a need to provide organic waste bins for the collection of food waste in commercial areas in UoL and at the administrative area of UoS as well as where there is a presence of students because, when such bins are not available, people tend to use the ones that are available, thereby contaminating the targeted waste, as observed at UoL and UoS. The benefits of waste recycling are enormous, and revenue generated from the process becomes an economic gain that could potentially reduce the operational cost of the process in both case studies. Hence, a number of waste management options such as reduce, reuse, recycle, and compost could be explored, and most importantly, awareness could be created to understand the benefits of waste recycling, and enforcement could serve as a tool to increase stakeholders' (academic and non-academic staff, and students') participation at universities. Finally, there should be separate bins for organic waste materials at UoL, and more organic waste bins at UoS, while composting of such waste should be adopted at UoL, instead of sending it to landfills so that potential environmental risks, e.g., greenhouse gas (GHG) emissions, are minimised.

4.7. Recommendations:

An effective waste minimization strategy would be the installation of water fountains at strategic locations at the UoL, as can be found at the UoS, which reduces plastic wastes, especially water plastics, such as bottles or and sachets waste, which constitutes a high percentage of the waste component at the universities. This is because water is an essential liquid, which everyone consumes on a regular basis, and people rely so much on plastic bottle or sachet water as a good source of quality drinking water, especially in developing countries, generating waste in the process. When such water fountains are installed as a source of public drinking water, it will reduce the use of plastic waste.

Organic waste is one of the key waste streams generated at higher educational institutions and a major source of contamination for other waste streams. This requires that organic waste be source-segregated and either composted or digested in an anaerobic digester (AD) to recover energy (electricity) and fertiliser from the waste. Adopting campus composting of organic waste at UoL and using similar model of vermicomposting as in the case of Kean University, USA. Formalizing the informal recycling at UoL through buy back centres, which could enhance recycling efforts of the university. Another potential approach to recycling is to introduce Bin -e which automatically segregates waste at source, even though, it could be expensive.Finally, an awareness campaign on the benefits of waste recycling can serve as a tool to increase stakeholder (academic and non-academic staff, students, and visitors) participation at both universities. According to the findings of Desa et al. (2012), who investigated environmental awareness and education at higher educational institutions, it was found that such knowledge is one of the key approaches to solid waste management, and awareness campaigns on inefficient recycling and communication strategies such as focusing on environmental education have proved to be effective for wider participation in recycling (Desa et al., 2012). More so, according to Mamady (2016), increasing knowledge-based campaigns on waste-related environmental and health issues can also foster positive attitudinal change toward safe waste management practice.

CHAPTER 5

RISK AND COST BENEFITS ASSOCIATED WITH WASTE MANAGEMENT PRACTICE IN HIGHER EDUCATIONAL INSTITUTIONS IN NIGERIA AND SCOTLAND: A COMPARATIVE CASE STUDY

5.1. Overview:

The disposal of municipal solid waste into landfills remains the traditional waste management practise common across the globe due to its low cost (Hoornweg and Thomas 1999; Chen and Kao 2012). Landfill, however, remains the least preferred waste management option under the EU Waste Framework Directive's waste hierarchy, primarily due to the environmental risks associated with such practices, a key one being the release of greenhouse gases (GHG), e.g., CO_2, CH_4, and NO_2, which exacerbate climate change. While solid waste going into landfill sites in developed countries is on the decline, such waste sent into landfill sites in developing countries continues to be on the increase (Abdel-Shafy and Mansour 2018; Frith, 2022).

Solid waste management contributes to around 5% of the world's greenhouse gas emissions (Bogner et al., 2007), and the potential effects of these GHGs cannot be overemphasized. Research has shown that these emissions occur primarily because of the biodegradation of organic materials, especially in landfill sites, resulting in environmental pollution (Hoornweg and Thomas 1999). This growing concern about the effects of GHGs has led to the development of international policies and measures aimed at reducing emissions. The goal is to make the best use of limited resources to reduce GHG emissions (Hoornweg and Thomas 1999; Turner et al., 2011). On the other hand, reducing GHG emissions also requires cost effectiveness and a sustainable management approach, which makes choosing a sustainable project important as it implies having a project that is environmentally and financially viable. This type of economic consideration makes cost-benefit analysis (CBA) useful, in which projects or management options are quantifiably valued to make a better decision while also considering other alternatives (Begum et al., 2006; Atkinson and Mourato 2008). CBA considers options for whose benefits outweigh their costs.

In a waste management context, the goal of CBA is to investigate which solid waste management options (e.g., landfill and recycling) are cost-effective, while giving more consideration to the environmental risks associated with each of the waste management activities after disposal. Although the use of CBA for project appraisal has been criticized, many scholars continue to believe in its utility in evaluating economic efficiency in the use of scarce resources (Hanley, 2001).

Even though, according to the EU Waste Framework Directive's waste hierarchy, the recovery of recyclable materials is preferable to waste landfilling, there is a need to always evaluate the economic cost and the sustainability of any waste management recycling options (Ferronato et al., 2017) to know when such a system becomes financially and environmentally sustainable.

Due to the difficulties in monetary weighting intangibles, studies of cost-benefit analysis in waste management frequently do not incorporate environmental risks into the evaluation process (Da Cruz et al., 2014). The purpose of this research is to investigate the risks and cost benefits associated with waste management practises (landfilling versus recycling) at Higher Educational Institutions (HEI). The University of Lagos and the University of Strathclyde were used as case studies. HEIs were selected for this study as such institutions, by their nature, are good analogies for small municipalities; in addition, limited research has been completed in such a setting where cost and sustainability often clash and HEIs play key roles in achieving sustainable development (Acurio et al., 1997).

5.2. Methodology:

5.2.1. Case Study areas:

A description of the case study areas in both Nigeria, i.e. UoL, and Scotland, i.e. UoS, are provided in Sections 4.2.1 and 4.2.2 respectively. Refer to Chapter 4 for the data used for the further analysis in this Chapter. Only 1% of the UoL's 11,718 tonnes of annual solid waste is recycled or recovered; the rest is dumped in landfills. According to the results of a waste audit in Chapter 4 conducted within zones A and B, the two areas account for over 70% of the total daily generated waste, which includes 30% organic waste, 28% mixed plastic waste, and 24% mixed paper waste.

The UoS generates around 49 tonnes of waste per month. Before May 2013, some of the total monthly wastes at UoS were landfilled, some were recycled, and a small portion were sent for anaerobic digestion, this has now changed progressively and none of its waste is landfilled. The audit results from the James Weir, Graham, and Curran buildings show that the activities in these buildings contribute to the university's high amount of waste, which was 7% organic waste, 21% mixed plastic, and 39% mixed paper, making it the waste composition with the highest percentage in the study area (see Chapter 4 for details).

5.2.2. Cost Effectiveness:

Waste composition analysis was undertaken to understand and inform the best waste management approach to address the waste generated at both institutions (as discussed in Chapter 4). However, another barrier to appropriate waste management is understanding how economically viable a specific waste management approach could be in addressing the waste challenges, while also considering the environmental factors, e.g., the potential to reduce GHG emissions resulting from the waste management process (Hoornweg and Thomas 1999; Turner et al., 2011). The current investigation employed cost-benefit analysis (CBA) as a methodology to ascertain a measurable monetary worth for various waste management alternatives. The objective was to facilitate an informed decision-making process regarding the selection of an optimal waste management technique, with particular emphasis on the comparison between landfilling and recycling. These two options were chosen due to their prevalence and widespread support in the literature (Begum et al., 2006; Atkinson and Mourato 2008).

Within the context of waste management, the main goal of cost-benefit analysis (CBA) is to examine and evaluate the most economically efficient solid waste management alternatives, such as landfilling and recycling. This analysis also considers the risk to the environment associated with these waste management practises. Despite facing criticism, the application of cost-benefit analysis (CBA) in project appraisal has garnered substantial support in the literature, particularly in assessing economic efficiency within the context of limited resources (Hanley, 2001). Therefore, the economics of landfilling as a management practise in the case study areas was compared to recycling as an alternative option, while considering its greenhouse gas emissions impact, for sustainable waste management. Various management scenarios were examined by considering different combinations of several different management costs, and financial benefits in the operation of the current waste management practice to determine their economic feasibility. This would be demonstrated by a Cost-Benefit Analysis (CBA) that exhibits a positive Net Present Value (NPV), utilising the vertical lookup (VLOOKUP) tool in Excel software.

5.2.3. Data Analysis:

When quantifying greenhouse gas emissions from waste management activities (see section 4.3.1 of Chapter 4), calculations were made using values that consider the greenhouse gas potential of pollutants using emission factors. These values were used to estimate the quantity of pollutants associated with a specific activity by establishing a correlation between the activity and the resulting release of pollutants into the atmosphere. Emission factors refer to numerical values that have been documented in many sources, including the works of Forster et al. (2007), GCU (2014), the Glasgow City Council Councillors and Committee (GCCC) Report of 2015, and the National Atmospheric Emissions Inventory of 2016.

GHG emissions from the waste management practises (landfilling and recycling) at the case study areas were determined using standard emission factors produced by each waste practise (Cruz, 2014; Glasgow City Council Councillors and Committee Report, 2015); these are based on carbon dioxide equivalent (eCO_2) to assess emissions (see Table 5.1), while the VLOOKUP tool in Excel was used to examine the sensitivity of the potential economic viability associated with the waste management processes under investigation, i.e. recycling and landfilling. Accounting practitioners regard the VLOOKUP as a problem-solving and decision-support tool, and it is included as one of Excel's features (Bradbard et al., 2014).

This study employed the CBA methodology of Begum et al. (2006), which evaluated the economic feasibility of a specifically defined process using estimated Net Benefits (NB) of the project, as shown in Hutchinson (2017) , from which the Net Present Value (NPV) of the project can be determined to know how financially viable the project is, while taking into account some intangible costs and benefits of the project, such as the gass emission's cost-effects on the project.

NPV shows whether a management system is economically sound from a financial point of view. For example, when NPV is less than zero (NPV < 0), such a project would be deemed unacceptable because it demonstrates that such a process is not economically viable. When NPV is equal to zero (NPV = 0), such a project might be considered, depending on the overall aim of the process, because at zero NPV, the process is still not yielding any monetary value. However, it could potentially address a problem, for example, in government projects. The NPVs were further analysed using VLOOKUP, which is a tool in Excel software that serves as a problem-solving and decision-support tool that looks at conditional formats that depend on defined criteria for selecting different combinations of variables to get a desired value or output (Bernard et al., 2009).

In this case, 625 scenarios for 125 combinations of five (5) different variables (percentage of recycling targets, cost of waste haulage, cost of sorting waste, waste reduction targets, and the NPV) were analysed to understand the viability of each scenario to get a positive NPV. The above variables have a significant effect on the overall profitability of the management process. For instance, when the cost of waste haulage is high based on fuel costs or regular collection, that could potentially affect the overall NPV. More so, the cost of sorting waste can increase the cost of management, which could also potentially affect the NPV negatively. The reduction target can also have an impact on the NPV in the CBA, either positively or negatively; thus, the use of the VLOOKUP tool to assess additional better combinations that could result in a positive NPV. The Hutchinson (2017) equation below was used to assess the cost-benefits of the management practises in the case study areas:

$$NB = TB - TC \quad \text{(Equation 1)}$$

Where,
NB is the net benefits
TB is the total benefit
TC is the total cost

The total benefits of the project include all the direct, indirect, and intangible benefits i.e. all the advantages of using a particular management approach which is expressed in Equation 2:

$$TB = RSM + CSCT + A \quad \text{(Equation 2)}$$

Where,
TB = total benefit
RSM = Revenue generation from selling of sorted material
CSCT = waste collection and transportation cost savings by recycling materials
A = intangible benefit of programme

While total cost is the overall cost associated in the management option, which includes the direct, indirect, and environmental cost (intangible cost). This is expressed in Equation 3 as shown below.

$$TC = CSC + EC + SC + A \quad \text{(Equation 3)}$$

Were,
TC = total costs of waste management option
CSC = collection and separation costs of construction waste management option
EPC = equipment purchasing co
SC = the storage cost
TC = transportation cost
A = intangible costs.

5.2.4. Economic Evaluation:

In this research, economic evaluation of environmental factors was used to measure environmental risks associated with the waste management processes or activities (Fankhauser, 1994). Such evaluations measure the values of environmental factors, e.g., pollution in air, water, and land, which are difficult to measure during any economic decision-making process. This technique considers assigning measurable weighted values to some environmental impacts that normally cannot be measured in terms of monetary value because they are not physically tangible. Such subjective weighting enables comparisons to be made (Pearce, 1994). Powell et al. (1996) argued that there has not been a fully established set of valuations or weighting methodology that is an accurate set of economic valuation; however, Fankhauser (1994), cited in Powell (1996), has been able to calculate the impact of expected values of principal greenhouse gases (CO_2, CH_4, and N_2O). The Fankhauser (1994) economic weighted values are adopted in this study (Fankhauser, 1994; Meyer and Cooper 1995; Downing et al., 2005).

5.2.5. Assumptions:

The Fankhauser (1994) economic weighted values are used here to figure out how the main greenhouse gases affect the environment (CO_2, CH_4, and N_2O). The expected value of the risks from the three main GHGs is £0.4/kg for CO_2, £7.2/kg for CH_4, and £61.4/kg for N_2O. All these risks have been added up to £69 per kg of GHGs (£69,000 per tonne), which is the total weighted risk of GHGs in the waste management process.

The loss of economic value and environmental benefits of recyclable materials (Figure 5.1) due to wastes being dumped has been estimated based on the value of the revenue for such recyclable materials at Nigeria standard market price in 2016 which are £0.04 and £0.06 / kg for plastic and paper wastes respectively (based on researcher's market survey and interview of the landfill operators/ scavengers during data collection in 2016, see Table 5.1. and Appendix 4.2), while taking the waste audit result for the two major recyclable waste category (plastic (PET or code 1 and LDPE or code 3) and mixed paper and card (from Chapter 4). The waste audit result showed that other types of waste made up a small part of the waste stream, so they were not considered in this assumption. Other assumptions were made in other to evaluate the cost benefits of the current waste management practice at UoL and UoS, including the assumption of identical unit costs for waste haulage (£10/tonne) and for waste sorting/recycling (£64/tonne) for both case studies, which is to deliberately simplify the model in order to compare the structural differences in their management practices (like benefit streams and model output) allowing differences in the overall cost benefit result that reflect the institutional and systemic factors rather than absolute local price distortions (Shand and Bowden, 2021). This is in line with the "ingredient" approach to comparative costing and comparability across context (Shand and Bowden 2021). However, in reality, variables like waste haulage and sorting cost vary substantially due to factors such as distance, labour, vehicle efficiency, technology approach etc (Van Camp, 2024), hence, adopting common value remains a better approach when evaluating the structural system efficiency and not for absolute costing (Olukanni, 2018), after which sensitivity testing of different variables to further understand the NPV is conducted, confirming that comparative conclusions are not totally dependent on the equal cost assumption (Ryder, 2009; Razvi et al., 2021).

This means any negative NPV will then require further sensitivity analysis to evaluate different variables that could potentially result to a positive NPV.

In the context of waste management, economic value is measured by the level of a hypothetical target that is expected and has its own environmental issues or effects. In this case, the normal issue is greenhouse gases (GHGs), which worsen climate change, which leads to global warming. More so, the overall cost of waste haulage is determined by adding the charges for waste collection and transportation, which are estimated based on the anticipated costs of fuel and maintenance services for waste haulage vehicles. This cost is charged per tonnage. It is expected that the contractual cost of waste transportation and material recovery will remain constant over time. The pricing for selling segregated recyclable materials, such as mixed plastics and mixed paper waste, was calculated by the prevailing market rates for these kinds of materials in the Lagos State market during data collection as shown in Table 5.1.

Table 5.1: *Waste Management Scenarios for UoL and UoS with their Associated Costs (based on the year 2016):*

S/N	Variable	University of Lagos (UoL)	University of Strathclyde (UoS)	Source
1	Waste recycling rate	1%	100% (as 0% of waste is landfilled)	Institutional data (between 2015 – 2018)
2	Market price of plastic/ ton (£))	40	95	Researcher's survey (Lagos, 2016) and WRAP UK (2016)
3	Market price of paper/tonne (£)	60	65	Researcher's survey (Lagos, 2016) and WRAP UK (2016)
4	Emission cost per (tonne) -CO2, CH4, and N2O (£)	69,000	69,000	Fankhauser (1994); The same weight applied to both, but actual emissions differ
5	Cost of sorting waste per tonne £	64	64	Contractor's interview/ assumption for UoL) and UoS Estates data (2016)
6	Cost of haulage/ tonne (£)	10	10	Contractor's interview/ assumption for UoL) and UoS Estates data (2016) for collection/ fuel cost/ maintenance
7	Emission factor for material (mixed) recycling	21.	21	Cruz. (2014) and *Glasgow City Council Councillors and Committee* (2015)
8	Emission factor for refuse commercial and industrial to Landfill (kg CO2e/t)	199	199, but reduced to 0 (as 100% waste is diverted)	Contractor's interview, Cruz. (2014) and GCCC (2015)
9	The opportunity cost (the lost recyclables) (£/ t)	High (cost of non-recycled waste/ landfilled)	Low/negligible (due too the high diversion rate)	Researcher's survey (Lagos, 2016)

5.3. Results:

There is huge progress on improving waste management at the University of Strathclyde. Out of an estimated 49 tonnes of monthly waste generated by the University of Strathclyde before May 2013, about 12.36% (6.0 tonnes) of the total monthly wastes was landfilled, 86.27% (42.2 tonnes) was recycled, and a small portion (1.37% (0.7 tonnes) was sent for anaerobic digestion (mostly biodegradable waste materials), resulting in the university's total waste diverted from landfill per month being 87.6%, approximately 43 tonnes). However, the record has changed progressively, that now none of the University of Strathclyde's waste goes to landfill, rather, such waste initially sent to landfill, now goes to Incineration, hence, 100% of the University of Strathclyde's wastes are diverted from landfill, where 85.29% (41.8 tonnes) is recycled monthly, 2.4% (1.2 tonnes) sent for anaerobic digestion, while 12.32% (6.0 tonnes) monthly waste is sent for incineration.. This is contrasted with University of Lagos where 99% of its waste was being landfilled during the period of study (2015 – 2018).

The 100% diversion of waste from landfill is a result of the University of Strathclyde's resolve to implementing its waste management policy, which centres on waste minimization and recycling (University of Strathclyde, 2019). One of the UoS waste management strategies is the source segregation of organic waste for anaerobic digestion, thereby reducing the impact of such waste in the environment, as organic waste is the main source of GHGs, which result from the biodegradation of organic materials, especially in landfills (Hoornweg and Thomas 1999). This source segregation of organic waste for recycling purposes has a positive influence on environmental sustainability because the waste management sector contributes to about 5% of the world's greenhouse gas emissions (Bogner et al., 2007). The university's organic waste is contracted to Energen Biogas, which is a company that processes organic waste to generate electricity and fertiliser (Ethersen R., personal communication, 26th March 2018). More so, the cost benefits arising from the current University of Strathclyde's waste management with associated environmental costs show a net present value (NPV) of £33,728,493.18 when compared with the University of Lagos, which has a NPV of -£263520,447, this indicates that such a management approach at the UoS is very sustainable as the benefits of the system outweigh its costs (see Appendix 5.1 and 5.2 for details). Unlike the UoS, 99% of the UoL's waste ends up at landfills, which has a negative impact on the environment (Aseto, 2016; Adeniran et al., 2017; Bhupendra et al., 2018). Hence, the focus of the risk management associated with the waste management practise was centred on the University of Lagos only.

5.3.1. Cost Benefit Analysis

The monthly environmental cost and savings (by diverting waste from landfill) based on the University of Lagos data are shown in Figure 5.1 and Supplementary, S 5.1. The highest environmental cost was observed in every first quarter, specifically in March, with a total environmental cost of -£16,828,476 and a saving of £169,985, while the lowest environmental cost and saving was observed in October 2014 with -£6,682,652 and £67,502, respectively.

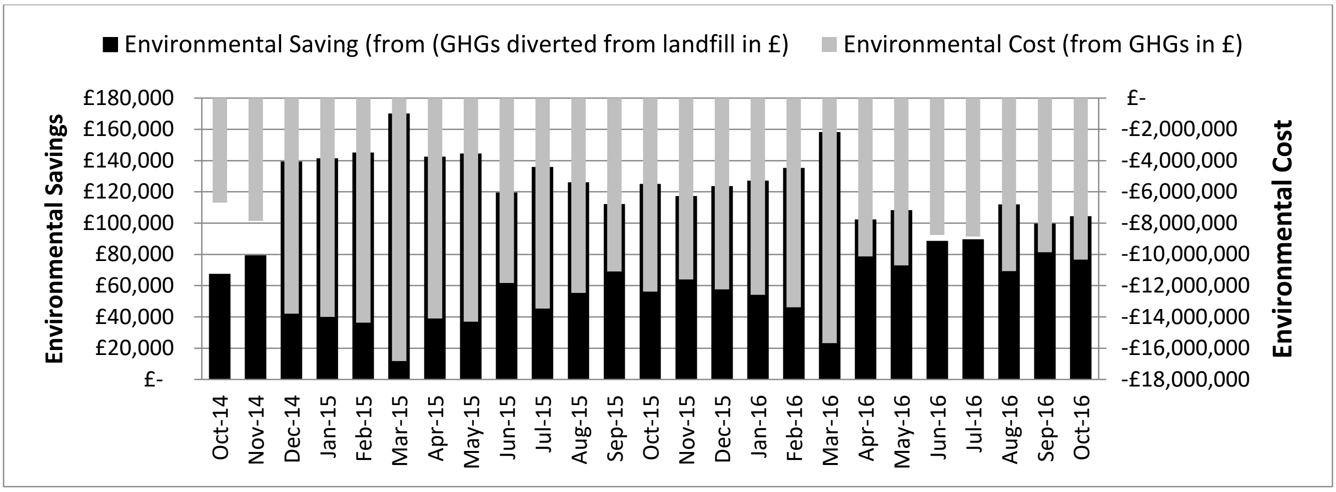


Figure 5.1: The monthly environmental savings and costs based on the University of Lagos current waste management approach.

The Net Present Value (NPV) maintained a negative value at the current University of Lagos's 1% recycling rate, and even if effort is made to reduce its waste in the 1% scenario, it is still at -£263, 520,447, until possible effort is put in based on a 51% recycling target scenario, at which point it potentially has a positive NPV of £4,725,372. Other combinations of reduction and recycling target scenarios have different NPVs, as shown in Table 5.2. The reported NPVs; UoL = -£263,520,447 and UoS = £33,728,493.18 represent the total Net Present Value which was calculated over the defined project period (October 2014 - October 2016 for UoL, and comparable period for UoS), discounted appropriately. These are not per tonne values, but are the economic assessment value of a project over a period of time to evaluate if they are profitable or not, as further shown on Appendix 5.1 and 5.2 for the detailed cash flow projections.

Table 5.2: Net present value (NPV) matrix result showing the waste reduction target in relation to the waste recycling target at University of Lagos when cost of haulage and sorting remain constant (see Supplementary 5.1), where the colour coding red represents negative NPVs, yellow been lowest NPV and the green colour code beeng the higher NPVs .

	1% Recycling Rate	20% Recycling Rate	50% Recycling Rate	51% Recycling Rate	80% Recycling Rate
Reduction 1%	-£263,520,447	-£161,587,036	-£639,544	£4,725,372	£160,307,947
Reduction 10%	-£239,565,059	-£146,898,321	-£582,420	£4,294,777	£145,733,481
Reduction 20%	-£212,947,961	-£130,577,527	-£518,948	£3,816,338	£129,539,631
Reduction 30%	-£186,330,863	-£114,256,733	-£455,477	£3,337,898	£113,345,780
Reduction 80%	-£53,245	-£32,647,684	-£138,119	£945,702	£32,396,846

5.3.2. Data Analysis:

The Pearson bivariate correlation showed that increase in recycling targets has a strong positive correlation with NPV, economic benefit, increase in recycling facility/cost, and strong negative correlation with risks and environmental cost. For the NPV, the results showed it has strong negative correlation with risk and environmental cost, and strong positive correlation with economic benefits. The risk and environmental cost have a strong negative correlation with the economic benefit, and all the correlations are significant at the 0.01 level (2-tailed).

5.4. Discussion:

5.4.1. Green House Gas Emission:

The greenhouse gas (GHG) emissions (for the current waste management practice i.e., normal scenario) are high (Appendix 5.1), and they recorded the highest emission in March and their lowest emissions in October within the data collection period (October 2014–October 2016) at UoL, hence resulting in the high environmental cost observed with the current management practice.

These emissions are assumed to be the actual cause of the occasional burning of waste materials at landfill sites, like the fire incidence at Olushosun landfill (Figure 4.23), which potentially causes a high loss of economic value for the waste materials. Open burning of municipal solid waste materials is reported to cause environmental pollution (Hoornweg and Thomas 1999; Aseto, 2016) and could trigger health impacts such as heart disorders and acute and chronic respiratory disease (Bhupendra et al., 2018). Based on a sustainable waste management strategy, it is important to choose management approaches that could protect the environment while also being economically worthwhile. To choose such an approach, a cost-benefit analysis of alternative management approaches is needed (Begum et al., 2006; Atkinson and Mourato 2008).

5.4.2. Cost Benefit Analysis:

One of the key waste management strategies incorporated in the two universities' waste management policies is the minimization of waste that goes to landfills, which the University of Strathclyde implements 100%, thereby encouraging environmental sustainability and risk reduction from such practises, which are improved by the act of managing waste outside the campus. In contrast, the University of Lagos still landfills 99% of its waste and recycles about 1% of it. More so, handling waste within the campus could also expose the population within the campus to risk, especially if pilled waste ignites because of high temperatures and methane generation (which is often the case), which causes environmental and public health hazards (Hoornweg and Thomas 1999). The cost-benefit analysis of the current 1% recycling rate since inception of the University of Lagos' current waste management approach from October 2014 to October 2016, with associated environmental costs, shows a net present value (NPV) of -£263,520,447 when compared to the University of Strathclyde's NPV of £26,014,941,675, which indicated that such a management approach is unsustainable as the costs outweigh the benefits. This is explainable as the net discounted cash flow (payback period) of the project maintained a steady decline in the negative direction within the first 25 months of the current management practice. According a World Bank study, the efficiency of an operation and price of recyclables are key to sustainable projects and buttresses that if the recycling rate (the diverted recyclables as percent of the total waste) does not improve continually, it could potentially result to a negative NPV (Word Bank, 2018). The NPV result for the current waste management practice at UoS that is based on the assumptions from Chapter 5.2.6, has a positive value, and same with Hogg et al., (2015), that also shows a positive NPV, although a very high NPV.

More so, Hogg et al. (2015) who looked at the analysis for an impact assessment on the revision of the European waste management targets indicate that there are notable environmental benefits that much outweigh any additional costs connected with achieving 80% recycling target. When targeting higher, there could be possible increase in financial cost; yet, the additional environmental benefits brought to society would be evident. In one of Hogg et al scenarios (scenario 19), which targeted 65% MSW preparation for reuse / recycling, 75% overall packaging recycling and 10% landfill diversion for all Non-hazardous/Non-mineral Waste, resulted in net benefits of €26 billion (£22,457,890,000). Therefore, there could be additional associated financial savings and environmental benefits when high ambitious recycling targets are set and the tactics to reach them are fully implemented (Hogg et al., 2015).

The negative NPV from the current UoL waste management practise occurred as a result of the low recycling rate (1%) and 99% of the waste being landfilled (high landfilling rate), which potentially increases the environmental risks that are considered during the analysis, and the consideration of environmental risks is required for any sustainable project that needs a cost-benefit analysis (Hanley, 2001; Da Cruz et al., 2014), while the environmental risks considered were the principle GHGs (CO_2, CH_4, and NO_2). The result of the decision support tool, VLOOKUP, that further analysed the sensitivity of the NPV based on 625 scenarios of 125 different combinations of 5 critical variables in the management practice shows that at a 1% recycling rate (considering associated total environmental costs), the NPV was far below zero (-£263,520,447); even at 20% and 50%, the NPV at these recycling targets still showed that such an approach is never sustainable. At the 20% scenario, the NPV was -£161,587,036, while at the 50% recycling target, the NPV was -£639,544 (Table 5.1). However, the result shows NPV greater than zero from the 51% recycling target upwards. At the 51% recycling target, the NPV is over £4,725,372. These indicate that such a recycling target of >50% is potentially economically and environmentally sound, demonstrating a high payback time because, at that point, their individual benefits outweighed their individual costs after discounting the net cash flows, for which their cumulative values maintained a continuous positive trend. Considering the two critical variables, recycling, and reduction targets, respectively, as shown in Table 5.1, the result indicated that the higher the reduction and recycling targets employed, the lower the total cost that would be incurred over time, hence a better NPV. For instance, at a 20% reduction target while maintaining a 1% recycling rate, there was about a 10% difference from the initial cost; likewise, when the recycling target was adjusted to 20% at a 1% reduction rate, the result showed about a 48% difference from the initial cost; hence, the higher the reduction and recycling targets, the better the system. Although the system is not profitable at these targets, as the NPV is less than zero, such an increase in the targets shows the least total cost of managing the system. This strategy has been used by Mbazima (2011) to investigate the economic viability of in-plant waste recycling at Scaw Metal Group in Johannesburg, South Africa, which observed scenarios that could have total least cost which could be incurred over time rather than the ones that could yield positive NPVs.

Nevertheless, the results showed that the system can only be sustainable if recycling targets above 50% are achieved, which is the condition that could show a rise in NPV above zero. Recycling targets of above 50% could potentially take time to reach; however, they could still be achievable if necessary recycling strategies are met, like increasing awareness campaigns on the benefits of recycling, among others. HEIs waste is legally classified as household waste (Zhang, 2011); hence, they could experience similar challenges as those faced in achieving a higher household recycling rate. An example of this problem may be seen in the United Kingdom, which was once a member of the European Union but failed to achieve their 50% recycling goal by 2020 (after exiting the EU), from the country's recycling rate of 45.7% in 2017

(Moore, 2017; Defra, 2019). While waste reduction offers the highest environmental benefit through avoiding all upstream/ downstream impacts like virgin resource exploitation, transportation, processing, disposal (Hoornweg and Thomas, 1999; Turner et al., 2011), recycling does mitigate downstream disposal impacts like the landfill GHG, as well as resource depletion. The CBA focused mainly on the operational costs/ benefits and GHG, hence, a limitation on the study because there are still other significant environmental costs that were not considered, such as soil contamination, water pollution from landfill leachate, air pollutants beyond GHGs like dioxins from the irregular waste burning, biodiversity loss from landfill sites, and even the health costs associated with pollution. These were not considered as a result of the methodological complexity as well as data scarcity, particularly for the Nigerian context (Da Cruz et al., 2014; Adeniran et al., 2017). Including these environmental risks would likely worsen the NPV for landfilling at UoL, while improving it for UoS due to its high-diversion systems.

The result shows NPV greater than zero from the 51% recycling target upwards. It is ideal to distinguish the drivers to positive NPV. The recycling targets directly increases the revenue (RSM) and avoided the landfill costs/ emissions (TC reduction). While the reduction targets primarily decreased the overall waste tonnage requiring management, which is in line with the United Nations' Sustainable Development Goal (SDG) 12, particularly Target 12.5, that seeks to reduce waste generation through prevention, reduction, recycling, and reuse by 2030. The reduction itself would lower the total collection, haulage, cost of sorting and disposal (TC reduction) and also the tendency to reducing the absolute potential revenue (TB decrease). Even though higher reduction target is environmentally beneficial, achieving high recycling was seen as the critical threshold to achieve a positive NPV in the model because it broke even with significant revenue and avoided the environmental cost (£69,000/t) assigned to landfilled GHG emissions (Fankhauser, 1994). Actually, the reduction target amplified the positive NPV but on itself was insufficient at low recycling rates (see Table 5.2: 80% reduction plus a 1% recycling rate still yielded a negative NPV).

More so, the 2017 waste recycling rate (59,876 tonnes) in Glasgow, Scotland, was 26.7%, albeit an increase of 9.8% from 2016 (54,552 tonnes). Comparing recycling rate among countries could be difficult as different measurements are used, however, when increased awareness of the recycling benefits is utilised there is usually an increase in recycling rate (Zhang, 2011), hence, there is high possibility to gradually achieve whatever recycling targets that are set by any institution.

Therefore, reduction and recycling as it relates to their distinctive environmental effects, is seen as equal to source minimization, and diversion respectively. In this regard, the environmental benefits of reduction would be to avoid all potential impacts, while recycling avoids the disposal impacts which are explained within the CBA model:

Which means recycling increases revenue (RSM), then, avoided Landfill Costs/ Emissions (Total Cost reduction (TC)). While, reduction lowers Total Tonnage, and reducing most costs (TC reduction), and slightly lowering potential revenue (TB decrease). Hence, the recycling of >50% was the critical NPV threshold as it is at this level that unlocks revenue which is already explained, and at this level it avoids much of the GHG cost. While reduction would potentially amplify that positive NPV, it couldn't achieve it alone at low recycling rates.

5.4.3. Assumptions:

The cost of waste collection and transportation, which are based on the estimated cost of fuel and maintenance services for waste haulage vehicles, were summed to be the total cost of waste haulage, which is charged per tonnage. The cost of waste haulage and recovering of materials (contract cost) is expected not to increase over time. The cost reflects the current charges from the university's waste management contractors, while the values used for the quantification of intangible costs and benefits (environmental aspects) were based on Fankhauser (1994). The cost of selling segregated recyclable materials like mixed plastics and mixed paper waste was based on standard market prices for such recyclable materials in the case study area at the time of data collection.

The evaluation criteria chosen for alternative management options focused only on two options (landfill and recycling), which could potentially offer reduced operating and environmental costs with high operational efficiency. Consequently, the recycling centre's operating costs, which were based on the estimated cost of staff salaries and assumed disinfectants used, were summed to be the total cost of material recovery by the waste contractors, who are also charged per tonnage. The amount of waste combusted on a monthly or annual basis because of assumed excess methane generation and hot temperatures was not considered in this study. While fire outbreaks at the recycling centre were observed at UoL, the associated emissions (i.e. from the waste burning) were not systematically quantified in the GHG calculations as a result of inconsistent availability of data, hence, a limitation to fully capturing landfill-related environmental costs at the case study site (Aseto, 2016; Bhupendra et al., 2018). The Fankhauser (1994) environmental weighted values were used for the intangible cost/

benefit valuations (environmental aspects) based on CO_2, CH_4, and N_2O, while the costs for recycling centres included the estimated disinfectants and staff salaries and charged per tonne by contractors. It is important to also note that the recycling infrastructure and market values for recycling differ vastly between Nigeria and Scotland. For instance, in Nigeria, formal recycling channels are limited, reliant mainly on informal scavengers, which lowers revenue, while, in Scotland, there are formal reliance such as recycling infrastructure and markets, including policy support, like the extended Producer Responsibility regulation, ensuring higher and more stable revenues (Zhang, 2011; DEFRA, 2019; Solaja et al., 2024). These variations are embedded in the case-specific cost assumptions but highlight a contextual constraint for UoL. The study further assumed no tonnage increase in waste combusted spontaneously and increasing recycling targets also incurred standard price adjustments. Other assumptions considered were increasing the recycling targets with associated costs at standard prices, among others, for sustainable management. In order to focus comparison of the systemic differences in the two case studies (UoL and UoS), the same unit cost of some variable were applied including haulage (£10/tonne) and sorting (£64/tonne) to avoid confounding structural differences with local price variation, even though real world haulage and sorting costs differs across the globe. The full result of the variables considered are reported in Appendix 5.1 and 5.2 respectively.

5.4.4. Data Analysis:

The statistical data analysis (Pearson bivariate correlation) for the University of Lagos indicates high significance among the variables (Recycling targets, NPV, increase in waste bin, awareness campaign cost, risk/environmental cost, and benefits), $p < .001$. This means it is unlikely the results occurred by chance alone. Each of the variables has a significant effect on each other, either positively or negatively. For instance, an increase in the recycling rate showed an increase in the NPV and the economic benefit of the system, while decreasing the risk and environmental cost. The increase in NPV was a result of an increase in the economic benefits and a reduction of environmental costs emanating from the waste management operation. This is explained in Aseto (2016), that the greener the waste management strategies, the more efficient the overall system, which reduces the risks and environmental cost of the system.

5.4.5. Awareness Creation:

Research has shown that creating awareness can have a positive impact on people's participation, especially in waste recycling and reduction (Hasan, 2004; Desa et al., 2012; Aseto, 2016). Creating awareness on the benefits of recycling, as well as on the effects of risks associated with landfilling, especially the biodegradable wastes, can potentially increase the level of student and staff engagement with the recycling practice within an institution (Desa, 2012), this assertion is also supported by Aseto (2016). According to Aseto (2016), it is the creation of awareness about the benefits of waste reduction and recycling that helps to maximise recycling potential and reduces the risks associated with landfilling waste. This is supported by Festus and Ogoegbunam (2012), which further stated in its "imperatives of environmental education and awareness creation for solid waste management in Nigeria", that in order to encourage people's participation in waste reduction and recycling, such awareness messages, especially the negative impact of not recycling, remain a great motivation for people to help engage in proper waste management. Such awareness messages could come in an informal or non-formal way, such as through newspapers, radio, television, and most importantly, leaflets, as they have shown to increase public participation in the recycling of solid waste (Festus and Ogoegbunam 2012).

5.5. Conclusion:

Landfill as a waste management option remains the least preferable waste management option under the EU Waste Framework Directive's waste hierarchy, primarily due to the environmental risks associated with such practices, of which the key risk is the release of greenhouse gas (GHG) emissions, e.g., CO_2, CH_4, and NO_2. This research investigated the cost benefits and associated environmental risks of waste management practises (landfill and recycling) in two higher educational institutions (the University of Lagos and the University of Strathclyde), which is necessary to understand the environmental and financial sustainability of the waste management process in the two case studies.

The outcome of this research demonstrates that waste management practises at higher educational institutions could pose potential risks and have associated costs or benefits, depending on the effectiveness of the management practice. For instance, in the UoL case study , setting higher recycling targets had a significant effect on recovering value from the waste and on potentially reducing the total environmental cost, especially from greenhouse gases (GHGs). This is explained by the nature and effect of direct disposal (landfill) when compared with recycling, resulting in a reduction of GHG emissions by the latter practice. Due to the high environmental risks associated with the management practise at UoL, the NPV of the management system was less than zero. The UoS case study has far better management practices, and because the school is committed to implementing its waste management policy, there were low environmental risks; thus, its NPV was far above zero. Furthermore, the findings of this study demonstrates that it is obvious the UoS case study has far better waste management practices. However, a key limitation to this study is the focus on GHG emissions as the main monetized (economic) environmental cost. While significantly, there are other environmental issues like, other air pollutants, leachate, and health impacts that are associated with landfilling, particularly in the contexts of UoL/ Nigeria, which has less engineered sites and often experience irregular burning, were not fully captured in the CBA, hence, likely underestimating the true cost of the landfilling practice at the case study.There is also need to set high reduction and recycling targets for universities, which encourages environmental sustainability in line with SDG target 12.5, while increasing awareness campaigns could potentially increase reduction and recycling rates, reducing the risks and environmental costs associated with current waste management practices. Awareness creation that centres on the benefits of waste reduction and recycling and enforcement could serve as tools to increase stakeholders' (academic and non-academic staff, students, and the public) participation in the universities, hence providing a channel to a big opportunity for the universities in targeting environmental sustainability.

CHAPTER 6

PUBLIC PERCEPTION OF SOLID WASTE MANAGEMENT IN A DEVELOPING COUNTRY: LAGOS STATE CASE STUDY

6.1. Introduction:

The management of municipal solid waste (MSW) is a global problem that has resulted in a variety of strategies being implemented by countries around the world. From today's 2.01 billion tonnes to 3.40 billion tonnes a year by 2050, the amount of waste being generated around the world is expected to increase significantly (Silpa et al., 2018). Poor waste management is common in developing countries such as Nigeria, where waste collection and improper disposal in unsanitary landfills and open dump sites are common (Ogwueleka, 2009). It is common in developing countries (UN Habitat, 2010; Abdel-Shafy and Mansour 2018) to practise waste disposal that is not in compliance with international standards, putting the public's health at risk. Those who live near areas where waste is improperly dumped are at risk for health issues, according to Sessa et al. (2010). Lack of understanding of the root causes of this waste management problem in developing countries, particularly Nigeria, is to blame. Environmental planning that promotes sustainable waste management and, thus, public health, is the primary benefit of gaining an understanding of the causes of improper waste management and societal behaviour change. Prioritizing waste prevention, reuse, recycling, and recovery before landfilling is the norm in most waste management strategies (European Commission, 2003). As a sustainable waste management approach, the hierarchy considers the several types of waste that are generated, but it does not consider how the public behaves when it comes to waste management to gain an in-depth understanding of current waste management. According to Bom et al. (2017), it is important to understand the public's perception of waste management practises to tailor a given policy that can be easily implemented and has an enforceable guarantee, as suggested by Almasi, (2010).

Improper waste management potentially exists because the agencies responsible for waste management have been ineffective, and the public also fails to adhere to waste management regulations, resulting in waste being disposed along roadsides and in drainage systems in developing countries (Ogwueleka, 2009; Edo, 2012). To achieve sustainable waste management, all stakeholders must be involved to gain a better understanding of the issue and, thus, an easier method of resolving the problem of improper waste disposal and management. Waste compositional analysis, cost benefits and questions about how to get rid of and manage waste are looked at, and the possible causes that can be combined to make an intervention or policy work better are also investigated.

According to research, these practises are good waste management approaches because waste composition (Chapter 4) and cost-effective management practises (Chapter 5) aid in determining the best waste management strategy. However, consultative approaches may further help identify and analyse barriers that prevent effective implementation of these waste management plans (both from agencies responsible for waste management, as well as from the public), which enhances sustainability and thus critical to achieving sustainable waste management (UNEP 2009; Mbeng et al., 2012; Lederer et al., 2015). People's perceptions of waste management were to be evaluated in this study to identify potential barriers to effective waste management. Qualitative assessment in the form of questionnaire was used to generate data that quantify problems associated with the waste management practices in the case study area, with a focus on behaviours, attitudes, and other clearly defined variables (Bailey *et al*., 2015).

6.2. Methodology:

6.2.1. Study Area:

Lagos is one of the largest cities in West Africa and the second largest in Nigeria. It is also one of the States located in the western part of Nigeria. The city has an estimated population of 21 million according to the latest data available as of 2020 (Matsuoka et al., 2020) and an annual urban growth rate of 5.8% (Aliyu and Amadu 2017). Such urban growth can potentially have a significant effect on the rate of waste generation in the state. The management of solid waste in Lagos State is the responsibility of the Lagos Waste Management Agency (LAWMA), which provides waste infrastructure, including trucks, for the collection and disposal of solid waste in the state (Afon, 2007; Adewole, 2009).

Urban settlements can be grouped into three main economic categories, namely low-, middle-, and high-income areas, as adopted from Haque et al., (2020) and Meili et al., (2022). The research was conducted in these three economic categorised areas to have a representative opinion, as well as understand their distinctive problems regarding waste generation and management (Figure 6.1).

The survey was conducted from 18th November to 20th December 2016, in the areas defined in Figure 6.1.

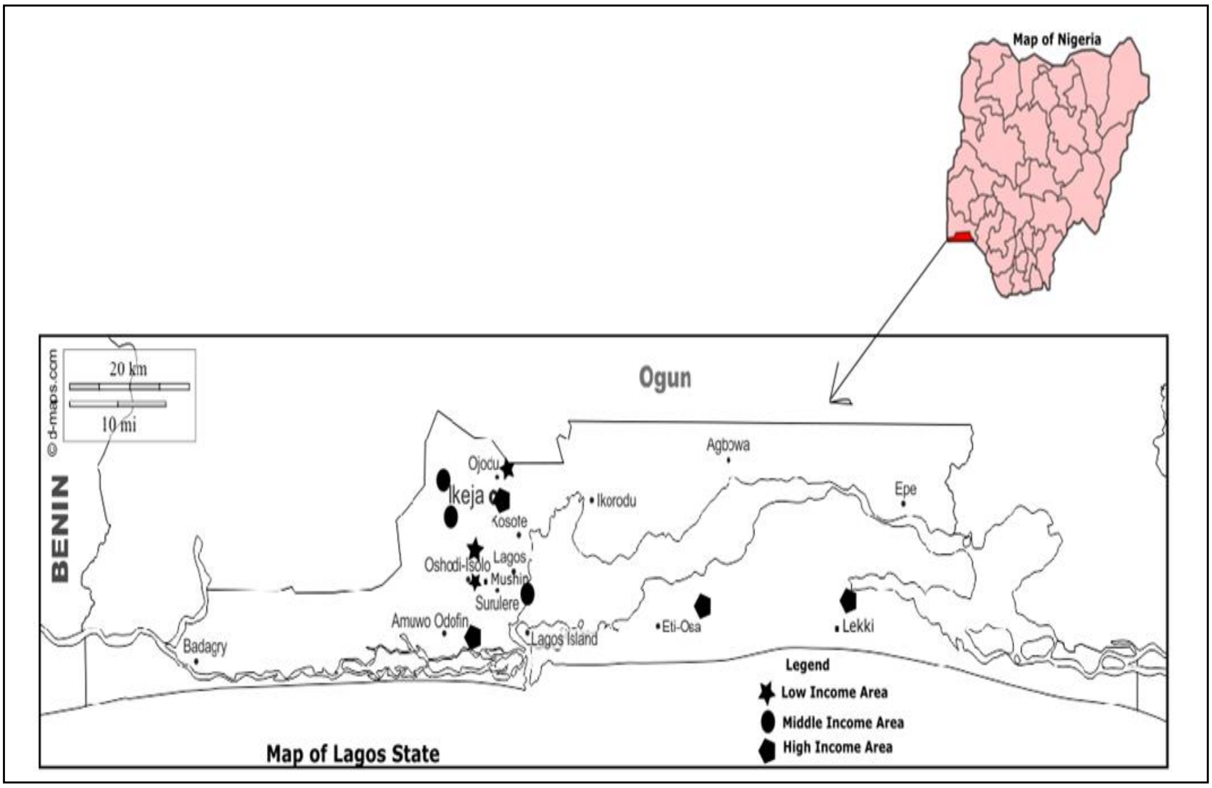


Figure 6.1: Map showing three classified income areas (low-, middle- and high-income area) where samples were taken in Lagos State, Nigeria.

Table 6.1: The questionnaire sampling areas in Lagos State, Nigeria.

Economic class	Areas	Reason
High-income	Victoria Island, Lekki, Dolphin, Eti-Osa, Allen Avenue, and Ikeja G.R.A.	These areas are known for upscale real estate and an opulent way of life. The area is host to numerous international firms, high-end hotels, and luxury retail centres. In comparison to other areas in Lagos, the cost of living and property prices are very high (Filani 2012; Sawyer, 2016).
Middle-income	Opebi, Ikeja, and Maryland,	These areas are known for a mix of residential and commercial properties. They have a bustling business district with numerous small and medium-scale enterprises. Though not as affluent as some high-income areas but offers affordable housing options and a vibrant commercial atmosphere (Sawyer, 2016).
Low-income	Ojota, Oba Atran, Mushin, Bariga, and Isolo	These areas are characterized by densely populated residential settlements and informal markets. Many residents here are low-wage earners, and housing is made up of informal structures and slums, and lacks adequate basic amenities and infrastructure, contributing to its classification as a low-income areas (Filani 2012).

6.2.2. Sampling Method:

A qualitative assessment in the form of a questionnaire was used to sample public opinion to address the issues associated with the waste management practises in the case study area and a face-to-face survey approach was engaged. A questionnaire possesses a distinct standardized data collection that is directly aligned with the study objectives that further ensures the data is internally consistent and coherent for analysis (Roopa and Rani 2012). The questionnaire was developed by focusing on questions relating to some of the management and challenges faced in respect of waste management in the state. This approach has also been validated in the past to understand and identify waste management problems caused because of poor waste management policies and practises to produce strategies for sustainable waste management (Yoada et al., 2014; Bailey et al., 2015).

The face-to-face survey method has been noted as generating a higher response rate than other types of surveys (Bowling, 2005; Hohwü et al., 2013); therefore, this methodology was selected to address the research objective of reviewing the effectiveness of organizational structure and public engagement for better MSW management to enhance environmental sustainability in Nigeria, as well as evaluating potential factors influencing its waste management problems. To achieve the above research objective, the researcher employed face-to-face random sampling, as described by Kelley et al. (2003) and Warunasinghe et al. (2016). Questionnaires were distributed to individuals within the population, consisting of both males and females aged 18 to 65 (who were available and willing to participate), residing in high, middle, and low-income areas to understand the variance in their waste management perception, as used by Zia et al. (2017). The specific questionnaire items and the ethics approval can be found in Appendix 6.1. and 3.1, respectively. The researcher engaged four trained research administrators who asked the respondent the questions and recorded their responses across the households and business within the three classified economic areas. The researcher additionally grouped the responses into households and businesses within these three economic classed categories. This was to have a tailored recommendation as households and businesses can have different waste generation and disposal patterns.

In order to simplify the assessment of waste generation by the respondents, a basic unit of measurement, i.e. a waste bag, was incorporated into the questionnaire. A bag of waste was defined as being equivalent to 7kg of waste. Four hundred and fifty-nine respondents completed the questionnaire across the data sampling area. The survey questions were based on those in Ferronato et al. (2017), which help gain insight into the waste management issues in the state, including the potential cause and solution.

6.2.3. Pilot study:

A pilot phase or pre-testing is required prior to conducting a major survey to check the consistency and precision of the measuring tool and the measurements being taken (van Teijlingen and Hundley 2001; Radhakrishna, 2007); thus, the questionnaire was piloted using informal pilots (Brace, 2008; Stopher, 2012). An informal pilot is the process of conducting a pre-testing of the survey, to ensure the questions are clear and prevent the respondents from misinterpreting the questionnaire during the main survey (Burns et al., 2008). Pre-testing involved using a few people knowledgeable on the subject matter as respondents to help establish the time taken to complete the questionnaire, while also considering environmental factors and their impact, e.g., noise, as it could take more time to complete the survey in a noisy environment. The pilot also helped identify if the wording of the questions were clear and could be easily understood. According to Brace (2008), the utilisation of pilot surveys may enable those who possess expertise in research design to potentially detect a greater number of concerns with a specific topic compared to those lacking such knowledge.

An ethics form in respect of the survey, from the Department of Civil and Environmental Engineering, University of Strathclyde was completed before undertaking the survey. Some ethical issues taken into consideration include dealing/ or handling people's personal data. The study implemented strategies to conduct surveys in a manner that restricted the sampling of personal data. This was achieved anonymizing respondents and classifying respondents' demographic characteristics, such as age range and gender, in a way that prevented their identification based on the provided data. Furthermore, participants had to complete a consent form and were given the option to either proceed with completion of the survey or to withdraw (see to Appendix 6.2).

6.2.4**.** Data Analysis:

Ordinal and nominal questions, as well as open-ended questions, were asked to gain insight on public perception on waste management to address the research questions on public perception of sustainable waste management in Lagos State (a copy of the questionnaire is given in Appendix 6.1). The answers were coded by assigning different numerical values to them, which were based on the Leahy (2004) methodology, to be able to analyse the answers to the questions easily. The nominal or categorical questions choose between two answers. Example: "Do you separate your waste?" This comes with either a Yes or No answer. However, the coding for categorical questions was then assigned as follows: 1 = yes, and 2 = no. Then, using the coded numerical values, respondents' answers were analysed. The same was done for the open-ended questions; however, word search, frequency, and matrix coding were deployed for the data analysis (Kammeyer et al., 1971; Behar-Horenstein and Feng 2018). This was done by identifying key words from the responses with similar meaning and grouping them together and assigning a numerical code to them, which were then analysed.

Descriptive and analytical statistics were used to analyse and interpret the data, providing a comprehensive overview and understanding of the variables under study. A Pearson bivariate correlation in SPSS statistical software was used to establish the linear relationships between different variable combinations in the case study area such as knowing if waste collection service is efficient, and why wastes are disposed on the road among others (see Supplementary, S6.1). This method of evaluation is widely used in the literature and helps to understand the strength of the linear relationship (Prematunga, 2012; Puth et al., 2014).

6.3. Results:

A total of 600 questionnaires were sampled from both the household and business areas, but not all the questionnaires were fully completed. This necessitated data cleaning to remove incomplete prior to further analysis; 459 questionnaires were fully completed. The incomplete ones were not analysed.

6.3.1. Demographic Characteristics:

6.3.1.1. Age Group:

A total of 459 participants provided information regarding their age group. The age of participants who were available and completed their questionnaire were between 18 to 65 years, in both household and business areas. There were 338 respondents in the household area and 121 in the business area (see Figure 6.2). More responses were at high and low-income areas, than at middle-income areas; however, the questionnaire administrators tried to ensure there was gender balance during the field survey.

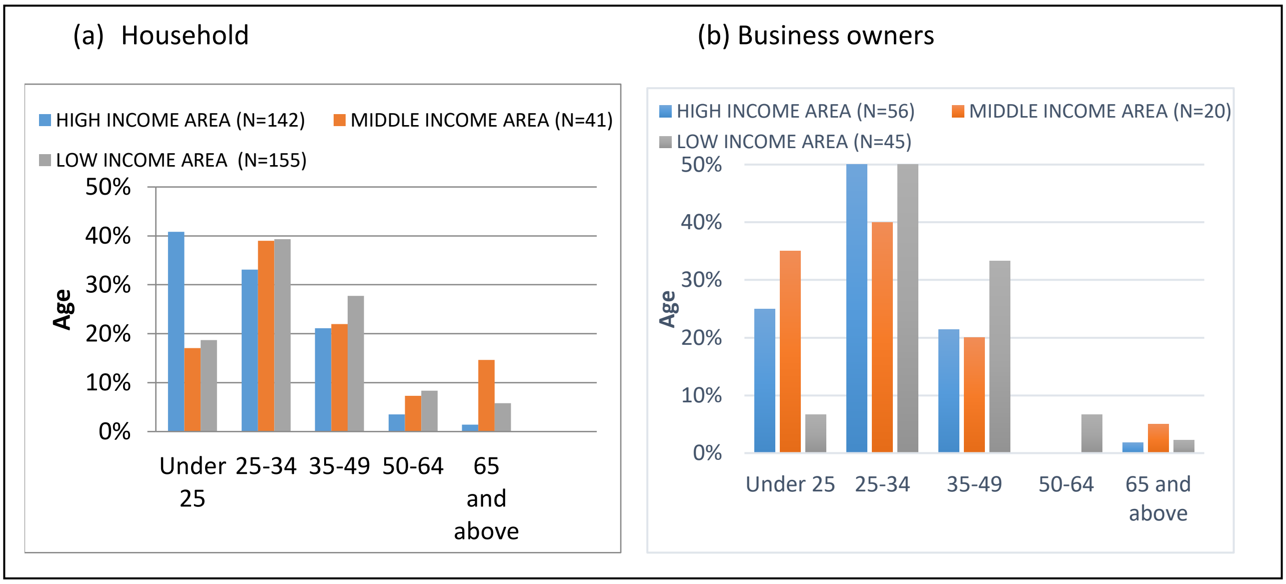


Figure 6. 2: Age group of the respondents, (a) households (b) business owners.

Despite attempting a gender balance in all 3 areas, in each area more males completed the questionnaire than females (Males High income 59%, Middle income 59%, Low 68%). The situation was reversed for the business owners, where 55% of the respondents in the high income area (n=56) were females, 58% female in the middles income (n=19) areas, but a bit more balance was present among the respondents in the low income (n=45) with 49% female and 51% male.

6.3.1.2. Educational Qualification:

The household respondents from the high income area has the highest number of university degree holders (about 75%, N=142), and had the least secondary education certificate holders (about 15%). This is followed by the middle income area that has 54% of university degree holders, and 34% secondary certificate holders (N=41), while the lower income areas had the least university degree holders (41%), but had the highest secondary school certificate holders (47%, N=155). This pattern was repeated for the business, where the high income area had 80% university degree holders, 16% secondary certificate holders (N=56), then followed by 45% both university degree and secondary certificate holders respectively in the middle income area (N=20), while still having the least university degree holders 24% and high secondary certificate holders in the low income area (N=45) as shown in the figure below.

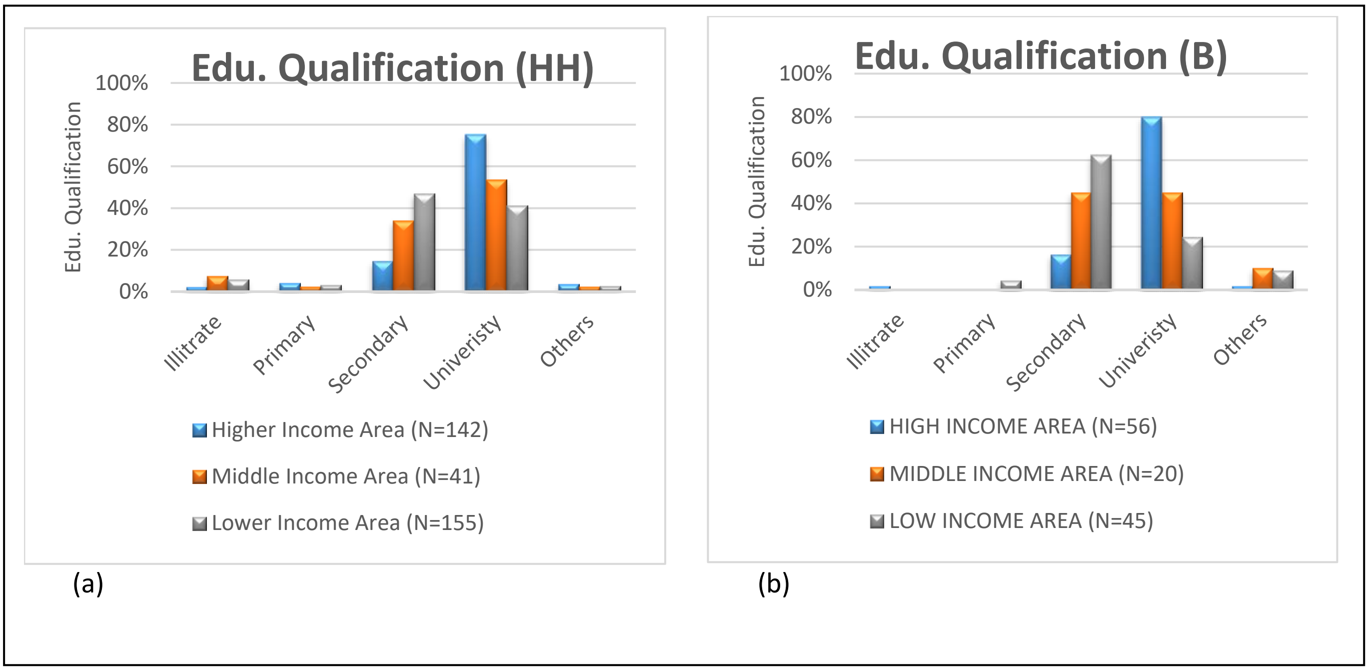


Figure 6.3: Educational qualification of the respondents, (a) households, HH (b) business (B) owners.

6.3.1.3. Employment:

Unlike the business owners, respondents from the households(HH) had the least unemployment (9%) and most student (43%) in the high income area (N=142). This is followed by 10% unemployment and 35% students in the middle income area (N=41), while the low income (N=155) had highest unemployed (16%) and least student (25%) and as shown below. Notwithstanding the above result, it further showed the level of employment for the high income area was 33%, which is lower than the low income area (40%), but higher that the employment level in the middle income area (18%) as shown below. There were also respondents that are retired; 4% (high income), 15% (middle income) and 6% (low income area).

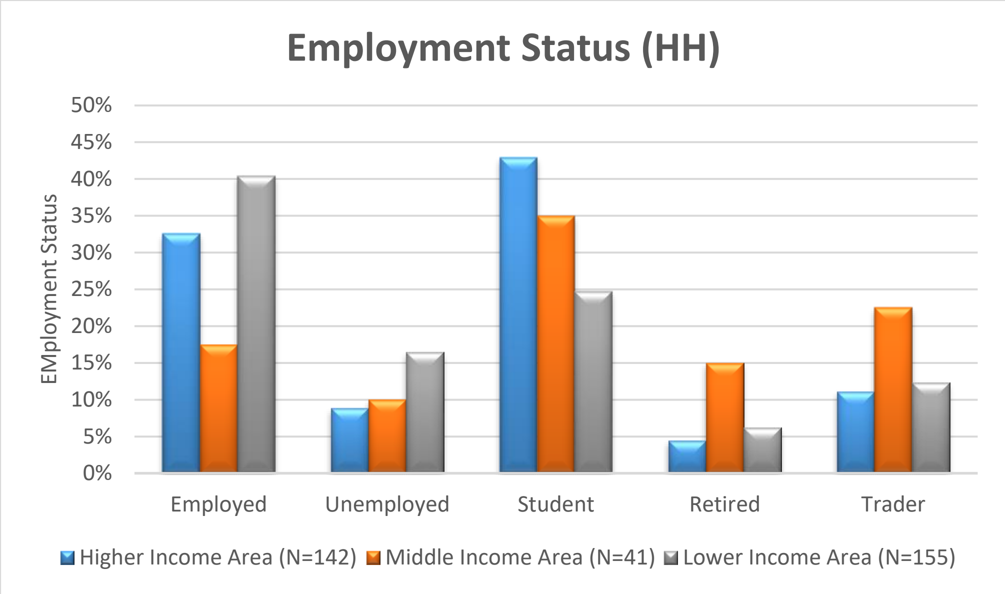


Figure 6.4: Employment status of the respondents in the households (HH).

6.3.2. Waste Management:

The number of households in all three areas producing either a daily bag of waste or a bag every 2 days was the same, around about 20%. Those producing a bag weekly were similar in the high and middle income areas at around 35%, whereas the low income area it is still around 20%. Around a third of respondents in both the high and middle income areas were producing a bag of waste per week, the level in the low income area was still around 20%, however a similarly high number was found in the low income area (30%) for generation of a bag of waste every 2 weeks – suggesting there are more people in the low income area producing less waste (see Figure 6.5. (a)). Those producing one bag per month was similarly low, around 5%, in all areas.. With respect to business owners (Figure 6.5b), the picture is slightly different, where around a third of owners across all areas state they are generating "1 bag per day" and just under a quarter estimate 1 bag per week. To standardize the waste bag, each **r**espondent was shown a standardized approximately 7kg bag (50cm x 60cm) which is commonly used as a bin during the questionnaire administration to ensure consistent understanding and visual reference. For the household-size adjustment, the waste generation data was normalized per capita (persons/ household) during the analysis. The low-income households have an averaged 5.2 members compared to 3.8 in high-income areas. This is similar to Thomas et al., (2021) publication showing an average of 4.9 people per urban household in Nigeria demographic and household survey.

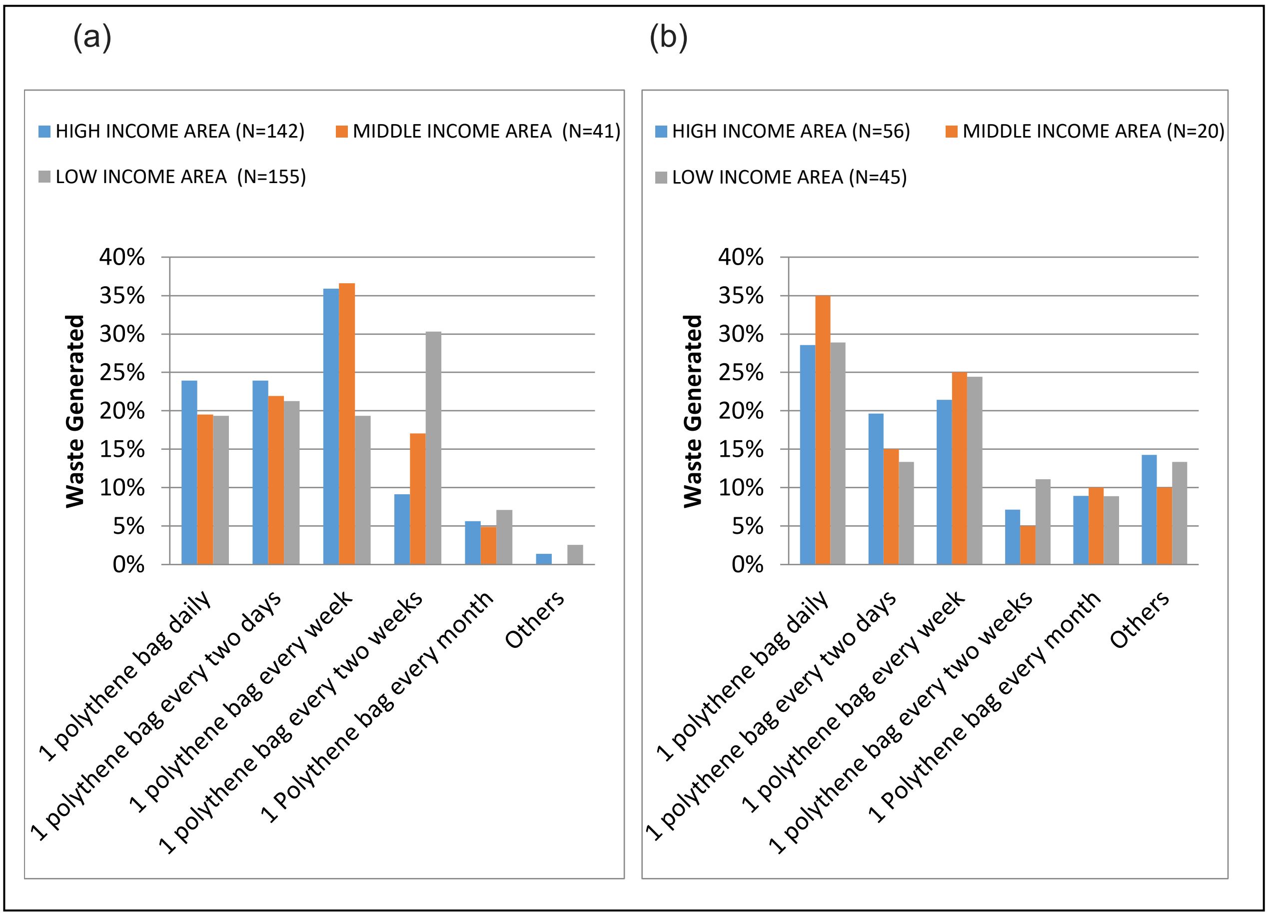


Figure 6.5: Solid waste generation from (a) household respondents, and (b) business owners.

6.3.3. Roadside Waste Littering:

When queried about the presence of wastes along the roadsides (as seen in Figure 6.6), no notable difference was observed across households with high and middle incomes, with around 76% of respondents in both areas reporting the presence of waste on the road. This value was even higher for low-income households where 92% acknowledged the deposition of waste by the roadside. A high number of business owners in the high- and low-income areas indicated the presence of waste on the roadside (95% and 93%, respectively), while only 65% of those in the middle-income areas gave an affirmative response to this question.

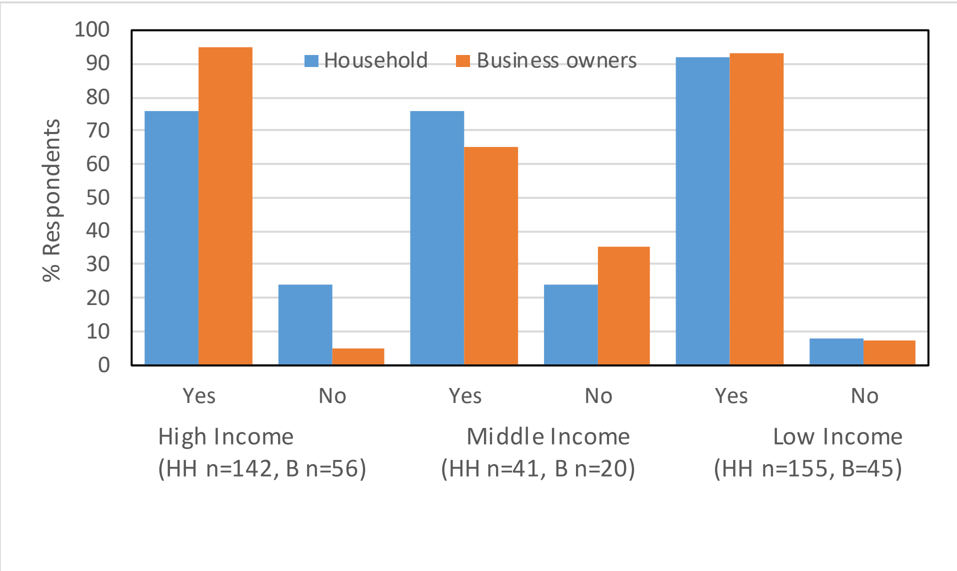


Figure 6.6: Responses to seeing waste on the road within household and business areas (HH=household, B=Business).

The roadside littering can be attributed to the inefficiency of waste collection and the lack of sufficient waste trucks been the major issues for Lagos State Waste Management, including the common break down of waste trucks on the road, as observed during the data collection field work as shown below, which potentially hinders the truck from waste collection until it has been repaired or serviced.

Figure 6.7: Waste collection truck broken down on a main road in Lagos (source: Observed during data collection field work in 2018).

6.3.4. Waste Management Performance:

For the open-ended question "What is the problem of waste management in the state?" Most respondents from both households and business owners signified it is ineffectiveness. The ineffectiveness was coded as a single outcome to reflect their most common responses; "They are not constant in collecting waste", "They don't come regularly", and "LAWMA don't collect our waste", as shown in the thematic analysis below. And these responses cuts across the respondents from all three socioeconomic areas, potentially showing the inability of the waste management agencies to provide a good waste collection service as shown in Figure 6.8.

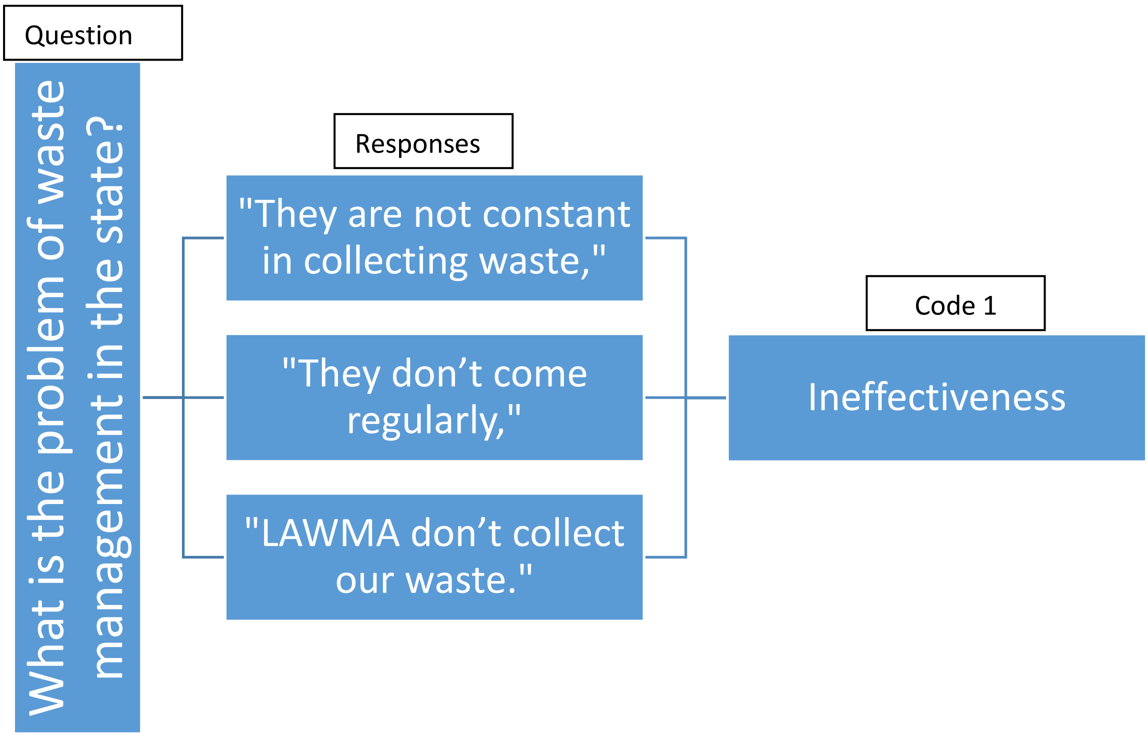
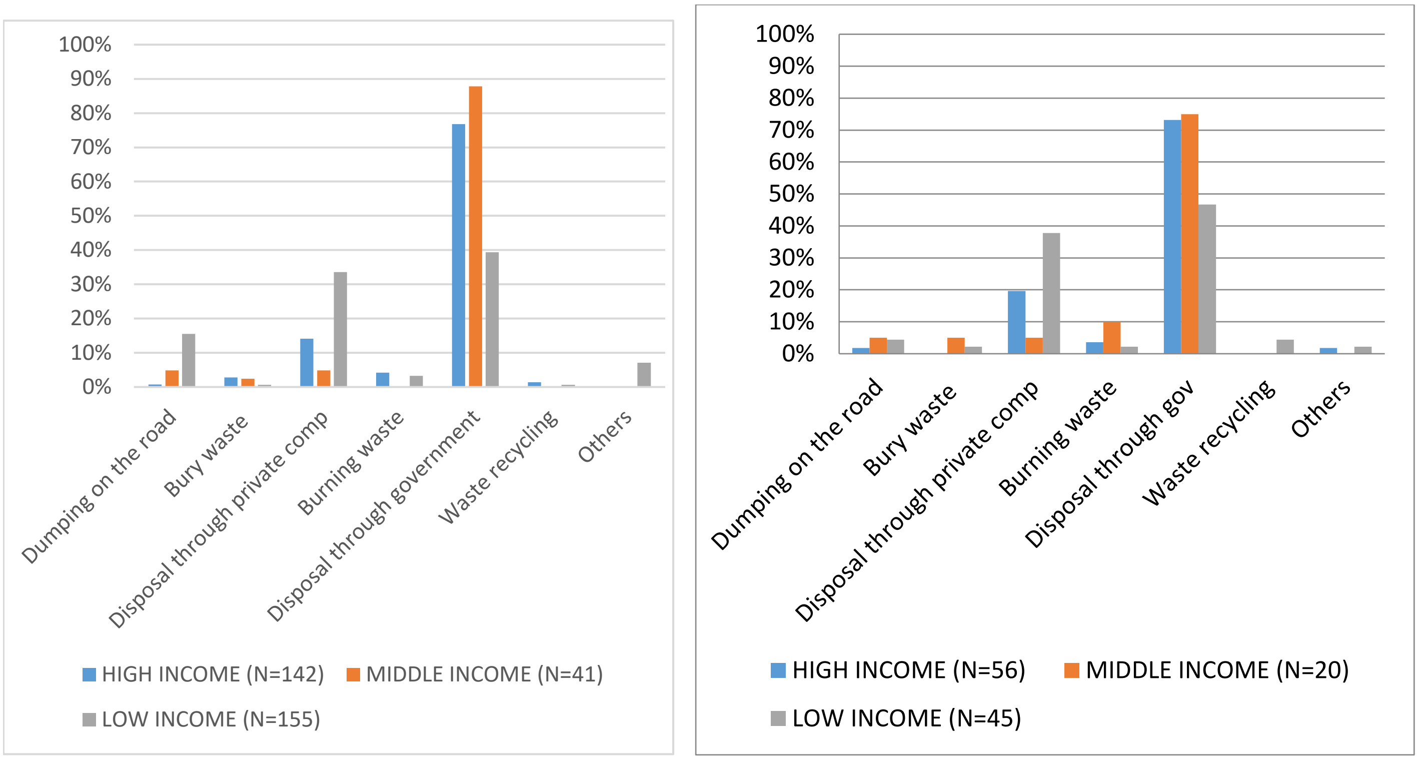


Figure 6.8: Example of the thematic analysis of response from the question "What are the problems of waste management in the state?" to understand the waste management performance, from both households and business owners.

Another point brought up was the economic shift. For example: "high fees or taxes", "self-centred politicians embezzle the money that could be used to solve this problem", "refusal of some communities to pay". The questionnaire results for both household and business owners revealed that government waste collection services are utilised by over 70% of households, as well as businesses in high- and middle-income areas, compared to only approximately 40% in low-income areas. While 34% and 38% in the low income area at HH and B respectively uses private company to dispose their waste, while not more than 20% utilises the services of private waste disposal companies in high income and middle income areas of both HH and B. Interestingly, not more than 15% also engages in other forms of waste disposal practices such as burying waste, dumping of waste on the road, etc. This disparity may contribute to the frequent littering of waste on the road (see Figure 6.6), particularly in the lower-income area with minimal utilisation of government waste collection services (see Figure 6.8).Environmental levies refer to the mandatory fees that are paid by households and businesses to the government waste management agency, LAWMA, for waste collection, and this rate can vary by income area as the low income areas tends to pay less than the high income areas. The regular payment of environmental levies by households within high income areas results to more waste collection service with this area when compared to the low-income areas (Sivakumar and Sugirtharan 2010; Akaateba et al. 2013; Zia et al., 2017). Non-payment of the environmental levy in the low-income area correlates with irregular waste collection and service as confirmed by Zia et al. (2017) and further supported by Akaateba et al. (2013).



(a) Household

(b) Business Area

Figure 6.8: Responses to different waste disposal practices.

6.3.5. Knowledge of Waste Segregation:

Among respondents, knowledge on waste segregation at source was poor. . As can be seen in Figure 6.7, around 46% of respondents in both the households and businesses in the high income area indicated their knowledge was poor or very poor.. While 36% of households and 32% of business in this area indicated they did not understand the question, suggesting unfamiliarity with the concept.. In same vein, in the middle-income area, 32% of households and 35% of (businesses indicated they had poor or very poor knowledge of waste segregation at source, and around half of respondents indicated that they didn't understand the question (52% household, 46% business).. Finally, in the lower-income area, 73% of households and 84% of businesses have poor or very poor knowledge of waste segregation at source, and given so many indicated they had poor knowledge, far fewer responded that they didn't understand the questions which is about 21% (household) and 7% (business) chosing N/A (not applicable/ don't understand), further confirming the common unfamiliarity with waste segregation concepts, and this was more common in the in lower-income zones (Figure 6.9), hence, knowledge based campaigns could enhance waste segregation (Mamady, 2016).

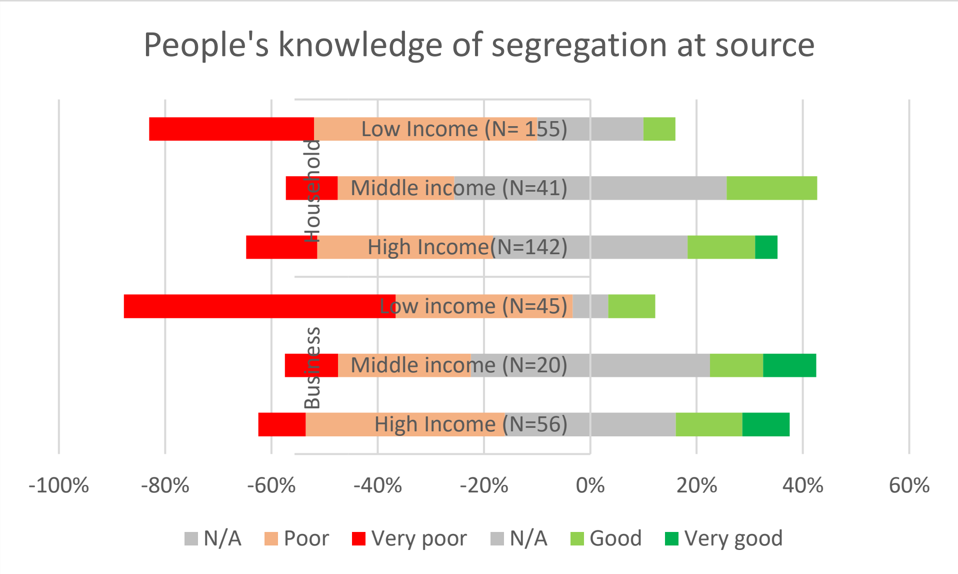


Figure 6.9: Responses to people's knowledge of segregation at source. households (HH) in high-income areas, n=142, middle-income areas, n=42, low-income areas n=155, for businesses (B) in high-income areas n=56, middle-income areas, n=20, and low-income areas n=45. N/A is not applicable indicating I don't understand.

6.3.6. Service Awareness and Practice:

The questions on the service awareness and practice, captured some behaviours regarding waste management. For example, "Do you separate waste?", "Do you pay environmental fees?". More so, the questionnaires looked at improper waste disposal, health knowledge, and communication with the government waste management agency, like "Do you know that improper waste disposal is a threat to health?" and "Have you been in communication with the waste management agency regarding waste and recycling?" Figure 6.10 displays the responses to questions about service awareness and practices. It reports the percentage of respondents who separate waste, pay environmental fees, understand the health risks of improper waste disposal, and identify communication issues between waste management agencies and the public. In hindsight it was realised that some of the questions could have introduced bias in the responses, for example, “Do you know that improper waste disposal is a threat to health?”, as the question could introduce submissive bias. Research has shown respondents could feel pressured to agree with the implied "exact" answer (Chyung et al., 2018). In order to prevent this, neutral phrases like “what kind of health impact, if there is any, do you associate with improper waste disposal?”, could have been used, and then follow up with an open-ended question to capture true perception, as has been suggested in literature (Desa et al., 2012).

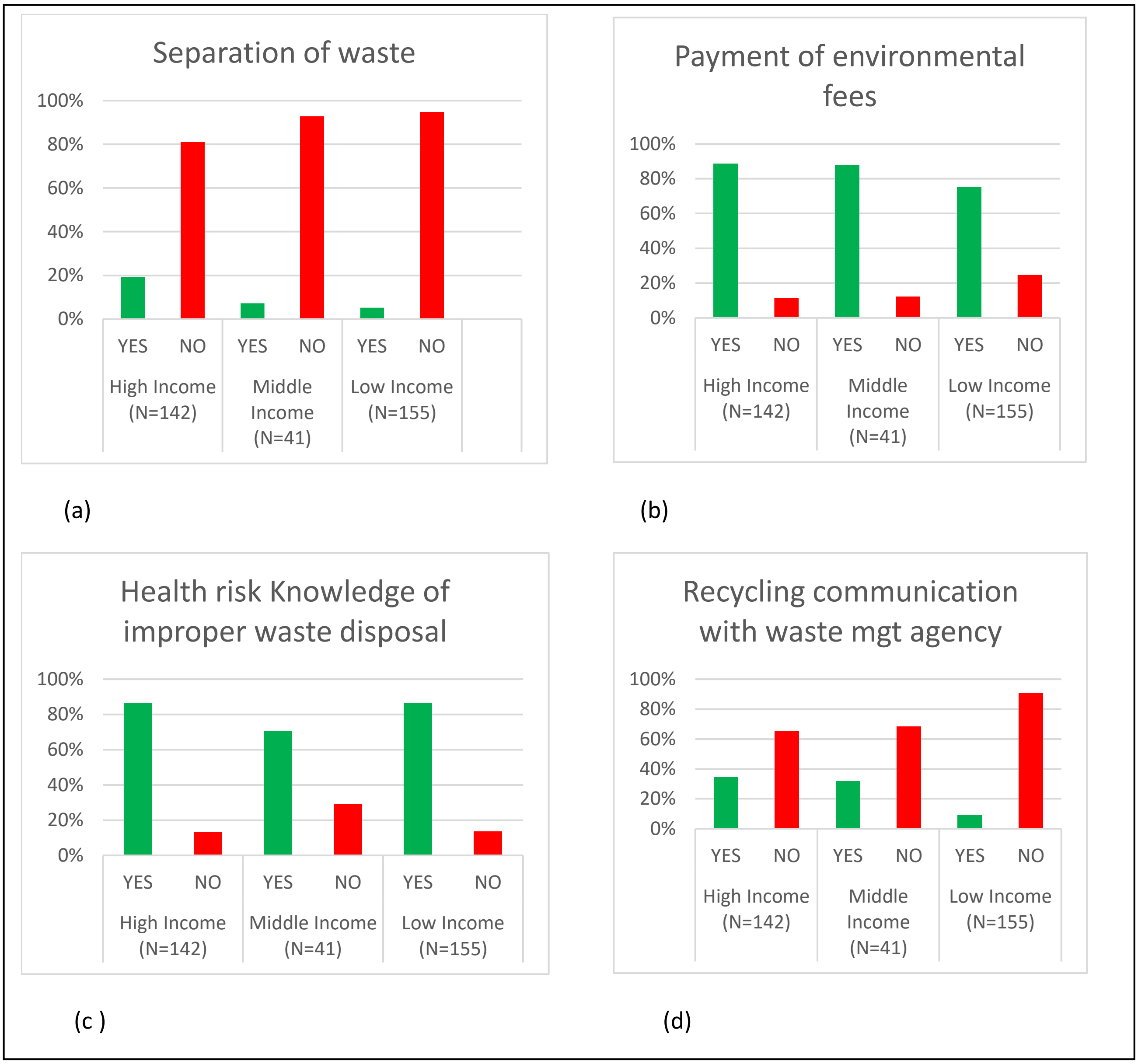


Figure 6.10 Service awareness and practice from respondents in (a) households, or (b) business owners.

Most of the respondents in the three socioeconomic groups and across the households (over 80%) and business (over 70%) areas do not separate their waste at source. Over 80% of residents in the high- and middle-income areas at both household and businesses answered "yes" to the payment of their environmental levies, however this figure was slightly less in the lower income areas, with 67% of household respondents and 75% of businesses indicating they also paid their environmental levies. Most of the local population within the households (over 71%) and business (over 75%) are aware of the adverse environmental and health consequences associated with inadequate management of waste within the area. Across the three socioeconomic groups, the results showed about 60% of households and 80% of businesses mentioned health risk as an associated risk of improper waste management (e.g. “it causes disease, cholera etc.”). While around 36% of household respondents and 18% of businesses acknowledged environmental issues/ climate change as an associated risks of improper waste disposal, for example “it causes flooding, pollution etc”, as shown in Figure 6.11. More so, at least 65% of the participants from the three socioeconomic groups, for both households and businesses, reported that they have not engaged in any form of communication with the waste management agency in relation to waste and recycling. Within this cohort, the majority (91%) of the respondents residing in low-income areas, encompassing both households and businesses, expressed a consensus on inadequate communication between themselves and the waste management agency in relation to waste and recycling.

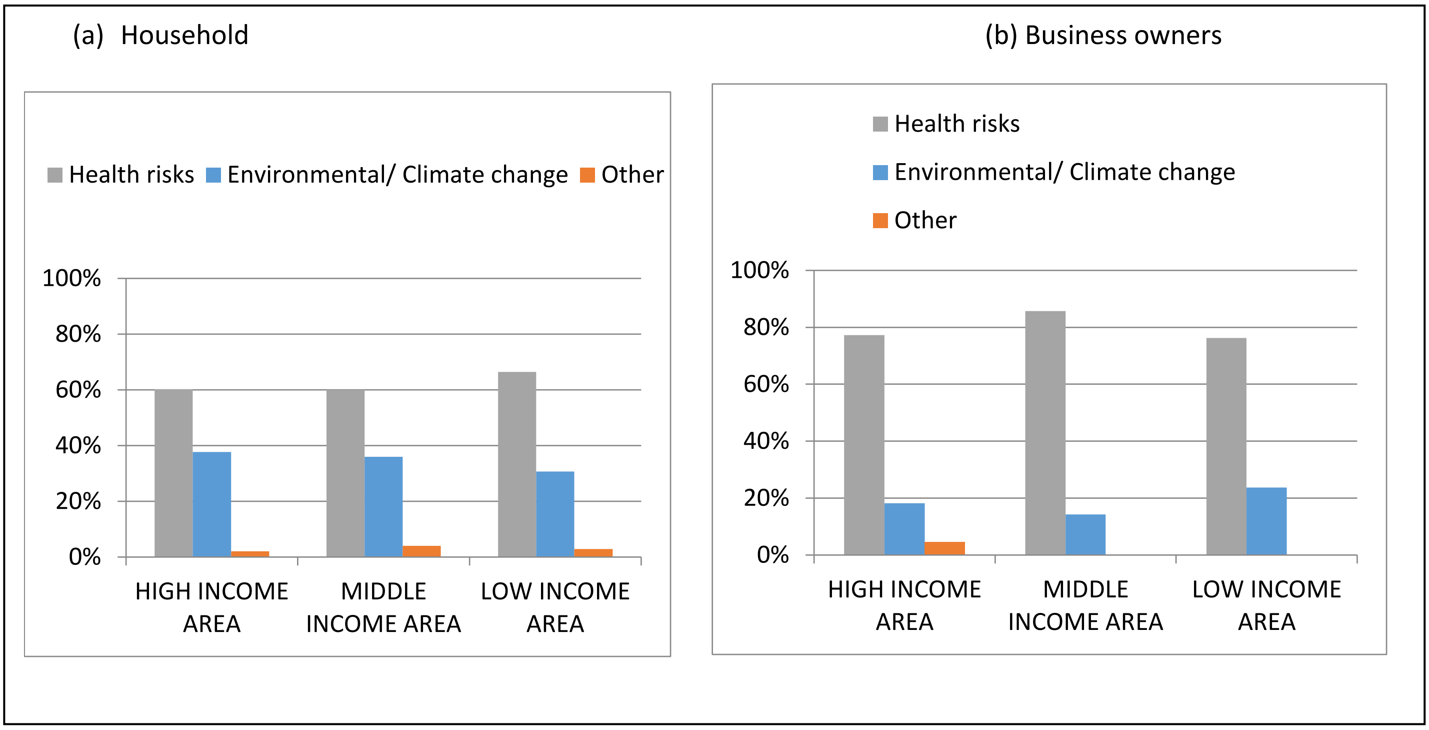


Figure 6.11: Themes revealed when respondents were asked how improper waste disposal is a threat to environment and health, where (a) is the respondents from the households and (b) is that from the business owners.

6.3.7. Communication:

The respondents from both households and business owners from the three socioeconomic areas had a preference for face to face communication when asked about contact from the waste management authorities. At the household level responses ranged from 32% in the middle income area to 56% in the low-income areas.. While at business level responses for face to face communication ranged from 39% to 53%, again the highest level was from low incomes areas. The higher level in the lower income areas may stem from illiteracy, however leaflets were the second most popular method of communication for all respondents. While less than 20% of all respondents had a preference for technology related communication, i.e. phone messages or websites, and this may stem from increased cost of devices. Use of preferred communication could enhance waste management awareness campaigns from the management authority (Figure 6.12), encouraging community participation in waste management. In hind sight including another method option, would have helped to understand respondents perception better, as there may be other methods of communication that could be effective in waste management, for example engagement of religion houses (churches/ mosques), or use of television and radio stations that could captivate the interest of household respondents, most especially from the low income area, that has lower waste management enlightenment that often results to low recycling rate (Zhang 2011; Mamady 2016) aligning with the high religious and media interest in Nigeria (Timlett, et al, 2008; Festus and Ogoegbunam 2012; Salvia et al., 2021).

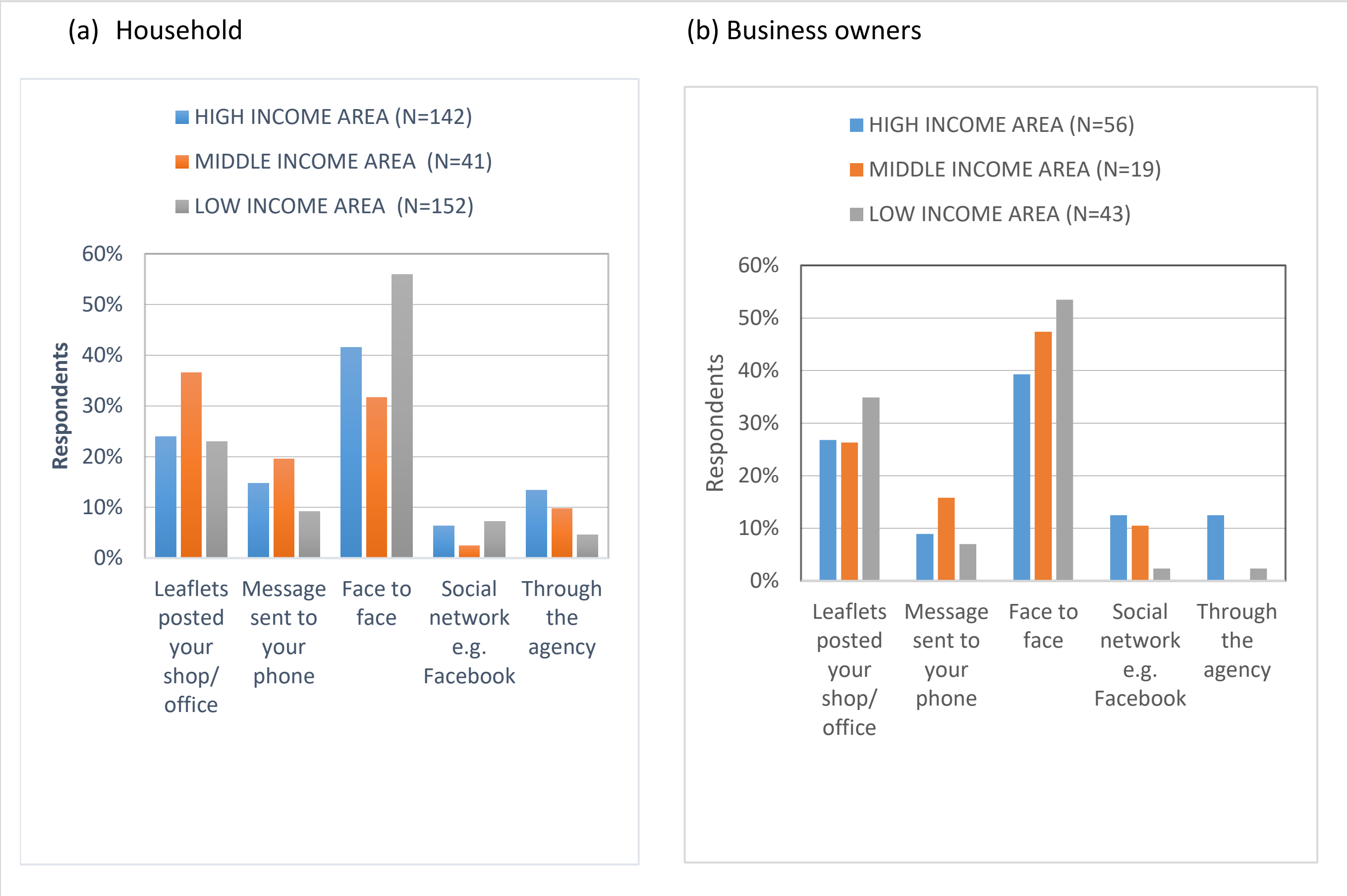


Figure 6.12: Communication preference from the respondents, where (a) is the respondents from the households and (b) is that from the business owners.

6.3.8. Attitudinal Scale:

The findings in Figure 6.13 to Figure 6.16 shows response to the attitudinal questions on waste management at both the household and business level. These were done with the goal of determining the causes that lie behind the most significant issues that have been encountered in the state. Interestingly, a sizable majority, at 78% of household respondents in low income area agreed that corruption can contribute to inadequate waste management"; 52% agreed, 26% strongly agreed. More so, in the high income area of the household, 76% agrees to corruption been a contributing factor to inadequate waste management (where 42% agreed and 34% strongly agreed). The figure was slightly lower for businesses with 47% in agreement in low income area (31% agreed and 16% strongly agreed) and with 63% agreeing in high income area (38% agreed, 25% strongly agreed).

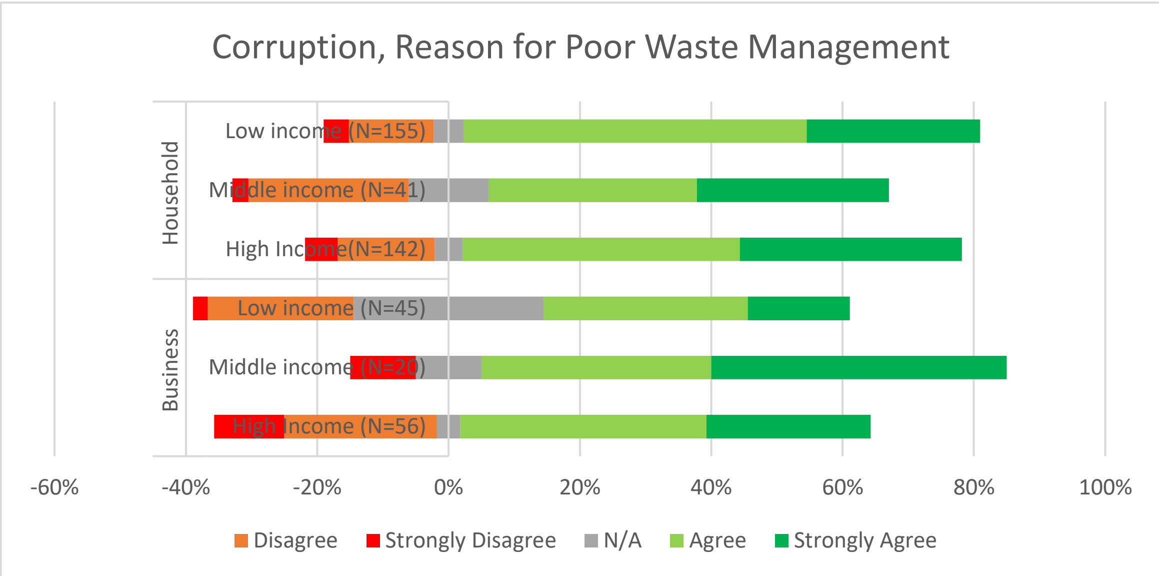


Figure 6.13: Responses on whether corruption plays a role in poor waste management (N/A = Not applicable; neither agree or disagree).

The response to "People throw waste on the street because they don't see government waste collectors" receives high agreement level, especially in the low income area where the level of agreement was at least 80% at both household and business; At the household level, 55% agree to it, while 30% strongly agree to it; however, at the business level, 58% agreed while 22% strongly agreed (in the low income area). However, the high income had the least agreement level, 50%

household (29% agreed and 21%strongly agreed) and 47% agreement level for the business (27% agreed, while 20% strongly agreed) as shown in Figure 6.14.

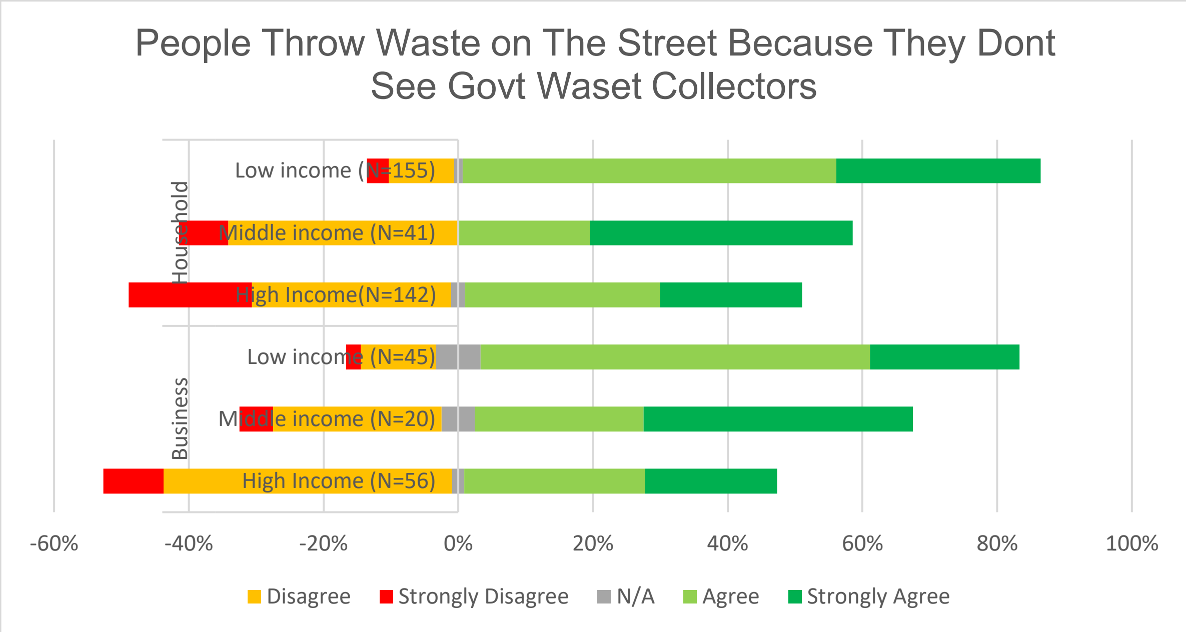


Figure 6.14: Responses to understand whether people throw waste on the road because they do not see government waste collectors (N/A = Not applicable; neither agree or disagree).

For the response to the question "If the collection of waste is done efficiently in the country, people will willingly pay their environmental levy" was noted to be very positive. This is at all income levels – at household level, those agreeing (agreeing or strongly agreeing) ranged from 81% in the middle income area to 96% in the low income area. It was observed that at the household level, about 65% agreed, while 34% strongly agreed. Even at the business level, 54% agreed to the assertion, while 39% strongly agreed as shown in Figure 6.15.

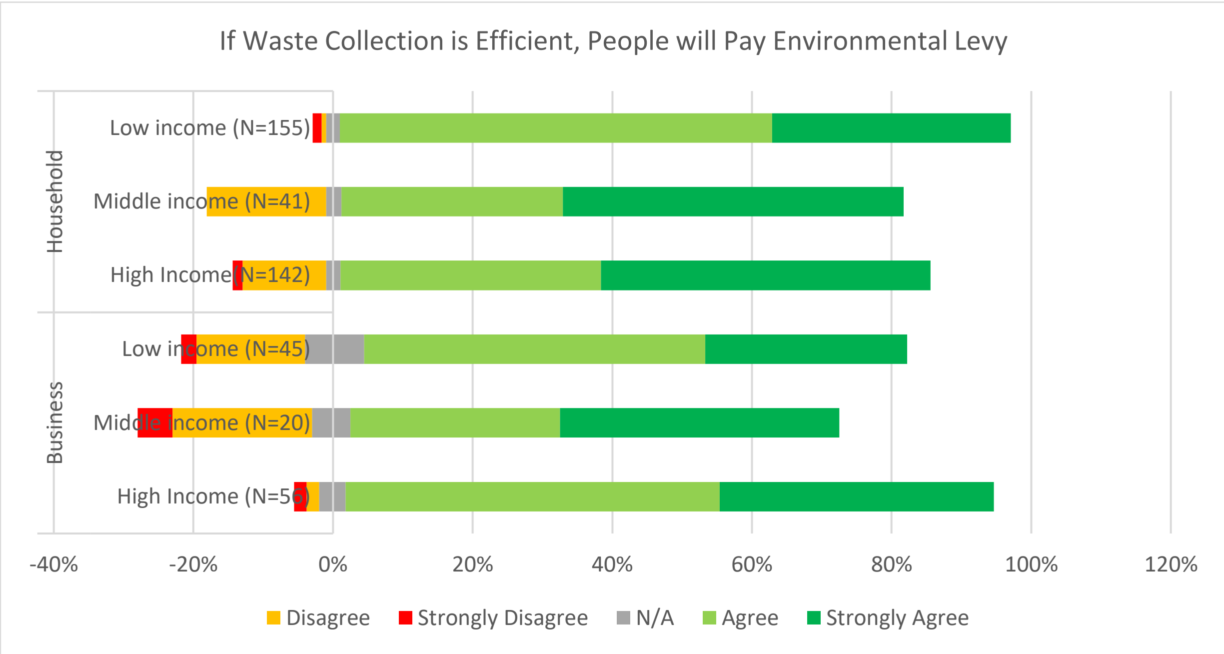


Figure 6.15: Responses to understand if waste collection is efficient, whether people will be willing to pay environmental levy (N/A = Not applicable; neither agree or disagree).

For the response to the question "regular waste collection is a solution to the waste problem in the state" was also noted to be very positive. It was observed that at the household level, at least 95% agreed to the assertion across the three economic classified areas. Even at the business level, at least 90% also agreed to the assertion in both high, middle, and low-income areas too as shown in Figure 6.16.

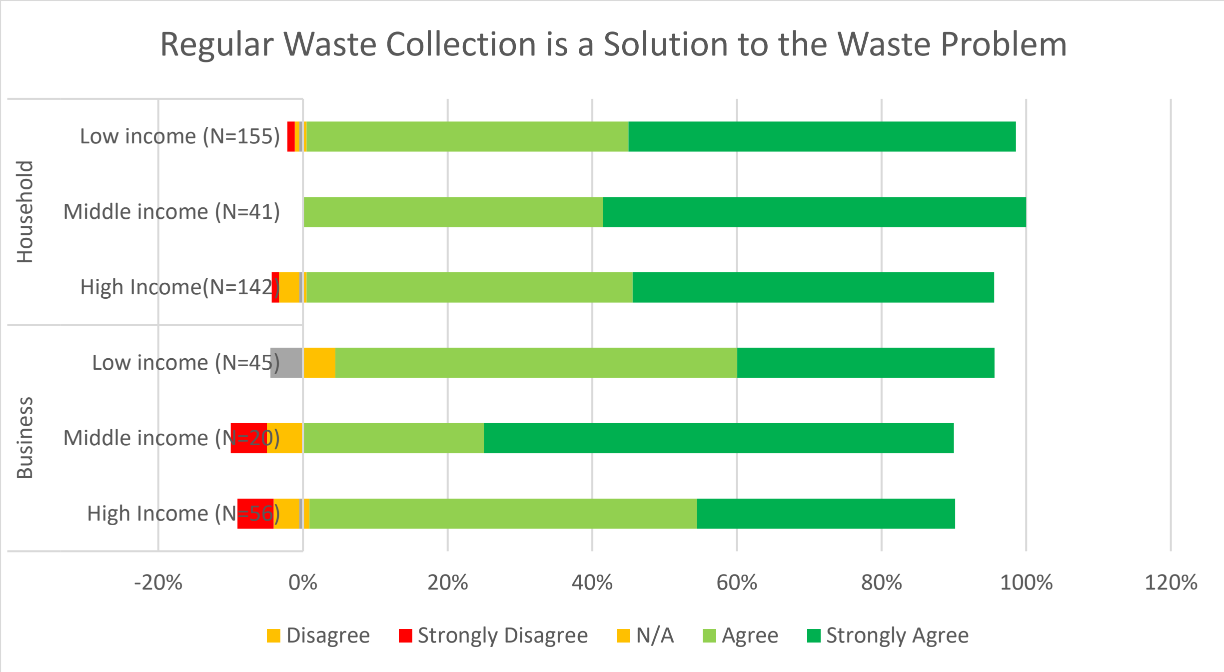


Figure 6.16: Responses to understand whether regular waste collection is the solution to the waste problem (N/A = Not applicable; neither agree or disagree).

It is worthy to note that responses to the question " government is doing enough to fix waste problem in Lagos State" has at least 76% (low- 48% agree while 42% strongly agreed; middle – 34% agreed while 44% strongly agreed; high- 46% agreed while 30% strongly agreed)respondents in agreement in the household area across the three economic classified areas. Then, at least 56% (low- 38% agreed while 18% strongly agreed; middle – 35% agreed as well as strongly agreed to the assertion; high- 39% agreed while 20% strongly agreed) respondents also responded in agreement with same question for in the business as shown in Figure 6.17.

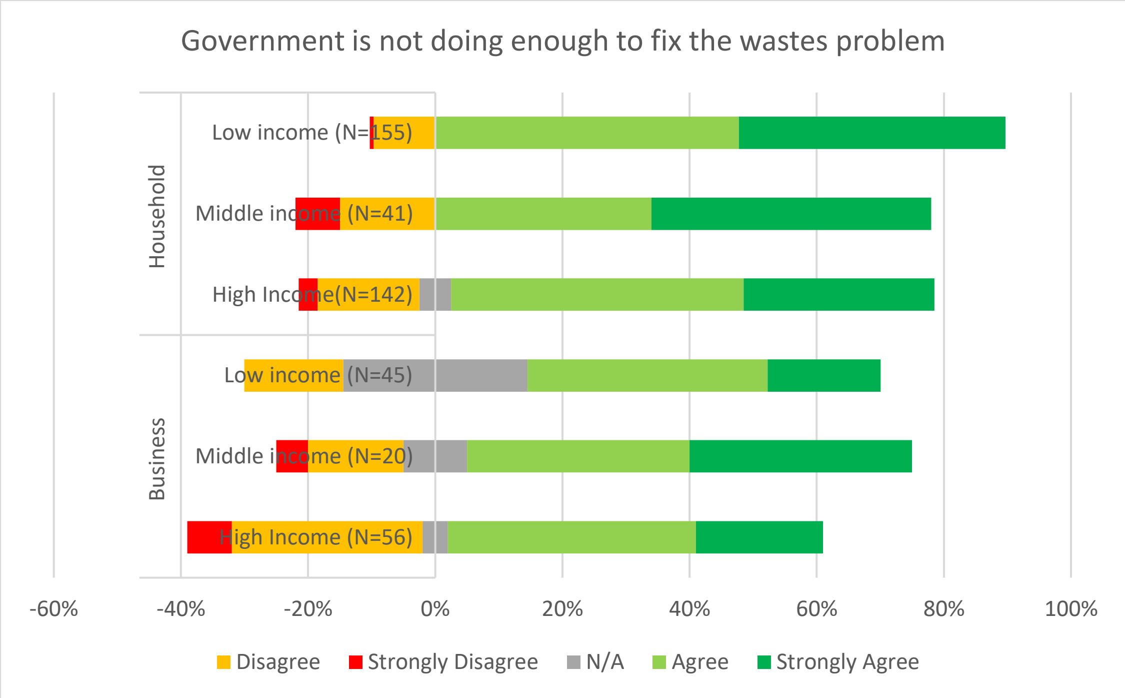


Figure 6.17: Responses to understand whether the government is doing enough to fix waste problem in Lagos State (N/A = Not applicable; neither agree or disagree).

The responses from the household has high level of agreement of at least 98% believing that the country need better environmental management structure. This was observed across the three economic classified areas (low-48% agreed while 50% strongly agreed; middle- 44% agreed while 56% strongly agreed; high- 42% agreed while 56% strongly agreed). Similarly, the respondents for the business had at least 84% (42% both agreed and strongly agreed) in low income area, 90% (25% agreed while 65% strongly agreed) in middle income and 97% (36% agreed while 61% in strong agreement) in the high income areas as shown in Figure 6.18.

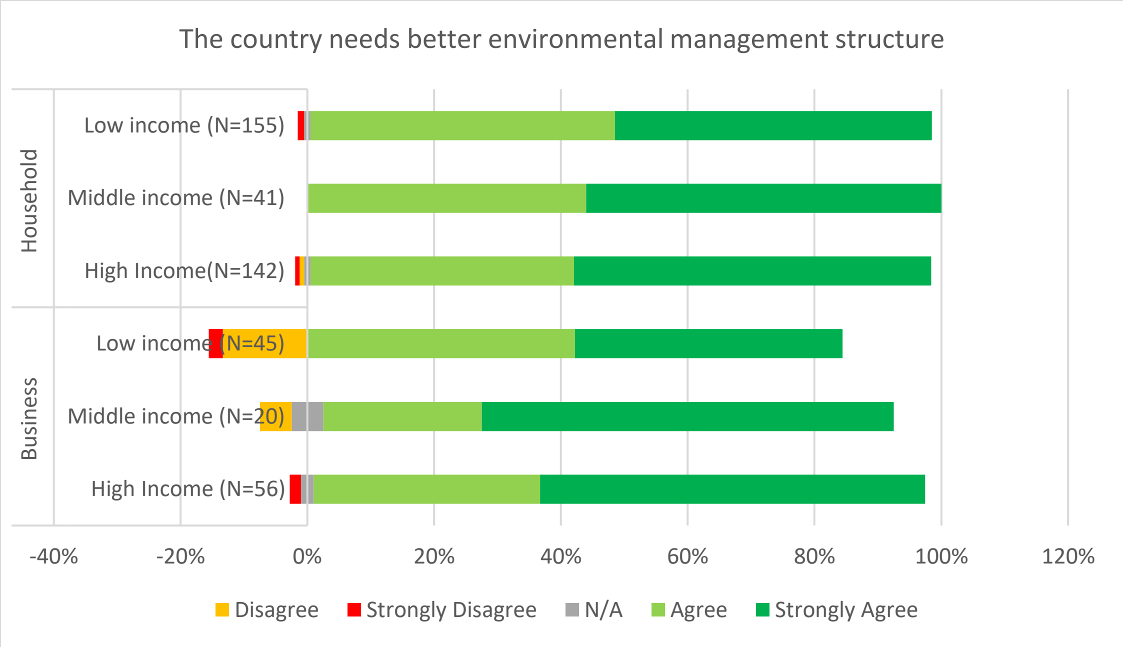


Figure 6.18: Responses to understand whether there is need for better environmental management structure in the country, Nigeria (N/A = Not applicable; neither agree or disagree).

In similar light, Figure 6.17 showed the respondents answers to the question "whether it is important the government put recycling laws in place to enhance waste management government". The results showed that at least 98% (low- 38% agree while 60% strongly agreed; middle – 39% agreed while 61% strongly agreed; high- 49% agreed while 59% strongly agreed)respondents in agreement in the household area across the three economic classified areas. Then, at least 93% (low- 36% agreed while 64% strongly agreed; middle – 20% agreed while 75% strongly agreed to the assertion; high- 38% agreed while 55% strongly agreed) respondents also responded in agreement with same question for the business as shown in Figure 6.19.

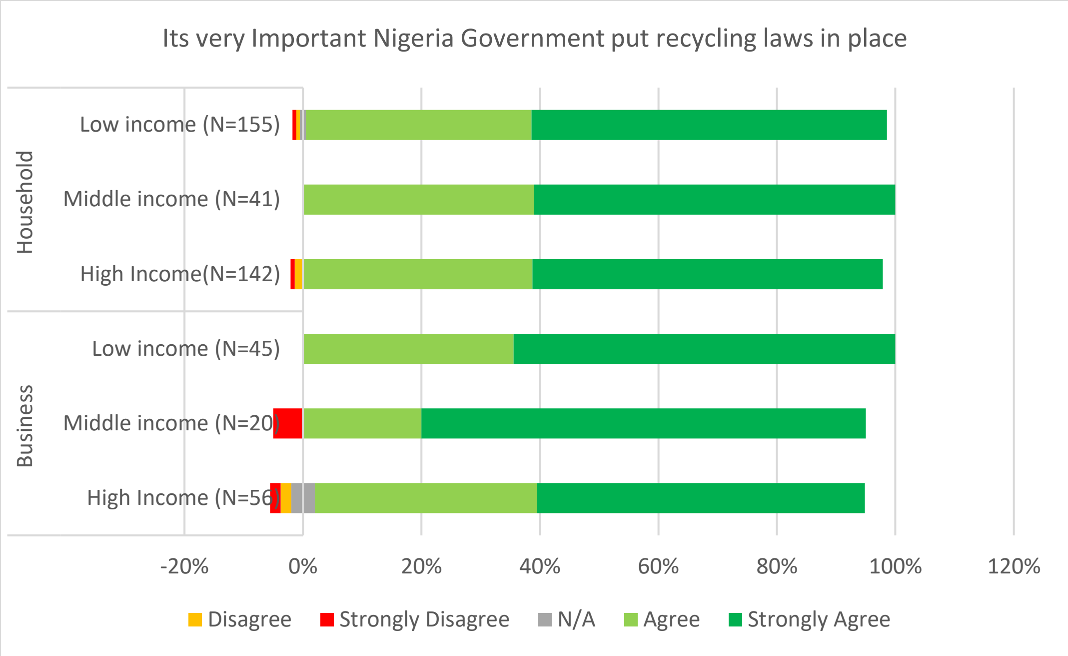


Figure 6.19: Responses to understand whether it is important the government put recycling laws in place to enhance waste management in Lagos state (N/A = Not applicable; neither agree or disagree).

For the question stating that waste management should be taught in schools, the respondents had high level of agreement of at least 98%.This was observed across the three economic classified areas (low-39% agreed while 59% strongly agreed; middle- 37% agreed while 63% strongly agreed; high- 40% agreed while 58% strongly agreed). Interestingly, the respondents for the business had also had high level of agreement of at least 91%, where 95% agreement in both low and middle income (low- 51% agreed and 44% strongly agreed in low income; middle – 30% agreed while 65% strongly agreed) and the high income showing 27% agreed and 58% strongly agreed as shown in Figure 6.20.

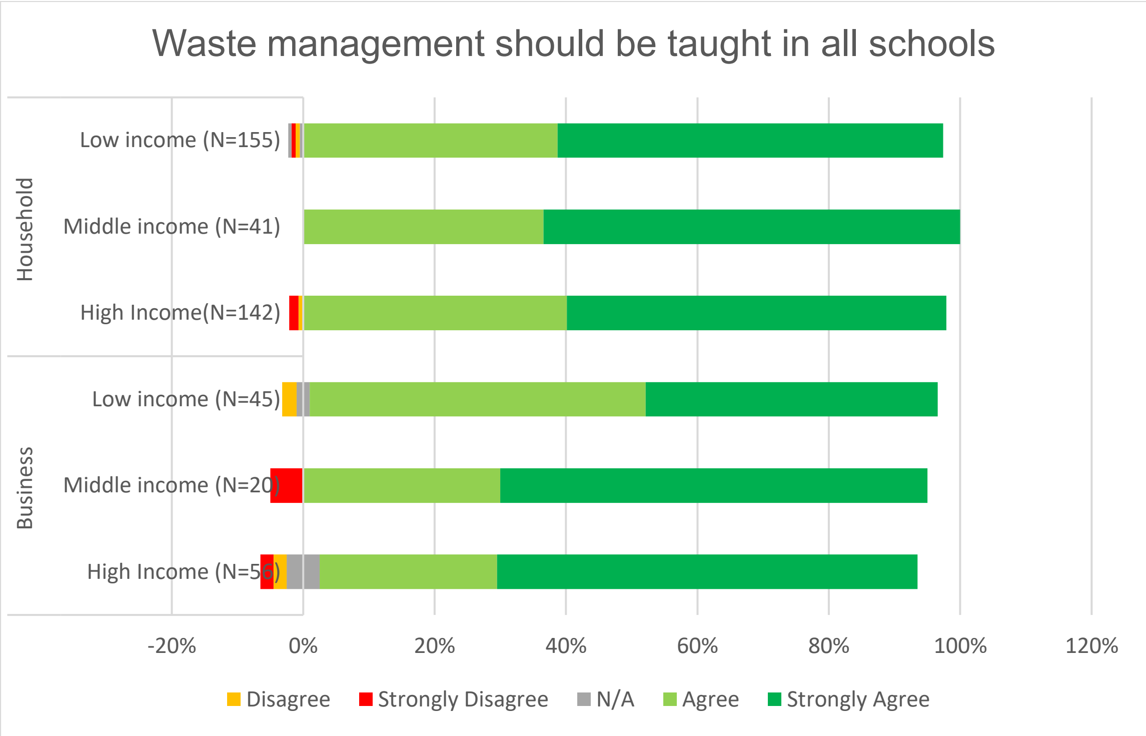


Figure 6.20: Responses to understand whether waste management should be taught in all schools (N/A = Not applicable; neither agree or disagree).

6.4. Statistical Analysis:

In the Pearson bivariate correlation analysis, the responses of agreement to different questions were analyse. Among the various responses and the correlation among its different combinations, just few of the responses were correlated in the different economic classified areas, as shown in Table 6.2. The correlation coefficient, r, and its interpretation which shows the degree of the strength of the relationship among the variables were evaluated. There is relationship when r- value ranges from -1 and 1. When value is closer to 1, it's a strong positive correlation, when value is closer to -1, it's a strong negative correlation, and when r-value is around 0, no correlation exists. The significance level (2 tailed) was further assessed to ensure any relationship between these variables did not happen by chance. At 95% confidence level, it is expected that the significance value is less than 0.05, which means the chance of error of relationship is less than 5% (Jain and Chetty, 2019).

Table 6.2: Correlation showing the relationship between people's different responses of agreement. (HH = household, B = Business).

Income areas	Combination of questions' response	Correlation coefficient (r)	Interpretation for "r" (Akoglu 2018; Schober 2018; Jain and Chetty (2019)	Significant level (2 tailed)
High HH	"The country needs better environmental management structures" (98% in support) and "The government is not doing enough to fix the waste problem,"(76% agreement)	r = 0.462 (N=142)	moderately positive correlation	0.00 (2 tailed)
	"Regular waste collection is the solution to the waste problem,"(95% agreement) and "The country needs better environmental management structures" (98% in support)	r = 0.452 (N = 142)	moderately positive correlation	0.00 (2 tailed)
	"Waste management should be taught in all schools,"(98% in support) and "The country needs better environmental management structures" (98% in support)	r = 0.605 (N=142)	**moderately positively correlation**	0.00 (2 tailed)
	"If the collection of waste is efficient in the country, people will willingly pay their environmental levy." (84% in agreement) with "Waste management should be taught in all schools," (98% in agreement).	r = 0.598 (N=142).	**moderately positive correlation**	0.00 (2-tailed).
High B	"Do you separate waste?" (74% respondents answered "no") with "have you been in communication with the waste management agency	r = 0.463 (N = 56)	moderately positive correlation	0.00 (2-tailed).

	regarding waste and recycling?"(where 65% and above responses signifying “no” across all sample areas, but 91% in low-income areas of both household and business owner).			
Middle HH	“people’s knowledge on segregation at the source” (32% poor while 51% do not understand the question, hence stating not applicable (NA) with “do you separate waste?" (93% of respondents do not).	r = -0.412 (N=41)	moderately negative correlation	0.08 (2 tailed).
	“people’s knowledge on segregation at the source” with "Do you see waste on the road?" (65% in both household and business owners responded “yes”).	r = 0.564 (N=41)	moderately positive correlation	0.00 (2 tailed).
	"People throw waste on the street because they don’t see government waste collectors,"(59% agreement) with" communication from a waste management agency regarding waste and recycling?" (65% responded in disagreement)	r = -0.480 (N=41)	moderately negative correlation	0.002 (2 tailed).
	open-ended question "What are the problems of waste management in the state?", (ineffective waste collection has 57% in response) with "How much waste is generated in your house?" (that shows 37% respondents generates about 7kg of waste weekly)	r = -0.548 (N = 14).	moderately negative correlation	0.043 (2-tailed)
	"If the collection of waste is efficient in the country, people will willingly pay their environmental levy." (which shows 81% agreement) with "People throw waste on the street because they don’t see government waste collectors." (that shows 59% agreement)	with r = 0.651 (N=41)	**moderately positive correlation**	0.00 (2-tailed).
	"If the collection of waste is efficient in the country, people will willingly pay their environmental levy." with "Regular collection of waste is the solution to the waste problem" (which has 100% agreement in middle income area) with	r = 0.596 (N=41).	**moderately positive correlation**	

	"People throw waste on the street because they don't see government waste collectors," with "government is not doing enough to fix the waste problem," (76% in agreement).	r = 0.776 (N=41)	**strong positive correlation**	0.00 (2 tailed).
Middle B	open-ended question "How can the waste management problem be solved?" (which pointed to efficient waste collection service (38%), monitoring (25%)), with "Communication with waste management regarding waste and recycling can help in the State's waste management?" (65% in disagreement).	r = -0.541 (N = 16).	moderately negative correlation	0.030 (2-tailed)
	"Do you separate waste?" (which shows 65% respondents noting "no" on their responses in the middle-income area) with "Have you been in communication with a waste management agency regarding waste and recycling?"(which shows same 65% respondents signifying "no")	r = 0.435 (N = 20)	moderately positive correlation	0.055 (2 tailed).
	"If the collection of waste is efficient in the country, people will willingly pay their environmental levy." (which shows 81% in agreement) with "People throw waste on the street because they don't see government waste collectors." (which shows 59% agreement)	r = 0.629 (N=20)	**moderately positive correlation**	0.003 (2 tailed),
	"If the collection of waste is efficient in the country, people will willingly pay their environmental levy." with "regular collection of waste is a solution to waste," (which shows 100% respondents in agreement).	r = 0.640 (N=20)	**moderately positive correlation**	0.002 (2 tailed).
Low HH	"The country requires a better environmental management structure" (98% in agreement). with "If waste is collected efficiently in the country, people will gladly pay their environmental levy," (which has 96% respondents in agreement)	0.421 (N = 155)	moderately positive correlation	0.00 (2 tailed).

	"The country requires a better environmental management structure" with "Regular collection of waste is the solution to the waste problem," (99% in agreement).	0.418 (N = 155)	moderately positive correlation	0.00 (2 tailed).
	"Regular collection of waste is the solution to the waste problem." with "It is very important the Nigerian government put recycling laws and programmes in place." (98% in agreement).	0.698 (N = 155)	**moderately positive correlation**	0.00 (2 tailed).
Low B	**"Do you separate waste?" (91% responded "no") with "Have you been in communication with the waste management agency regarding waste and recycling?" (where 91% noted "no")**	with r = 0.584 (N = 45)	**Moderately positive correlation**	0.00 (2-tailed).
	"Corruption can be one reason why there is poor management of waste. (which show 47% respondent's agreement)" with "government is not doing enough to fix the waste problem" (56% in agreement).	r = 0.435 (N = 45)	moderate positive correlation	0.003 (2 tailed).

**At 95% confidence interval, the Significance level (2-tailed) is expected to be less than 0.05 (Jain and Chetty 2019).

6.5. Discussion:

6.5.1. Demographic Characteristics:

6.5.1.1. Age Group:

The survey result showed that there is good representation in the age categories under 50, but poor representation above 50 (less than 16%). This shows no full representative of the age group demographic distribution across both the household and business areas (see Figure 6.2), hence would be seen as being slightly age biased in the population. When compare with the Lagos state's population in 2006, about 64% of the population fell between the ages of 15 and 59. While 31.2% of the whole population was under the age of 15, and interestingly, just 4.2% were 60 years or above (United Nations Population Fund, 2015). This reflects the demographic change the state has experienced in past decades (Bloom et al., 2003). Demographics are a known factor that could affect the quality of data in a survey, potentially leading to a biased outcome (Mitchell et al., 1996; Bowling, 2005).

Most of the people surveyed were younger than 35 in all socioeconomic areas and from both households and businesses (Figure 6.2). This shows the willingness of young people to participate in the survey, which is in line with the report of United Nation (2020) that this present generation of young individuals possesses the capacity to initiate a fund amental change in the field of sustainable development and they strive to engage in community participation as a means of effecting change within their immediate surroundings. More so, the above age group (younger than 35) falls among the youths who can potentially be the champions of waste management for great behavioural changes, as studies have shown that such young people are change agents for sustainable city transformation when they are carried along (Velasco and Harder 2014; Azeiteiro et al., 2017).

6.5.1.2. Education:

The high income area was seen to have the highest number of university degree holders, which was about 75% (N=142), and the percentage of secondary school certificate holders was very low (about 15%), which suggested the focus of this area towards achieving higher education degree like the university degrees. This further suggests that family's socioeconomic status has a significant change in the academic attainment of a person, as wealthier families can afford and encourage their children to go to school (Yan, 2022). This is in line with other research that suggests also that income level is associated with academic achievement (Lurie et al., 2021; Munir et al., 2023; Vadivel et al., 2023).

However, when result was compared with the middle income area, the percentage of university degree holders dropped to 54%, but that of secondary certificate holders increased to 34%, suggesting similar influences of socioeconomic status to accessing education (Oreopoulos, and Salvanes, 2011; Llie et al., 2021). However, there was a clear change for the low income area, which had the lowest number of university degree holders (41%) and 47% for the secondary school certificate holders (highest). The above pattern from HH was also observed in the business, which supports other research that shows economic status affecting or influencing access to attaining higher education, hence, bringing concern of the inequality in the low income area, while at same time highlighting the need to addressing such inequality in education across the least classified economic areas (low income area) in order to also boast rise in economic lifestyles in this area too (Kena et al., 2016; Llie et al., 2021).

6.5.1.3. Employment Status:

The business owners are already in business, however, respondents from the households(HH) in the high income area had the least unemployment level (9%) and mostly student (43%, N=142). This suggests people in this area are engaged as well as desiring higher education which is in line with the educational explanation in Chapter 6.5.1.2. and de. This is followed by 10% unemployment and 35% students in the middle income area (N=41), while the low income (N=155) had highest unemployed (16%) and least student (25%) and as shown below. Notwithstanding the above result, it further showed the level of employment for the high income area was 33%, which is lower than the low-income area (having 40%), but higher that the employment level in the middle income area (18%) as shown below. There were also respondents that were retired; 4% (high income), 15% (middle income) and 6% (low income area). The above supports studies affirming the challenges face by low income areas towards education and more job opportunities (Halpern, 2000; King et al. 2008; Mammen et al., 2011), hence, need to even explore further studies that could understand and address those challenges in the low-income area.

6.5.2. Waste Management:

6.5.2.1. Waste Generation:

To make the assessment of waste generation easier for the respondents, simple measures such as a bag of waste was used in the questionnaire. A bag of waste was roughly equivalent to 7kg of waste. In households, the daily waste generation at this level was highest at the high-income area (24%), followed by the middle-income area (20%) and then the low-income area (19%). This suggests that the people in the high-income areas tend to generate more solid waste daily compared to middle and low-income areas. But for the business area, the middle-income area tended to generate more daily waste (35%) when compared to other income area that have 29%. The high daily waste generation could be because of the nature of business for those areas. For instance, there is variety of different businesses for example provision stores, pharmaceutical shops, unisex hair salons, etc., which also deal in consumable goods and offer services that generate daily waste. These sales and services further demonstrated the growing concern over the increase in daily waste generation (Koushki et al., 1998; Miezah et al., 2015; Apeh, 2018).

Over one third of respondents in the high- and middle-income areas indicated they were producing this amount for waste on a weekly basis. While at the business level, on weekly waste generation, there was not much difference (21%-25%) between the three socioeconomic areas (high, middle, and low income areas), at household level about 35% of the high and middle income areas were generating this amount of waste - this number of respondents in the low income area was producing this level of waste every 2 weeks – a big pointer to those in low income areas generating less waste. However, under 20% of the low income areas produced this amount of waste suggesting waste disposal occurs less frequently. This confirms that waste generation varies across income areas and could be attributed to factors such as difference in consumption pattern or waste management practices across the classified economic areas. This result varies from that of Warunasingle et al. (2016), which showed that over 70% of household's waste generation is over 2 kg daily (about 14 kg per week) in developing country, however, the results show that changes in income can indeed affect the rate of waste generation in the assigned economic areas. Income variation affecting the rate of waste generation has been affirmed by Sivakumar and Sugirtharan (2010), who found there is often a higher consumption rate as well as higher waste generation in high-income areas than in the low-income zones. The result of Sivakumar and Sugirtharan (2010), further showed a direct correlation between family income and size with the amount of residential solid waste generation. This assertion is further supported by Grover and Singh (2014), who also stated that high-income earners consume more than lower-income ones; hence, the waste generation rate is always higher for the former when compared to the latter (Sivakumar and Sugirtharan 2010). This could be one of the reasons there are more government waste collection services in those high- and middle-income areas than in the low-income area. Another factor is compliance with the payment of the environmental levy which could potentially cover the cost of regular waste collection. The result shows that at the household level, 89% of respondents in high-income areas pay their environmental fees when compared with 75% of the respondents at low-income areas. Similarly, at the business level, 91% of respondents pay their environmental fees at the high income area when compared with 67% that pays at the low income areas. This is in line with the assertion that the high-income areas may be better placed to pay, while the low-income areas may find it difficult to comply with such payments, thereby limiting the services of the waste management agencies in those areas (Zia et al., 2017).

6.5.2.2. Roadside Waste Littering:

The findings of the survey indicate that, despite the government's endeavours in waste management, specifically in waste collection services, there is a substantial presence of littered waste on the roadsides. This conclusion is supported by the replies obtained from participants and the visual evidence presented in Figure 1.3. The result shows about 76% of people in both groups agreed that waste is littered along roadsides between homes within high and middle incomes. This suggests that regardless of their financial situation, people usually deal with waste-related issues. This further indicates that the continuous problem of waste on roadways could be caused by factors other than income, such as government, public involvement, or waste infrastructure (Salvia et al., 2021; Rossi et al 2023).

On the other hand, the considerable increase to 92% among low-income households highlights a worrisome disparity. This result could point to systemic problems that economically underprivileged areas face such limited access to waste management services. It shows that targeted projects in economically underdeveloped areas are desperately needed to address the notable amounts of waste collection issues. Waste management plans to increase environmental knowledge and community-driven projects addressing littering are needed (Salvia et al., 2021; Perkumienė et al., 2023). This finding is in line with Ogwueleka (2009), who stated that inefficient collection methods and insufficient coverage of the collection system remain a big challenge in Nigeria. Although according to Babayemi and Dauda (2009), such ineffective waste collection service could be attributed to locational issues (Babayemi and Dauda 2009), as seen in the high-income area and the middle-income areas that have a greater presence of waste collection service than the low-income area. There are also issues with waste haulage trucks breaking down and, hence, would not be able to meet up with the day’s task (see Figure 3.7).

Funding was a huge factor identified as a challenge by respondents, as it hinders the waste authority's ability to cover all the areas of the state. This funding is bifurcated, as some individuals complain of financial hardship that prevents them from paying environmental levies, while the waste management authority lacks adequate funding in the sector as a challenge that impedes their service efficiency (Ogwueleka, 2009). However, some are of the opinion that it is corruption that is a key challenge faced in the waste sector, apart from some areas not being able to pay up their waste management levies. According to Taiwo (2009), Nigeria, like other developing countries, has yet to address the problems of solid waste management through adequate legislation and other implementation measures, which are linked to a lack of coordination mechanisms and corruption. Despite their hard work, the government waste management agencies are usually accused of either ineptitude in waste management or corruption (Taiwo, 2009; Amasuomo and Baird, 2016).

6.5.2.3. Waste Management Performance:

Over 70% of households and business owners in high- and middle-income areas use government waste collection services. This is twice as high as the finding of Babayemi and Dauda (2009), who found that only 35% of respondents use the government waste collection service in Abeokuta, Nigeria. This figure is more in line with approximately 40% that uses such service in the low-income areas. The high usage of the service in the high- and middle-income areas could be attributed to the availability of the services in those areas, as they are not often the areas that pay their environmental levy, as the low-income areas also claim to pay for waste management services, but do not often receive regular waste collection services (Kubanza 2024). In view of the challenges of funding and inadequate waste collection coverage, which are the primary causes of the obvious observable ineptitude as perceived by the public, there should be a good strategy to address waste collections issues through structural organization, especially through community engagements, building capacity of stakeholders, technological adoption like route optimization, regulatory framework including implementation and effective enforcement, as well as penalties for non-compliance among others will help maximize the efficiency in waste collection service.

Research has shown that over 60% of waste management budgets are used for waste collection and transportation (Chalkias and Lasaridi 2009; O'Connor *et al*., 2013); however, much of this cost ends up in the payment of salaries and fuel. To be more efficient in waste collection, it is therefore essential that strategies such as GIS routing of waste management coverage areas is completed to identify the shortest route during waste collection to improve and collect waste more efficiently. Routing using GIS has been found to be an efficient and cost-effective approach to waste collection and transportation. For instance, it has been used in the past to optimise waste collection bin positions in Sfax City, Tunisia (Kallel *et al*., 2016). Kallel et al. (2016) developed three optimal scenarios using an ArcGIS Network Analyst tool to compare with solid waste collection and transportation based of the three different scenarios to understand and improve the efficiency of waste collection. The findings showed that up to 57% of time could be reduced and 48% of fuel consumption could be saved when waste collection was optimised (Kallel *et al*., 2016). For Lagos State, this could potentially reduce the cost of waste collection and transportation, thereby enabling waste collection coverage, which will further assist in reducing the rate of bad waste management practises.

More so, there should be enforcement of environmental laws and working with local community leaders to ensure a higher rate of waste payment compliance (Gunningham, 2011; Paddock *et al*., 2011). Waste management regulators often do not engage in strict enforcement of environmental laws as it usually plagues into problems ranging from increase in indiscriminate dumping of waste on the roadside to dumping on river network, which makes achieving sustainable waste management results difficult (Ogbonna et al. 2002; Gunningham, 2011; Odiete 2022). There is also a need for constructive collaboration between waste management regulators and traditional or community leaders, as well as law enforcement agencies, which will enhance a better result towards achieving environmental compliance (Paddock *et al*., 2011).

6.5.3. General Assessment of Attitudinal Scale:

The responses from the survey showed that there were levels of "agreement" to the fact that "corruption can be one of the reasons why there is poor management of waste". The survey results indicated that most respondents from the low-income area expressed agreement with the statement at the household level, with 52% agreeing and 34% strongly agreeing. For the business level, 38% of respondents agreed and 25% expressed strong agreement with the assertion in the high-income area, while about 35% agreed and 45% strongly agreed to the assertion too in the middle-income area, as shown in Figure 6.7. This shows that some of the public still perceives that the government is corrupt. It further confirmed the alignment with the result of Taiwo, (2009) which suggests the waste management agencies are usually accused of either ineptitude in waste management or corruption.

More so, the high response rate of "people throwing waste on the street because they don’t see government waste collectors" at both the household and business level, complements the finding that the waste management agencies are inefficient and ineffective in waste collection services, which results in the waste seen on the roads of Lagos.

The effective waste collection service provided by the appropriate authority remains the key to solving the problem of waste management. Although payment of the environmental levy and inadequate funding are identified as the major setbacks to regular waste collection, poor funding, according to Ogwueleka (2009), is one of the main reasons that most environmental protection agencies in the country resort to hiring waste collection vehicles and maintaining a low workforce on a permanent basis, resulting in poor waste collection services because they will not be able to deploy a good coverage and, as a result, waste is disposed of indiscriminately. However, if good service is provided, there is a possibility that the public will pay their levy. This is demonstrated in the response to the question "If the collection of waste is done efficiently in the country, people will willingly pay their environmental levy.", where most households (65% agreed, 34% strongly agreed) and business (54% agreed, 39% strongly agreed) agreed. However, attitudinal or behavioural change goes beyond knowledge dissemination, often, requiring more context-specific strategies, through social incentives for example due to inadequacy of institutional infrastructure and lack of a comprehensive management and planning strategy that hinders the effectiveness of SWM in South Africa, community participation including developing a pro-poor approach, which could involve both the homeless and unemployed (which reduces shortage of human resources and creating jobs) presents an opportunity towards achieving sustainable waste management in Johannesburg, South Africa (Kubanza, 2024). Infrastructure-service pairing is another behavioural change that needs to be addressed, like the regular waste collection, it must coexist with education. For example, regular waste collection and a monthly sanitation exercise as part of community cleanup in Rwanda's Umuganda, reduced littering drastically, making people more mindful mindful of their waste disposal approach (Yee 2018; Chen and Redkar-palepu 2023). A nudge to enhance the application of knowledge, is important in changing behaviour. Using signage with localized messages, for example written in pidgin English "Don't Trash Lagos!", which can encourage citizens to improve bin usage in the low-income areas (Obeirne 2023). Other interventions incorporate the COM – B model which changes behaviour by interact with three primary factors, capability, opportunity and motivation, and has been shown to be globally effective in addressing behavioural change (Michie et al., 2011; West and Michie 2020; MacDonald et al., 2023).

6.5.4. Service Awareness Practice and Communication:

The low rate of communication between the waste management agencies and the public has a negative effect in the overall compliance with the waste management laws and even on safeguarding public health. Preventive measures against the health risks of improper waste disposal and management, such as being aware of the negative consequences of improper waste disposal, could significantly reduce the incidence of health impacts caused by poor waste management practices. For instance, some of the health impacts on people near landfill investigated in previous epidemiological research literature include cancer, birth defects, respiratory diseases, etc. (Elliott et al., 2001; Porta et al., 2009; Kah et al., 2012). The incidence of such health impacts is within 2 km of landfill sites (Dolk et al., 1998; Elliot et al., 2001; Vrijheid et al., 2002). It is also known that some people in developing countries live close to landfill sites (Minh et al., 2003; Gouveia et al., 2010; Ferronato and Torretta 2019) and practise bad waste management practises that could endanger their health. Poor solid waste management regulations, implementation and enforcement contribute to this, hence, potentially increasing public health risks. However, when preventive measures (such as service awareness and effective communication) are implemented, some of the risks associated with bad waste management practices as mentioned above could be mitigated.

The preferred modes of waste management communication from waste management authority as perceived by the respondents were "face to face" and "leaflets." Approximately 56% of low-income households and 53% of business owners have this preference for specific mode of communication. This is attributed to their desire to be informed on measures taken by government to ensure good waste management, hence, leading to the public change in behaviour regarding good waste management practice.

Creating awareness of the benefits of waste recycling can serve as a tool to increase public participation. According to the findings of Desa et al. (2012), who investigated environmental awareness and education as a key to solid waste management at the University of Malaysia, it was found that such knowledge is one of the key approaches to solid waste management, and awareness campaigns on inefficient recycling and communication strategies that focus on environmental education have proved to be effective for wider participation in recycling (Desa et al., 2012). This is further supported by Amasuomo and Baird (2016) and Mamady (2016), who are of a similar opinion that increasing knowledge-based campaigns on waste-related environmental and health issues can foster positive attitudinal change towards safe waste management practice.

6.5.5. Statistical Analysis:

. Nevertheless, several questions were responded to inaccurately or left unanswered, which was removed during data cleaning, resulting in a limited number of viable responses, particularly in relation to the open-ended inquiries. The identification of this issue is commonly observed in surveys (Leo et al., 2015). The bivariate correlation analysis conducted using Pearson's correlation coefficient was the statistical method used to further understand the results, which revealed the presence of both positive and negative correlations among the questions, as indicated in the obtained results session. An explanation of correlation coefficient can be found in appendix 6.4

6.5.5.1. High income area:

For household level, the responses to the question about "the country needs better environmental management structure", had a moderately positive correlation with that of the question about "the government is not doing enough to fix the waste problem", and with the question "regular collection of waste is the solution to the waste problem," as well aswith that of the question "waste management should be taught in all schools," showing that management structure is a key to more efficiency in the waste management sector. A good management structure entails proper understanding of the standard working relationship with other stakeholders for good synergy to produce the best result. According to Thyberg and Tonjes (2015), a good waste management structure should encompass, among others, competence and training of staff, evaluation of compliance, monitoring and measurement, and communication with relevant stakeholders. Stakeholders are crucial to the success or failure of a waste management system because of their unwillingness to support a mission, usually leads to the potential failure of such mission (Bal et al., 2013; Tennakoon and

Kulatunga 2021; Koiwanit and Filimonau 2023). Recent studies of the relationships between a waste management project's success and stakeholder performance shows significant system management performance is enhance by stakeholders' participation (Bal et al., 2013; Tennakoon and Kulatunga 2021).

While at the business level, the response to the question "Have you been in communication with the waste management agency regarding waste and recycling?", being "no" had a moderately positive correlation with that of the question "Do you separate waste?" which is also a "no." This demonstrates the importance of communication in better understanding the recycling concept, as it has been shown to be effective in increasing recycling participation (Desa et al., 2012; Mamady, 2016). The same thing applies to the responses to the question "communication from waste management authority on waste collection days," which had a positive moderate correlation with that of the question "people's knowledge on segregation at source."

6.5.5.2. Middle income area:

The responses to the question which focused on "people's knowledge of segregation at the source," had a moderately negative correlation with that of the question "Do you separate waste?". More so, a moderately positive correlation with waste littering, which is reflected in the question "Do you see waste on the road?" shows a lack of understanding of the benefits of proper management practices. Waste littering on the roads will be reduced if the public is educated about waste separation, good management practice and its importance (McAllister, 2015). The prevalence of waste on the streets, especially in developing countries, has been witnessed in lots of literature (McAllister, 2015). This is also relative to the negative attitude toward improper waste disposal, as in the case of the question "People throw waste on the street because they don’t see government waste collectors," which also had a moderately negative correlation with the question, "Communication from the waste management agency regarding waste and recycling?". The lack of communication from appropriate authorities had the tendency to result in people throwing waste on the street when government waste collectors did not show up.

The open-ended responses to the question which surveyed the problems of waste management in the state, had a moderately negative correlation with that of the question "How much waste is generated in your house?". The amount of waste generated may have an impact on the issue of waste collection inefficiency, as when there is usually more waste than waste collectors can collect, it potentially leads to people disposing their waste improper. This is an issue that has resulted in improper waste disposal in the state (Ogwueleka, 2009; UN Habitat, 2010; Abdel-Shafy and Mansour 2018).

In the responses to the question "Do you separate waste?", there was a moderately positive correlation with that of the question "Have you been in communication with a waste management agency regarding waste and recycling?" at both the household and business levels. While the responses to the question "If waste is collected efficiently in the country, people will willingly pay their environmental levy" had a strong positive correlation with that of both the question "People throw waste on the street because they don't see government waste collectors" and "Regular waste collection is a solution to waste management", implying the role communication can play in helping to increase public participation in waste recycling. According to Desa et al., (2012), awareness programmes focused on efficient recycling behaviours and effective communication strategies have demonstrated their efficacy in promoting broader participation in reuse and recycling efforts, hence contributing to the reduction of waste production.

6.5.5.3. Low-income area Household:

For the responses to the question "the country needs a better environmental management structure" had a moderately positive correlation with that of both the question "if the collection of waste is efficient in the country, people will willingly pay their environmental levy," and "regular collection of waste is the solution to the waste problem," which is similar to the high income area and further demonstrated that management structure remains a key to more efficiency in the waste sector as explained in Chapter 6.4.5.1.

The responses to the question "Regular collection of waste is the solution to the waste problem." had a strong positive correlation with that of the question "It is very important the Nigerian government put recycling laws and programmes in place". These indicate the importance of stringent environmental laws in achieving sustainable waste management. When there is no law and its implementation, people relax and will never take responsibility for their environment, leading to some attributes quoted from Taiwo (2009): enhanced lack of coordination mechanisms and corruption when solid waste management is not addressed through adequate legislation.

For the business, the responses to the question "Do you separate waste?" had a moderately positive correlation with that of the question "Have you been in communication with a waste management agency regarding waste and recycling?"

This shows the importance of communication to better understand the recycling concept, as explained earlier in Chapter 6.4.5.1.

More so, the responses to the question "Corruption can be one reason why waste management is bad," had a moderately positive correlation with that of the question, "The government is not doing enough to fix the waste problem," which shows how important it is to get rid of corruption in the system in order to fix waste management problems (Taiwo, 2009).

6.6. Conclusion:

This study looked at people's perceptions of waste management to identify drawbacks to effective waste management and suggest ways to address such problems. The findings are similar to those of other studies, which include high waste generation, ineffective waste collection, corruption, and a lack of adequate communication with the public about waste management best practices. However, some measures suggested to improve waste management in the state include the enforcement of environmental laws to enhance good waste practice. More so, there is a need for the waste collection and transportation routes to be optimised, which could potentially reduce the high environmental and economic cost of waste management. This will result in more revenue saved or used for other projects, with less time spent in operations and less fuel consumption by haulage trucks, thereby saving time and money on waste management in the State.

Environmental awareness and education are some of the key approaches to effective solid waste management; most importantly, awareness campaigns on the effects of inefficient recycling are important. Good waste management practises and a communication strategy that focuses on environmental education have proved effective in increasing public participation in sustainable waste management. Finally, there is a need to improve the waste management structure in the state, which will involve a wider engagement of the staff and other waste management stakeholders, including LAWMA potentially partnering with religious centres and radio/ television stations for awareness campaigns. More so, a nudge to enhance the application of knowledge, like eye-catching signage is important in changing behaviour. The use of signage with localized messages, can encourage more public participation which would improve waste bin usage

CHAPTER 7

SYNTHESIS OF RESULT

7.1. Introduction:

Many developing nations, such as Nigeria, are faced with waste management problems and are heavily reliant on landfills, whether in open dump sites or unsanitary facilities, for the disposal of municipal waste generated by the populace, with limited consideration of both direct (environmental pollution) and indirect (use of limited resources) environmental impacts. During this study, a variety of research approaches were utilized, with each methodology targeting a distinct facet of waste management such as waste compositional analysis, cost benefits evaluation, estimation of landfill emission, waste management survey among others, to properly assess and manage the risks associated with improper waste management

One of the challenges for proper risk assessment of waste management sites in developing countries is the lack of appropriate data for a thorough examination of the source of potential hazards or risks of improper waste management, or even the solution of improper waste management practices (such as reliance on landfills, improper waste segregation or recycling) (WHO, 2012; Nwosu et al., 2016; Ajibade et al., 2019). While risk assessment of landfill sites has been explored through air quality monitoring and investigations of human health problems in nearby areas of landfill sites, research findings on the potential risk of landfill exposure based on the proximity of residential buildings to landfill sites had remained largely unexplored. For instance, Olawoye et al. (2019) evaluated the socio-economic and environmental implications of residential buildings near the Olushosun landfill using 85 questionnaires sampled within 200 to 500 metres from the site and found no association between building condition and distance. The study did not evaluate the actual exposure of these residential structures which could help town planners and other government environmental authorities in optimizing the effectiveness of their policies. More so, waste compositional analysis among other waste management approaches has only been used as means of waste management, while research on its efficiencies are also largely not explored, as is using Higher Education Institutions (HEI) as case studies, as they can be likened to towns and cities. HEIs have comparable challenges to municipalities regarding waste management, and these institutions, like municipalities, generate large amount of solid wastes because of their large population and the complexity of their activities, as noted by various researchers (Acurio et al., 1997; Schmieder, 2012; Ezeah et al., 2015; Ishak et al., 2015).

This chapter presents a holistic assessment of the environmental and human health risks of improper waste management, including landfilling and recycling, as common waste management techniques in developing countries, with a view to offering recommendations on waste management issues specific to Lagos, Nigeria, from the lessons learned from Glasgow, Scotland, to further enhance a sustainable waste management approach in a way that aligns with SDG 12, Target 12.5 to reduce waste generation through prevention, reduction, recycling and reuse by 2030.

Figure 7.1: Sustainable development goals of the United Nations (UN)

This chapter summarizes and synthesizes the above research findings. This method in research is used not only to summarize the field of studies, but also to identify studies in agreement and disagreement or those that require further investigation in the field of science (Mosteller and Colditz 1996). The method used for this synthesis of findings is the textual narrative and thematic method as used by Lucas et al. (2007). This will give a more integrated approach to waste management (ISWM), which is key to achieving sustainable waste management (UNEP 2009; Mbeng et al., 2012; Lederer et al., 2015). Therefore, this chapter emphasizes the significance of results integration and collaborative examination of the different study areas presented in previous chapters, to gain an in-depth understanding of the overall waste management and better environmental approach and discern prospects for enhancement and novelty. More so, this research proposes future research initiatives to tackle current difficulties which offers a scholarly contribution to the existing body of literature on waste management by providing a comprehensive analysis of research findings.

7.2. Synthesis of Results

This synthesis of results presents the findings of research on the effects and management of improper waste practices in Nigeria, such as over-reliance on landfill, and through waste composition analysis, alternate municipal waste management pathways were identified, with the methods compared to those in Scotland. The goal of this chapter is to promote more sustainable waste management in Nigeria, through the following objectives:

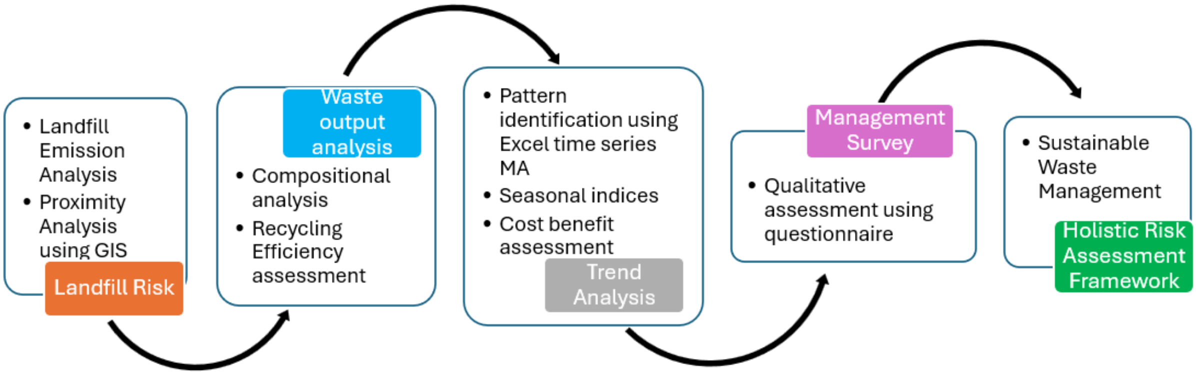


Figure 7.2: Synthesis of Results

7.2.1. Human exposure to chemical emissions, based on proximity of residential buildings to landfill sites:

7.2.1.1. Waste Generation and disposal:

The waste generation data and amount of waste landfilled showed that landfills are the common waste management option in Lagos State, Nigeria, which is evident in the amount of waste they received at the Olushosun landfill site. This is in line with the assertions of Arukwe et al. (2012) and Abdel-Shafy and Mansour (2018) that the major method for MSW disposal in Nigeria, like in other low-income nations, is landfill or open dumping, as opposed to Glasgow, which considers landfill as a last resort. The waste generated and landfilled within the data collection period (2015–2018) mostly demonstrated a downward trend at Olushosun landfill, with some reduction also found at the Patersons site between 2015 and 2017. For instance, there was a 27.57% decrease in waste landfilled at Olushosun from 2015 to 2017 (from 980,106 to 709,863 tonnes and a further decrease of 31.33% in 2018 from 2017 (487,450 tonnes), while at Patersons of Greenoakhill landfill site, there was a 6.78% decrease from 161,918 to 150,943 tonnes of waste sent to the site between 2015 and 2017 (see Chapter 3), however between 2017 and 2018 landfilled waste increased by 10.97% (167,502 tonnes). The percentage reduction and increase measures the changes in the data to understand the impact of certain actions in the management of waste, which provides valuable insight for analytic purpose and decision-making.

The variation in the amount of waste landfilled in the two case studies, Olushosun and Patersons is evidence that population is a contributor to waste generation. This can be seen in the rate of waste generation in Lagos and Glasgow, whose populations are far apart. Lagos, with a population of 17.5 million, generated an annual average of 1,499,920 tonnes of waste within a 4-year data period (from 2015 to 2018), while Glasgow, with a population of 593,245 people, generated an annual average of 227,154 metric tonnes of waste within the same waste data collection period (from 2015 to 2018), which is over 560% difference between the annual average waste generation in the two case studies. According to Ndanguza et al. (2020), an increase in population is known to affect the rate of waste generation, which is in line with Cheng et al., (2020). . According to Cheng et al., 2020, , the growth in population and urbanisation contributes to the generation of municipal solid waste (MSW), which has prompted many countries implementing waste policies to control such increase of waste.

The efforts of the waste management authorities to provide awareness and training programmes for stakeholders in waste management may have resulted in these decreases in waste generation and landfilling in both case studies between 2015 - 2017 (Awodele et al., 2016). More so, a rising awareness about the advantages of efficient waste management, such as waste recycling and reuse, is known to promote stakeholder participation in efficient waste management (Desa et al., 2012; Awodele *et al*., 2016; Mamady, 2016; Olawoye et al., 2019). Desa et al. (2012) investigated environmental awareness and education as a key approach to solid waste management and discovered that awareness campaigns on inefficient recycling and communication strategies have proven to be beneficial and enhance wider participation in reuse and recycling, which can help to reduce waste generation (Desa et al., 2012).

7.2.1.2. Landfill Emission:

Solid wastes that are disposed into landfill can cause significant amount of air pollution through emissions, especially the biodegradable waste materials. The estimated landfill emissions, which are caused by the decomposition of the biodegradable materials at Olushosun and Patersons landfill sites revealed a high presence of chemical pollutants such as carbon dioxide , methane, and Non-Methane Volatile Organic Compounds, all of which pose a serious threat to the environment and public health (details in Chapter 3). Some organic pollutants considered as toxic such as volatile organic compounds (VOCs), non-methane organic compounds (NMOCs), and polycyclic aromatic hydrocarbons (PAHs) are among them (Ho and Lee. 2002; Lee, 2010; Alegbeleye et al., 2017).

Emissions of these pollutants were shown to be high at the Olushosun site, but lower within the Patersons site, which can obviously be attributed to the 560% difference in the annual average waste generation and landfilling between the two sites. This finding is consistent with Ndanguza et al., (2020), who studied the effects of toxic wastes on population dynamics and found that higher waste generation results in higher toxic emissions, which can potentially harm the public, and that the effects on the population are caused by poor waste management.

More so, carbon dioxide and methane have been identified as significant contributors to the phenomenon of global warming and the exacerbation of climate change. Additionally, non-methane volatile organic compounds (NMVOCs) have been associated with various health issues, including cancer, congenital abnormalities, and other diseases (Kar et al., 2016; Xiong et al. 2024). Consequently, these compounds pose a considerable risk to both the environment and public health, particularly for individuals residing near landfills. The potential risks posed by chemical pollutants originating from landfill sites have been extensively studied by Vrijheid et al. (2002) and the International Agency for Research on Cancer (IARC, 2010). These studies identified a few chemicals, including benzo[a]pyrene, naphthalene, anthanthrene, chrysene, and others, that have been classified as carcinogenic by the IARC due to their ability to potentially induce cancer in humans (IARC, 2010).

Moreso, Khala et al., (2010) used two databases,'MedlEMBASE and 'Embase,' to conduct a comprehensive assessment of the association between benzene exposure and cancer risk from 1950 to July 2009. The findings reveal an increased risk of leukaemia in workers, which is backed up by D'Andra et al., (2018), who investigated benzene exposure in children and found that exposure is linked to abnormalities in hematologic, respiratory, hepatic, and pulmonary functions in children. Blood-forming organs can be damaged, and blood can be lost because of high-level exposure D'Andra et al., (2018). Furthermore, because of their poisonous nature (such as toluene, benzene, naphthalene, benzo[a]pyrene, and others), these emissions are classified as priority substances under Directive 2008/98/EC (IARC, 2010). The categorization of these priority substances aids in the regulation and control of their release into the environment.

These emission results underline the need of proper segregation of waste and treatment before disposal of non-recyclables to landfill. Also, due to the potential dangers of landfill emissions, it is necessary to support the development of engineered landfill sites, which can help not only to capture some of the chemical emissions, but also to create energy processes from the system. Although Glasgow showed leadership by establishing one, Lagos has yet to develop an engineered landfill site, making it critical for the state to do so.

One of the study's limitation is that it did not consider any other emissions besides air emissions. The landfill's leachate and other water pollutants were not considered, leaving room for future research in those areas. This outcome is beneficial to researchers, government bodies in the health and waste sectors, and anybody interested in learning more about the subject..

7.2.1.3. Landfill Exposure:

When landfill releases emissions, it causes potential risks to the surroundings especially to the public and structures that are exposed by proximity to such landfill

(WHO, 2012; Ajibade et al., 2019; Olawoye et al. 2019). When comparing the Olushosun dump site in Lagos to the Patersons of Greenoakhill site in Glasgow, the results suggested a potentially high level of exposure to risk from landfill sites based on their proximity within 0.25 km (250 meters). When compared to the results of 5000 building polygons within the Paterson Greenoakhil landfill site in Glasgow, which has only about 18 building structures, there were 355 high-risk exposed building polygons out of 38,235 digitised vector polygons within the case study area at the Olushosun landfill site (see Chapter 3). Based on proximity to the landfill site, there is a 95% difference in the exposure level of building structures between the Olushosun and Patersons of Greenoakhil sites, indicating that the latter has a potentially very low risk of exposure, as compared to the Olushosun landfill site.

More so, there were 856 residential buildings within the buffer distance for Olushosun dump at 0.5 km (500 m), but Patersons Greenoakhil landfill has 255, a difference of 236% between the two case studies. Due to residential concerns such as odour, dust, noise, and other factors, the Environmental Agency (2012) recommends that landfills be located more than 0.25 km (250 m) away from residential areas. This is because staying close to a dump site poses a greater risk to the environment and public health (Vrijheid et al., 2002). This finding will aid the government in regulating policy and development planning, as knowing the people who are affected can assist city planners in making decisions that do not damage the environment or the public. One of the study's drawbacks is that it did not model pollutant dispersion to see how they interact in the environment within the buffer zones, nor did it conduct spatial analysis in relation to population density to see how densely packed the population within the buffer zones is.

This conclusion backs up findings from earlier studies that show individuals, particularly in underdeveloped countries, are nonetheless willing to live near landfills. Some research suggests that people live close to landfill sites because of the low cost of renting properties rather than because they are unaware of the risks associated with such practises (Olawoye et al., 2019), while others argue that it is a lack of knowledge about the potential dangers of living near such waste facilities, particularly in developing countries that makes people live close to landfill site (Jonsson, 2019).

Regardless of why people live near a landfill, research has shown that short- and long-term exposure to chemical emissions from unsanitary landfills can cause cancer, genital malfunctions in males, birth defects, and other health problems (Irvine, 2001), which is backed up by Elliott et al. (2001), Porta et al. (2009), and Kah et al. (2012), among others. According to Elliot et al. (2001), who studied the risk of adverse birth outcomes associated with residents living within 2 km of 9565 operational landfill sites in Great Britain between 1982 and 1997 and compared them to residents living further away, the population living near landfill sites had more congenital anomalies and low or very low birth weight.

In support of this argument, Porta et al. (2009) examined and evaluated all evidence and graded the uncertainties in published and peer-reviewed literature addressing the health effects of waste management between 1983 and 2008, for which the result showed an increase in congenital anomalies and low birth weight with only landfill sites that deal with toxic waste, and additionally, such hazardous waste disposal sites were linked to a heightened level of stress and anxiety (Kah et al., 2012). More especially, Dolk et al. (1998) in EUROHAZCON investigated the risk of congenital anomalies near hazardous waste landfill sites in Europe, where studies of 1089 livebirths, stillbirths, and abortions with non-chromosome congenital anomalies, as well as 2366 control births without malformation, within 3 km of 21 landfill sites, revealed an increased risk of congenital anomaly.

This research will aid policy intervention and enforcement in the areas of development control and waste management. However, more modelling of these pollutants is needed to interpolate the results within the population, as well as monitoring of the subsurface waste source. More specifically, spatial analysis to further evaluate and categorise areas suitable for siting new sanitary landfill sites outside of urban settlement, as done in developed countries, which will mitigate the potential risk of landfill sites, is to be investigated further.

7.2.1.4. Landfill Alternatives:

Landfill reliance poses severe environmental risks, however, alternatives exist. For instance, composting organic waste (like the 30% waste stream from UoL, based on waste audit (Mbama et al. 2023)) diverts waste from landfill hence reducing methane emissions while adding to agricultural inputs (Irvine, 2001; Hoornweg and Bhada-Tata, 2012). Material Recovery Facilities (MRFs) for the plastics and paper (about 52% of HEI waste) could also cut landfill usage as well as help to generate revenue (Akaateba, et al. (2013). Another alternative is Waste-to-Energy (WtE) which is viable for non-recyclables but does requires high capital investment which may be out of reach in low income settings (National Research Council, 2000; Adekomaya and Majozi 2020; Lee et al., 2020).

7.2.2. Temporal Pattern of MSW Generation and Composition, using University of Lagos and University of Strathclyde as case studies:

7.2.2.1. Waste Generation Pattern:

The challenges of waste generation and its management necessitates an understanding of waste generation patterns to help in providing better management strategies, as the trend will be fully captured (Watanapa et al., 2006). These management strategies could be waste reduction approach, recycling, and landfill as a last resort due to its potential risk. Meanwhile, the result of the waste generation and composition analysis makes it easier to understand the nature of waste that could potentially exacerbate the risk of exposure to waste when sent to landfills. Considering that biodegradable waste is the constituent of waste that presents the most significant hazard when deposited in landfills (see Chapter 4). In both case studies, where the temporal MWS generation patterns in higher educational institutions were evaluated, the results demonstrate a slight negative circular tendency in seasonality, with peak generation occurring between March and June and a nadir occurring in July at UoL. This shows the effect of seasonality in waste generation. Hoang, (2005), argues that waste generation is influenced by external factors such as the season; however, Taghizadeh et al., (2012), found that seasonal variance is most pronounced during university vacations.

More so, the waste trend estimate using the UoLs seasonal indices of 114.276% (Q1), 100.809% (Q2), 91.23% (Q3), and 93.69% (Q4) indicates a reduction of around -23.67% from 2015 (11684.66 tonnes, the total annual waste) to 2017 (8919.19 tonnes, the total annual waste). Such decrease is similar to UoS, which had seasonal indices of 101.08% (Q1), 108.00% (Q2), 94.2% (Q3), 96.7% (Q4), showing also a waste reduction of -14% from 2012 (635.98 tonnes of total annual waste) to 2014 (550.39 tonnes of total annual waste) (see Chapter 4, session 4.3.2).

UOL showed a notable decline in capacity (seasonal indx) after first querter, suggesting possible issue that affected performance. Even though there was no recovery of the seasonal index, the UOS seems to have a slight but more consistent capacity performance, with an initial increase in the second quarter and then continual stabilisation through the fourth quarter. This decreasing waste trend contradicts the findings of Wikurendra et al. (2023). Wikurendra et al. (2023) used a linear regression model to anticipate waste generation and waste fleet. They forecasted that Sukolilo District in Surabaya City, Indonesia, is expected to generate around 65,442 tonnes of waste per year in 2030, representing a 115% increase from 2021. The research result differs from that of Wikurendra et al (2023) due to the University's efforts in waste reduction during the evaluation period, despite the population gap between Sukolilo district (115,855) and the University of Lagos (87,000 estimated daily population).

Waste generation prediction is essential for planning and budgeting. Over 60% of waste management expenses are spent on waste collection and transportation, according to Chalkias and Lasaridi (2009) and O'Connor et al. (2013). When generated waste is predicted, waste management solutions can be optimised to reduce waste generation, lower collection, and disposal costs. More importantly, such prediction helps with long-term infrastructure planning and resource allocation, even in emergency situations like disease outbreaks. Therefore, understanding waste capacity and predicting waste generation helps with waste management planning.

7.2.2.2. Waste Audit:

When wastes are generated, it is very important to understand the various waste streams that are generated in order to explore recyclability of such waste and at the same time enhance existing policy to accommodate more proactive measures to manage wastes more efficiently (Byer et al., 2006; Ferreira et al., 2012; Mbeng et al., 2012; Ishak et al., 2015; Baharum et al., 2016). Notwithstanding the universities recycling policies and efforts to provide recycling facilities across the campuses, there is a level of contamination across waste bins posing a challenge at the University of Lagos (UoL) and University of Strathclyde (see Chapter 4 for full details). According to UoL's findings, material recovery of organic waste, mixed plastic, and mixed paper may be maximised, indicating that these three waste streams have more potential. For example, according to the waste characterization assessment, 88% of the UoL's waste could be diverted from landfill; 30% is organic material that could be composted; and the rest could be recycled (see Chapter 4, Figure 4).

These findings are like those of Adeniran et al. (2017), who researched waste management at the same university and found that 75% of the waste generated could be recycled, as well as similar studies on waste streams at HEIs. According to Smyth et al. (2010), 70% of the waste stream at the University of Northern British Columbia (UNBC) might be diverted from landfill through recycling, composting, and waste reduction programmes. Furthermore, Ezeah et al. (2015) and Taghizadeh et al. (2012) found that over 80% of the waste generated at the University of Wolverhampton and the University of Tabriz, respectively, could be handled through waste reduction, recycling, and composting/landfill diversion efforts.

Organic (30%), mixed plastic (28%) and mixed paper (24%) wastes had the highest proportion of biodegradable and recyclable components out of all the waste samples. This differed with the findings of Smyth et al. (2010), who found that mixed paper and card made up 29% of the University of Northern British Columbia (UNBC) campus waste, followed by non-recyclables (28%) and organic materials was approximately 22%. This could be due to regional and cultural differences, which have both been identified as influencing variables in waste composition (Mihai, 2012). The current findings show three significant waste streams that may be recovered from the research region, namely plastics, paper, and organic waste, which should be the university's key priority for sustainable waste management. These streams have also been identified as the primary waste streams at higher education institutions in the literature (Armijo de Vege et al., 2008; Smyth et al., 2010; Taghizadeh et al., 2012). According to Badgie et al. (2012), resource recovery should be the waste management choice for underdeveloped countries.

The University of Strathclyde, on the other hand, had a minimal amount of contamination, which might be attributed to the university's commitment to enforcing its waste policy. This may be observed in the University of Strathclyde's attempts to divert 100% of its waste from landfills and recycle more than 80% of it, whereas at the University of Lagos, all its waste is landfilled. If source segregation could be maximised and waste collection and transportation routes could be optimised, UoL's high environmental and economic waste management costs could be reduced, as more revenue could be generated through the marketing of recovered waste materials for them with less time and fuel consumption by haulage trucks, reducing waste management time and cost.

Statistically, the University of Lagos' findings revealed that there was no significant difference between the waste bins, implying that all the bins are used for general waste. Mixed paper bin samples, for example, had a p value of 0.507; mixed plastic bin samples had a p value of 0.539; and red can bin samples had a p value of 0.474, indicating that there was no significant difference in all waste bins at the University of Lagos, implying that students and staff do not follow the university's recycling policy.

However, at the University of Strathclyde, the statistical result showed that across the different waste bins, no significant difference was found in the waste composition in the blue, mixed paper bin samples ($p = 0.218$) or in the red, can bin samples ($p = 0.611$). The reason mixed paper had no significant difference was because of cross contamination with other waste materials making it lose the quality desired for pure material; hence, the contamination with such paper affected its value. However, the green bin samples had a p value of 0.000, hence showing a significant difference. This means that only mixed plastic waste bins are significantly different, as the rate of their contaminants was very low, which indicates that the required waste is significantly different from other compositions in them (other contaminants). Therefore, the students' and staff still partially complying in recycling at the University of Strathclyde than at the University of Lagos.

A few waste management options, such as reduce, reuse, recycle, and compost, could be explored further, and most importantly, awareness creation to understand the benefits of waste recycling and enforcement could serve as a tool to increase stakeholder participation at universities (including academic and non-academic staff and students). One of the limitations is that the studies were not conducted during the active study period, when students are fully engaged in their studies; instead, they were conducted during the exam period, when there were fewer activities in the school, and the study did not cover all areas of the university in both case studies, which would have provided a more comprehensive understanding of the true waste conditions of the institutions. Future research will look at conducting the study during the regular school session and covering a broader range of areas. This research will assist universities in developing further techniques to improve the implementation of their waste and recycling policies.

7.2.2.3. Cost Effectiveness of Recycling as A Waste Management Option:

Once a waste audit is carried out to understand various waste streams, it is important to evaluate the economic benefits and the cost effectiveness of the waste management techniques (Begum et al., 2006). This is to ascertain that any approach to management the waste is environmental and economically viable (Atkinson and Mourato 2008). The economic effectiveness of recycling as a waste management option is presented for the University of Lagos to determine how effective waste recycling could be when compared to traditional landfill. One source of concern was that, even though the waste management policies of both the University of Lagos and Strathclyde University are designed to reduce the amount of waste that goes to landfill, which the University of Strathclyde implements 100 %, thereby encouraging environmental sustainability and reducing the risks associated with such practises. However, the University of Lagos still landfills 99% of its waste and recycles only about 1% of its total waste (see Chapter 5). The evaluation process incorporated environmental risks, which included monetary weighting of intangible materials in the process, such as greenhouse gases (Da Cruz et al., 2014). Although the solid waste management process provides less than 5% of global greenhouse gas emissions, the potential effects of these greenhouse gases cannot be overstated, according to Bogner et al. (2007).

Meanwhile, when adopting a formal waste management plan for any waste management project, it is important to consider the management options that are unique to the type of waste generated in each geographic location, as well as the associated cost benefits (Hanley, 2001; Edjabou et al., 2015). Some of these waste management alternatives are weighed in terms of their operational, financial, and environmental benefits and drawbacks (Hanley, 2001; Ferronato et al., 2017). The Net Present Value (NPV) was a significant factor in determining the waste management process's environmental and economic viability in the two case studies (see Chapter 5). According to Ferronato et al. (2017), it is critical to assess the financial cost and long-term viability of any waste management recycling solutions to determine whether a system is both financially and environmentally viable.

The University of Strathclyde has a positive NPV, but the University of Lagos has a negative NVP. The university's good waste management policy, which includes a high rate of recycling 85%, is credited with a positive NPV that maximises the use of limited resources (see Chapter 5). The most challenging goal to achieve in terms of reducing GHG emissions is resource efficiency (Turner et al., 2011). Meanwhile, the negative NPV at UoL was linked to a poor recycling rate (1%) and high waste to landfill ratio, which increased environmental risks and caused the environmental cost to outweigh the benefits, resulting in a negative NPV. The NPV was far below zero (-£263,520,447) at a 1% recycling rate (considering associated total environmental costs), and even at

20 or 50 percent, the NPV at these recycling targets still showed that such an approach is never sustainable, according to the results of the decision support tool VLOOKUP, which further analysed the sensitivity of the NPV based on 625 scenarios of 125 different combinations of the five critical variables in the UoL management practise. These imply that a recycling target of >50% is economical and environmentally sound, demonstrating a long payback time because, after discounting the net cash flows, their cumulative values maintained a continuous positive trend and their benefits outweighed their individual costs. While for UoS, it has an NPV of £33,728,493, 85% of monthly wastes are recycled, and 100 percent of waste is diverted from landfill sites.

The greater the reduction and recycling objectives are used, the better the total least cost that might potentially be spent over time, according to the two essential variables used at the UoL, recycling and reduction targets. It may be determined that the UoL's low recycling targets and landfilling of most of its waste only served to lower the net benefit value, in contrast to what is done at the UoS, where the enormous environmental advantages surpass the increased financial expenses of fulfilling the target.

According to Hogg et al. (2015), an impact study on the adjustment of European waste management standards, there are enormous environmental advantages that significantly outweigh any additional financial expenses connected with attaining their 80% recycling target. Hogg et al., (2015), went on to say that one of its scenarios (Scenario 19), which targeted 65% MSW preparation for reuse or recycling, 75% overall packaging recycling, and 10% landfill diversion for all non-hazardous and non-mineral waste, resulted in a net benefit of €26 billion (£22,457,890,000), implying that while higher recycling may increase financial costs, the additional environmental benefits the project brings to society outweigh the financial costs. As a result, when highly ambitious recycling goals are set and the tactics to attain them are implemented to near-completeness, significant financial savings and environmental advantages may result (Hogg et al., 2015).

Cost-benefit analysis (CBA), in which projects or management options are put into quantifiable financial value to make a better selection while also examining other options, is particularly beneficial in this type of economic assessment (Begum et al., 2006; Atkinson and Mourato 2008). In the context of waste management, the purpose of CBA is to determine which solid waste management choices (such as landfill and recycling) are the most cost-effective, while also considering the environmental concerns associated with each waste management activity after disposal. Despite criticism of the use of CBA for project appraisal, numerous sources continue to believe in its utility in evaluating economic efficiency with limited resources (Hanley, 2001).

One of the study's limitations is that the value of the environmental cost for the evaluation process was focused solely on greenhouse emission costs, ignoring other intangible values or environmental costs such as the monetary value of health risks or issues associated with the practise, which would have made the study more robust if considered. The findings of this study will aid policymakers and the public in understanding the benefits of recycling participation. There is a need to set high waste reduction and recycling targets for universities of at least 51%, which might improve environmental sustainability, minimise risks, and lower environmental costs associated with present waste management practises.

7.2.2.4. Higher Education Institutions as Municipal Similarity: Justification and Limitations:

While the HEIs as case studies (UoL/ UoS) mirror municipalities in waste complexity, as well as population density (Schmieder, 2012; Ezeah et al. 2015; Ishak *et al*., 2015), the exclusion of non-campus residences in Glasgow case study is a limitation. However, the two case studies remain valid proxies/ municipal similarity because they exhibit similar per capita waste generation (for example UoL is 0.17 kg per person per day while UoS is 0.15 kg per person per day**)** when compared to the urban averages (for example Lagos is 0.72 – 0.75 kg/person/day and Glasgow is approximately 1.1 kg/person/day) (Olukanni and Oresanya, 2018; Glasgow City Council 2021; Akpokodje et al., 2022).

7.2.3. Public Waste Management Perception in Lagos:

The effectiveness of waste management is centred on the understanding of the underlying factors, which makes stakeholders involvement is critical. More so, understanding public perceptions on the waste management realities to enhance government service delivery (Almasi, 2010; Bom et al. 2017). To maintain a sustainable and environmentally cleaner setting, it is imperative to comprehensively examine and acknowledge the needs and concerns of the community. This necessitates an in-depth study of current behaviours and the perception among the public in regard to waste management (see Chapter 6). In view of the above, the results of a quantitative analysis of 458 surveys centred on public waste management perceptions in Lagos are presented and divided into three socioeconomic groups or categories, as shown below, based on the unique characteristics of each area.

7.2.3.1. High income area:

Over 70% of people in high-income areas use government waste collection services, according to the findings. However, according to Babayemi and Dauda (2009), just 35% of Abeokuta, Nigeria's residents use the government waste collection service, which is half the rate indicated in this study. This implies that, in this high income area, there are more government waste collection services, indicating that differences in income or availability of services might influence the waste collecting rates. Sivakumar and Sugirtharan (2010) and Akaateba, et al. (2013) also corroborate this conclusion. According to Sivakumar and Sugirtharan (2010), higher-income areas have a higher consumption rate than low-income areas, whereas Akaateba, et al. (2013) suggested that operating waste collection service in high-income areas rather than low income/ highly populated area is more profitable because to their good accessibility and consistent payment patterns, whereas for low income areas, waste collection fee is usually difficult. Another publication made by Zia et al. (2017), further supported Akaateba et al., (2013) assertion, that willingness to pay for waste collection services could be linked to waste collection services been more frequent among high-income earners than among low-income earners. This may be one of the reasons why high-income areas use government waste collection services more frequently.

The statistical results for the household questionnaire showed that the question "the country needs better environmental management structure" had a moderately positive correlation with that of the question "government is not doing enough to fix the waste problem", which shows that respondents percieves that improving governance and structural support will enhance the effectiveness in addressing environmental issues. And the former also had a moderately positive correlation with the question "regular waste collection is the solution to the waste problem,", which respondents also percieves that a thorough environmental management plan depends critically on a methodical approach to waste collecting. However, the question "the country needs better environmental management structure" also had a strong positive correlation with that of the question "waste management should be taught in all schools," indicating that education will help in developing consciousness and responsibility towards waste management techniques. This relationship highlights the consensus on the need of including waste management education into the school syllabus, therefore fostering the growth of a society more conscious of and worried about the surroundings. Therefore, establishing a more effective integrated waste management system depends on enhancing governance, applying regular waste collecting services, and offering waste management education, all of which are clearly related events that have to be addressed to adequately tackle waste issues.

For good synergy to provide the optimum result, it necessitates an awareness of the typical working relationship with other stakeholders. According to Thyberg and Tonjes (2015), a good waste management structure should include, among other things, staff competence and training, compliance evaluation, monitoring and measurement, and communication with important stakeholders, which are all key functions of a good waste management structure (Thyberg and Tonjes 2015). Stakeholders are critical to a system's or project's success or failure, as their refusal to support a project's mission always results in project failure (Bal et al., 2013).

For the question "Have you been in communication with a waste management agency regarding waste and recycling?" (which shows 65% of respondents noting “no” in the business questionnaire) showed a moderately positive association with the question

"Do you separate waste?" as the 65% of the responses from the questions stated “no”. This demonstrates the importance of communication for a better understanding of the recycling concept, as it has been demonstrated to be successful in increasing recycling participation (Desa et al., 2012; Mamady, 2016).

7.2.3.2. Middle income area:

According to the results, similar to the high-income area, more than 70% of middle-income families use government waste collecting services. The study shows an increase that is less the amount as the one documented by Adedara et al., (2023), who suggested that over 50% of the people in middle to high income used the waste collection service .

The difference in socioeconomic status of a place makes the kind of waste generated and collected in a given area differ (Chatsiwa, 2015; Adedara et al., 2023). According to Chatsiwa (2015) and Adedara et al., (2023), the Middle- and upper-income citizens' lifestyles, consumption patterns and waste management activities often reflect those seen in developed nations, as such areas have wide, paved streets that enable the access of conventional trucks for waste collection. This observation also suggests that economic status can have an influence on availability of such waste collecting service as further suggested by Akaateba et al., (2013). The poor understanding of people regarding source segregation and the responses to the question "Do you see waste on the road?", (which over 65% in both the household and business areas noted “yes”) had a moderately positive correlation with waste littering, indicating a connection between a lack of understanding of the benefits of effective management practises and waste littering. Waste littering on the roadways will be reduced if the public is aware of the need for waste separation (McAllister, 2015). Many works of literature have documented the presence of waste on the streets, dumpsites, rivers, particularly in developing countries (Ezeah et al., 2013; McAllister, 2015).

This is also comparable to the negative attitude toward improper waste disposal as in the question "People throw waste on the street because they don’t see government waste collectors," (which 59% of respondents are in agreement) had a moderately negative correlation with the responses of lack of communication from the question "Communication from the waste management agency regarding waste and recycling?". The lack of communication from appropriate authorities had the tendency to result in people throwing waste on the street when government waste collectors did not show up.

Furthermore, the inefficient waste collection as a common response from the open-ended questionnaire on the question "What are the problems of waste management in the state?" had a moderately negative correlation with that of the question "How much waste is generated in your house?" (where 37% of respondent generate 7kg of waste weekly) indicating that the amount of waste generated could have an impact on waste collection inefficiency, as there is usually more rubbish than waste collectors can collect. This is an issue that has resulted in improper waste disposal in the state (Ogwueleka, 2009; UN Habitat, 2010; Abdel-Shafy and Mansour 2018).

The responses to question "Do you separate waste?" which 65% and above of the respondents noted “no” for both the household and business area), had a moderately positive correlation with that of the question "Have you been in communication with the waste management agency regarding waste and recycling?" which have 65% and above of the respondents stating “no” too. More so, the question "if the collection of waste efficiently in the country, people will willingly pay their environmental levy" (which 81% respondents showed agreement to the assertion in the household area) had a positive strong correlation with both the question "people throw waste on the street because they don't see government waste collectors" (which 59% of respondents agreed to the assertion) and the question "Regular collection of waste is a solution to waste management" (which 100% of respondents agreed). These suggests the role communication can help to increase public participation in waste recycling, while in the other hand, shows how efficiency in waste collection can improve the environmental sustainability including people's willingness to pay.

7.2.3.3. Low-income area Household:

The results suggest that 40% of people in low-income household areas use government waste collection services. The findings are comparable to those of Oduro-Kwarteng et al (2013), who found that same 40% waste collection is done in Tamale, a low-income metropolis in Ghana (Osumanu, 2007). According to the results of the questionnaire, the question "The country needs better environmental management structure" had a moderately positive correlation with both the question "If the country collects waste efficiently, people will willingly pay their environmental levy" and that of the question "Regular waste collection is the solution to the waste problem," demonstrating that a well-organised structure would assist the waste sector achieve higher efficiency, as explained in Chapter 6.4.5.1.

For the question "Regular waste collection is the solution to the waste problem," (which has 99% respondents' agreement) there was a strong positive correlation with that of the question "It is very important for the Nigerian government to put recycling laws and programmes in place," indicating the importance of strict environmental laws in achieving long-term waste management including the efficient waste collection service. When there is no law and no enforcement, people relax and never take responsibility for their environment, which leads to some of the characteristics listed by Taiwo (2009), such as increased lack of coordination and corruption when solid waste management is not addressed through adequate legislation.

For the business, the responses to the question "Do you separate waste?" (which has 91% respondents noting “no”) had a moderately positive correlation with that of question "Have you been in communication with a waste management agency regarding waste and recycling?" (91% respondent also stating “no”). This shows the importance of communication to better understand the recycling concept, as explained earlier in Chapter 6.4.5.1.

Meanwhile, for the question "Corruption can be one reason why there is poor management of waste" (which is 47% respondents’ agreement) had a moderately positive correlation with that of the question "The government is not doing enough to fix the waste problem," which further stresses the need to eradicate corruption in the system in order to fix waste management issues (Taiwo, 2009). Poor waste collection service Coverage in the low-income area from this result is like other results, like those in Ogwueleka (2009) and Taiwo (2009), which should have poor and efficient waste collection services. One of the reasons for the lack of coverage can be attributed to the excessive cost of haulage, as a large amount of fuel is required to cover a large area.

Research has shown that over 60% of waste management budgets are used for waste collection and transportation (Chalkias and Lasaridi 2009), yet much of this money is spent on salaries and gasoline (Chalkias and Lasaridi 2009; O’Connor et al., 2013). To improve waste collection efficiency, GIS routing of waste management coverage regions should be used to determine the shortest route during waste collection to improve efficiency and collect waste more efficiently. Routing waste collection and transportation using GIS has been found to be an efficient and cost-effective method (Bien et al., 2005). It has, for example, been used to optimise waste collection and bin positions in Sfax City, Tunisia, in the past (Kallel et al., 2016).

To better understand and improve waste collection efficiency, Kallel et al. (2016) used an ArcGIS Network Analyst tool to create three optimal scenarios to compare to the system's base scenario. The findings showed that waste collection could save up to 57 percent of time and 48 percent of fuel when it was optimised (Kallel et al., 2016). This could help to minimise the cost of waste collection and transportation in Lagos State by boosting waste collection coverage and reducing the rate of bad waste management practises.

This research will benefit the development of knowledge in the case study areas and the implementation of waste management policies in the state and across the country. However, some limitations of this study include the inability to cover waste management authorities' financial budgeting as well as the sampling of opinions of private waste contractors who are primarily responsible for waste collection services and their staff in order to balance the rationale behind ineffective waste management, particularly in waste collection services; thus, future research in this area will be conducted.

7.2.3.4. Waste Collection Provider’s Insight:

Interviews with the Lagos waste management agency (LAWMA) on their private sector participation (PSPs) revealed a few critical barriers, for example underfunding, informal sector exclusion, regular truck breakdown (as shown in Figure 6.7) and route inefficiency, which results to insufficient supplies of waste management equipments, hinders the potential for enhanced recycling efficiency, as informal sector can be more resource-efficient, also leads to the delay in waste collection, which potentially increases operational costs and leading to more environmental and health issues, and finally, longer waste collection times, hence, potentially increasing the fuel consumption. In agreement with the literature, the scavengers recover most of the recyclables but are excluded from formal policy (Zisopoulos et al., 2023). Importantly, GIS-optimised routing could reduce travel distance along the routine waste collection road network, inclusion of technology has shown to reduce travel distance by 59.12% (Lella et al. 2017), additionally reducing the time it takes to complete waste collection tasks, as well as save on fuel consumption (Kallel et al., 2016; Lella *et al.,* 2017).

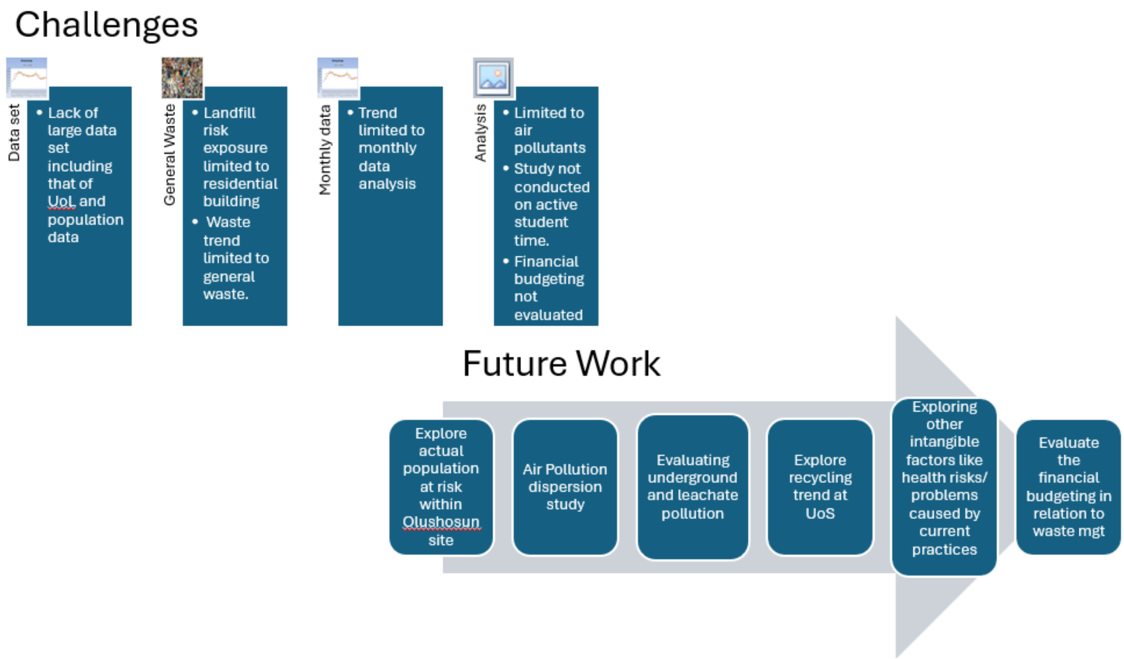
7.2.3.5. Awareness Creation:

In the past, door to door intervention campaign and the use of community-based social marketing (CBSM) are widely used as a framework to create awareness campaigns that foster pro-environmental behaviour (Haldeman, and Turner, 2009; Fries et al., 2020; Gupta, 2021). Communication campaign has been beneficial to promote environmental behaviour, helping people understand the environmental problems as well as encouraging them to engage in activities that can only safeguard the environment (Idamah, 2015). The promotion of awareness has been found to have a positive impact on people's engagement in waste reuse, reduction, recycling (including source segregation), and proper disposal, according to research (Hasan, 2004; Desa et al., 2012; Aseto, 2016). According to Desa et al. (2012), increasing public understanding of the benefits of recycling as well as the concerns associated with landfilling, particularly for biodegradable wastes, can potentially enhance public engagement. Aseto (2016) supports this assumption by emphasising that raising awareness about the benefits of waste reduction and recycling helps maximise recycling potential while decreasing the risks associated with waste landfilling.

This claim is further backed up by Festus and Ogoegbunam (2012), who stated in their "imperatives of environmental education and awareness creation for solid waste management in Nigeria" that in order to encourage people to participate in waste reduction and recycling, such awareness messages, particularly the negative consequences of not recycling, remain a powerful motivator for people to help engage in proper waste management. However, there is need for enhanced knowledge and behavioural change through other methods that could potentially be effective in waste management. This includes social media like television, radio, and other electronic gadgets and also collaborating with religious houses like the mosques and churches as most Nigerians follow a religion (Timlett, et al, 2008; Salvia et al., 2021). Such messages could be delivered in a variety of ways, including newspapers, radio, television, and, most crucially, leaflets, have shown to increase public engagement in solid waste recycling (Timlett, et al, 2008; Festus and Ogoegbunam 2012).

7.2.3.6. General Limitations of Study:

Household pollutant monitoring was not part of the scope of this research like measuring air and water quality near landfills, due to resource constraints as well as ethical risks. Instead, a proximity-based exposure modelling was used (see Chapter 3 for full detail) which implies emission impacts were inferred, and not measured, so future work could potentially integrate environmental sampling, such as measuring VOCs in residential air and water source as shown in Figure 7.3 below. Landfill diversion policies will result in waste compositional differences between Glasgow and Lagos, as such, Scotland's source-segregated waste produces lesser biodegradable landfill content, which reduces methane generation when compared to Lagos, Nigeria.



7.3. *Figure 7.3: Challenges and Future Work*Novelty of Research Contribution:

The research novelty is in the findings on the proximity risks with chemical emissions specific to the Olushosun case study, advancing awareness of the potential risk associated to the landfill sites. More so, GIS-based exposure risk mapping for Olushosun Lagos landfill, which shows 355 high-risk buildings within 250 m of Olushosun landfill site, which could inform buffer zone legislation. Results can assist town planners and government authorities in sustainable building and waste management practices including influencing positive future legislation.

Another novelty is in tailoring waste audit to a university setting, demonstrating the unique challenges and opportunities at the two case studies which are not typically addressed in broader studies. The HEI as an evidence based practice ground demonstrated 88% of landfill waste diversion potential at UoL through composting and recycling, which could be a potential model in Nigeria towards achieving a sustainable waste management. More so, the economic benefits towards achieving high recycling targets is when the NPV turns positive, when recycling exceeds >50% (see Chapter 5), hence could potentially support ambitious economic policy shifts. The findings guide the university policy makers at enhancing and targeting interventions, including waste reduction strategies, enhancing recycling rate, optimizing waste collection by understanding the universities' seasonal indices, to encourage efficient resource allocation and fostering sustainability culture among students and staff.

More so, another novelty was the application of a mixed qualitative method susurvey to understand the public perception and waste management challenges particular to Lagos State, Nigeria. Stakeholder-base frameworks which integrates the public, PSPs and informal sectors, i.e. scavengers, into waste governance could improve system resilience. This data-driven method to solving real time problem could provide actionable recommendations for the government authorities and also guide in policy development to manage waste problems efficiently. The overall contributions of novelty, which assessed and addressed risks associated with waste disposal through a holistic approach, contribute to achieving sustainable waste management. This aligns with the United Nations' Sustainable Development Goal (SDG) 12, specifically target 12.5, as illustrated in Figure 7.4.

Figure7.4: Sustainable Waste Management

7.4. Conclusion:

This chapter offers great insights into the complexities of waste management in Nigeria, by linking waste management holistic issues and proposing a multi-faceted approach to improving sustainable waste management through lessons learn from Scotland waste management approach. It assessed the results obtained from the conducted evaluation of the risks associated with improper waste management in developing countries such as Nigeria, where Lagos State was used as a case study, and those in developed countries such as Scotland, where Glasgow was also used as a case study, in order to identify drawbacks to effective waste management and suggest practical ways to address the problems based on lessons learned from waste management processes in Scotland. High waste generation with more recyclable and compostable waste materials, lack of adequate waste segregation, with ineffective waste collection, poor waste disposal management, high risks of public exposure to waste disposal facilities such as landfills, corruption, and a lack of effective communication with the public on waste management best practises are among the findings that limit the efficacy of the waste management services in developing countries like Nigeria.

The presence of a high level organic materials in the waste, especially at the University of Lagos, underlines the need for waste composting initiatives, to lower the overall landfill load/ pressure, and at the same time, providing significant organic fertilizers for agricultural purposes. Moreso, landfill alternatives like composting, MRFs, and WtE could potentially offer scalable solutions for Lagos but could require more strict enforcement of recycling laws like mandating >50% recycling targets. This is because increasing recycling targets to at least 50% will not only be cost effective but will enhance environmental sustainability. The findings also indicate serious issues with waste management in Lagos, Nigeria, and the need for urgent action to address these evidence-based challenges. Nevertheless, it is suggested that certain measures be taken to enhance waste management in the state, drawing insights from waste management strategies implemented in Scotland. These measures encompass raising public awareness regarding the advantages and risks of improper waste disposal methods, augmenting waste reduction targets and promoting greater adoption of recycling practises. Additionally, it is imperative to enforce environmental legislation within the state, including the imposition of restrictions on public access to potentially dangerous waste disposal sites such as landfills, with the aim of enhancing public welfare and mitigating associated risks. More importantly, waste collection and transportation routes should be optimised, which might minimise the state's high environmental and economic costs of waste management. This will result in more revenue being saved or used for other initiatives, as well as less time spent operating haulage vehicles and less fuel consumed by them, reducing overall waste management time and expense in the state.

Good waste management practises and a communication strategy that emphasises environmental education have been shown to be successful in increasing public participation in long-term waste management. However, waste management awareness campaigns must transcend the past generic efforts, and utilize behavioural "nudges" such as the social norm messaging or localizing the massage to capture more public interest in waste management participation. These could specifically target low-income areas, which has poor waste management knowledge and involvement in waste recycling, for example using radio and/or religious and community leaders. Route optimisation using GIS could cut collection travels by 59.12%. Glasgow’s waste management lessons are clear, source segregation and landfill taxes lead to high reduction of waste going to landfill, and it could potentially be more beneficial for Lagos to replicate this through integrated policies addressing technical, social and economic gaps highlighted in this thesis. More so, the existing waste management structure in the state needs to be improved, which should include a broader engagement of staff and other waste management stakeholders, including the formal integration of scavengers into the scheme, as their role as waste management stakeholders cannot be overstated.

CHAPTER 8

CONCLUSION AND RECOMMENDATIONS

8.1. Conclusion:

This thesis compares the risk associated with the management of waste disposal facilities between the Olushosun landfill site in Lagos, Nigeria, and the Patersons of Greenoakhill landfill site in Glasgow, Scotland. It also gives an overview of the cost-effectiveness of waste management at two higher education institutions, University of Lagos, Nigeria, and University of Strathclyde, Scotland, with the goal of producing a set of recommendations for better, more sustainable ways for developing countries like Nigeria to deal with waste management. A few new ideas or conclusions can be drawn from the results, which can be summed up as follows:

8.1.1. The thesis started with a comparison between the Olushosun landfill Lagos, Nigeria, and Patersons of Greenoakhill, Glasgow, Scotland, as case studies to figure out how close homes are to landfills and how likely it is that people will be exposed to chemical emissions (Chapter three): This objective was to figure out how much pollution came from landfills in Nigeria and Scotland and how people area exposed to such pollutants. The objective was met as secondary data was deployed to estimate the number of household population within the case study areas. This objective estimated pollutants for Olushosun landfill using LandGem model and assessed that of Patersons via the SEPA database. It also used proximity analysis buffering, one of the spatial tools in GIS, to look at the distances that could put people at risk of being exposed to emissions from landfill sites. It was thought about putting a buffer zone within 3 km (350 m) of the landfill sites because it is known that harmful chemical pollutants that are released within this distance of a typical hazardous landfill site can influence people's health. The results show that the Olushosun landfill site has a lot of chemical pollutants like carbon dioxide, methane, and non-methane volatile organic compounds (NMVOCs) that could be dangerous to the environment and people's health when compared with Patersons of Greenoakhill landfill. This is because 355 and 856 residential buildings are within 0.25 and 0.5 km, respectively, of the Olushosun landfill site in Nigeria, when compared to the Patersons of Greennoakhill site in Scotland, which has only 18 and 255 building structures within the same 0.25 and 0.5 km, respectively, of proximity to the site. There is about 89,393 people within 2 km of the Olushosun landfill site that are exposed to potential risk of landfill emissions, when compared to the 28,712 population within 2 km of Patersons landfill site. This finding backs up what other research has found, which is that people are still happy to live near landfills, especially in developing countries, even though they know the potential risk associated with such practice. The population living within 0.25 km of the Olushosun landfill site emitted an average of 16,199 tonnes of CO_2e (16,199,833 kg) per capita, compared to the Paterson landfill's average of 295 tonnes (295,000 kg) per capita, indicating how the burden of landfill emissions, when distributed per person within the 0.25 km radius, is disproportionately larger for population near Olushosun landfill than near Petersons landfill. This further shows greater environmental pressure on the population around Olushosun landfill based on the proximity scale. The organic component of waste materials that ends up in landfills makes it easier for the waste to break down and release those pollutants that could be harmful to health and the environment, as seen in the high estimation of landfill pollutants at the Olushosun site when compared to Paterson, which manages its emissions. The results are like those of other studies that suggest there are often high risks associated with organic materials going into the landfill as its emission poses risk to public being exposed to the waste disposal facilities.

8.1.2. Evaluating MSW generation and waste composition by comparing the University of Lagos (UoL) in Nigeria with the University of Strathclyde (UoS) in Scotland: In these case studies, the types of waste and how the wastes were managed were also looked at. The objective was to figure out how well recycling worked within the higher education institutions, so that the lessons could be learned and used to make suggestions for how to improve waste management in developing countries. This objective was reached, but it was not comprehensive enough. A broader assessment is needed to better understand the characteristics of waste across all institutions. Although it is the location the research was assigned for the study, the result shows a slight negative circular trend in seasonality, with the peak generation observed in March–June and the nadir observed in July over time in both case studies. This demonstrates the institutions' efforts in waste reduction strategies, which have the potential to improve environmental sustainability. This is like other findings that show that efforts at waste reduction and recycling are gathering momentum.

The result also shows at UoL that material recovery from organic waste, mixed plastic, and mixed paper could be maximised, which means that these three waste streams could provide more opportunities. For example, the waste characterization study shows that 88 % of the UoL's waste could be kept out of landfills. Thirty percent of the waste is organic material that could be composted, and the rest could be recycled (see Chapter 4, Figure 4). However, the UoS should focus more on having pure source segregated waste streams of paper, plastics, and non-recyclables for sustainable waste management. The finding of high levels of organic materials, particularly at the

University of Lagos, highlight the critical need of structured composting initiatives. Such initiatives not only mitigate the pressure exerted on landfill systems but also provide a sustainable source of organic fertilizer for agricultural applications. Furthermore, scalable options for improving environmental sustainability in Lagos may be provided by landfill alternatives, including composting, WtE, and MRFs.

8.1.3. Exploring cost-effective waste treatment options to deal with waste, using the effect of the current case study's landfill practise as a basis and considering the environmental risk, especially greenhouse gas (GHG) emissions from the current landfill practise at the University of Lagos, Nigeria, and the University of Strathclyde, Glasgow: This is done by looking at the effects of the different types of waste and the costs and benefits of the different recycling goals while keeping in mind the environmental risks that come with them. This is important for making good decisions about how to handle waste. If you know how the management processes affect the environment and the economy, you might be able to understand and accept the cost-effective treatment option or target you choose. The result showed that the NPV value was £4,908,775 at a recycling goal of 51% at UoL. These numbers show that a recycling goal of more than 50% could be both cost-effective and good for the environment. It also shows a high payback time because, at that point, the recycling benefits outweigh their individual costs after discounting the net cash flows, for which their cumulative values have kept a positive trend, compared to UoS, which has an NPV of £26,014,941,675 because 85 % of the waste produced each month is recycled and 100 % of its waste is diverted from landfills. This means that when aiming for higher recycling, there could be an increase in financial costs, but the extra environmental benefits the project brings to society could make up for that. So, when highly ambitious recycling goals are set and the strategies to reach them are mostly put in place, there could be more money saved and fewer negative effects on the environment

The results of this research will help policymakers and the public see why recycling is important. Universities need to set recycling and waste reduction goals that are at least 51% higher than what they are now. This could make the environment last longer and cut down on the risks and costs that come with the way waste is handled now.

8.1.4. Review the effectiveness of organisational structure and public engagement for better MSW management that will enhance environmental sustainability in Nigeria: This was done by using Lagos State as a case study to find out what the public thinks about how waste is handled in Nigeria. One of the challenges of municipal solid waste management is the ineffective management of waste through service delivery. With the help of public opinion in the case study area, it becomes easier to plan for better waste management. This objective was reached, which was to look at the gaps found in the way waste is managed in Nigeria to figure out how much certain programmes could be improved. This was done by getting public opinionsthrough questionnaires and visits to the waste management facilities in the case study area. The results show that littering on the roads, especially in low-income areas, is caused by the lack of adequate waste collection services in those areas. This shows that efficient waste management is the key to making the waste sector, especially in waste collection, more effective. Some people think that corruption is one reason there is not enough waste collection. This is the same as other writings that say corruption is the most important problem in Nigeria's waste management sector. Another problem is that there is not enough communication with the public, which makes it hard for people to help reduce waste and recycle. Good waste management practises and a communication strategy that focuses on environmental education have been shown to be effective ways to get more people involved in managing waste in a sustainable way. Waste management awareness programs should extend beyond conventional strategies by incorporating social norm messaging and adapting communication into local dialects to foster stronger public participation. Targeted engagement with low-income communities, particularly through radio, religious institutions, and community leaders, would further enhance effectiveness. In addition, optimizing waste collection routes through Geographic Information Systems (GIS) has the potential to significantly reduce travel time. Lessons from Glasgow demonstrate that source segregation combined with landfill taxation can substantially reduce landfill dependency. Lagos, Nigeria, could replicate these outcomes by implementing integrated policies that simultaneously address the socioeconomic and technical challenges identified in this synthesis. This thesis could help researchers, health workers, housing developers and planners, waste management agencies, and other stakeholders to enhance their knowledge on the subject matter and to make further research progress and good management decisions.

8.2. Research Limitations:

8.2.1 Aside from air emissions, the study did not consider other landfill emissions. Leachate and other water pollutants from the landfill were not considered; hence, there is room for future research in exploring current risks of leachate, water pollution and other emissions associated with landfill in the case studies.

8.2.2. The waste composition analysis at UoL and UoS was completed during student exam period and vacation, when there were fewer people on campus. Additionally, it should be noted that the studies conducted did not encompass the entirety of the university in both case studies. This limitation hinders a comprehensive understanding of the waste conditions within these institutions. Future research endeavours should aim to address this gap by conducting similar studies during regular school sessions and encompassing a wider area within the case study region. This comparative approach will allow for a more robust analysis and comparison with the current findings.

8.2.3. During the evaluation process of the cost benefit of waste management practices in the higher education institution (Chapter 5), the environmental cost was based on greenhouse gases emissions. Other intangible values or environmental costs, such as the monetary value of health risks or leachate, air toxics, health expenses, biodiversity loss, were not considered. So, future research incorporating health risks could gain a better understanding of the entire system if it compares other environmental costs, which is likely to increase more the nep present values of UoS. Furthermore, in both case studies, the projected standard market value of recyclable materials, specifically mixed plastics, and mixed papers, was based on the Nigeria market pricing as a reference point. There is potential for doing research aimed at incorporating the precise market value of recyclable materials in the United Kingdom into the assessment of cost advantages, considering environmental factors. This would contribute to a more comprehensive and equitable evaluation.

8.2.4. The existing case studies do not adequately address the financial budgeting practises of waste management authorities, the collection of opinions from private waste contractors responsible for waste collection services, and the perspectives of their staff. These aspects are crucial for understanding the underlying reasons for the inefficiencies in waste management, particularly in waste collection services. Consequently, further research is needed to explore this area.

8.3. Recommendations:

8.3.1. The Olushosun landfill site needs to be closed, and a new sanitary landfill site be put in its place. There should be full enforcement of international standards at the potential new site, including making sure that no homes are built within 3 km of the site to limit people's exposure to risks from the site, such as smells, dust, etc.

8.3.2. Good waste management practises and a communication strategy that puts an emphasis on environmental education should be adopted, as strategies have been shown to be effective ways to get more people involved in managing waste in a sustainable way. There is a need to improve the way waste is managed in the state. This could be done by getting more of the waste management agencies staff and other stakeholders involved in waste management, such as scavengers, who play a significant role in waste management and should be included in the scheme.

8.3.3. Source segregation of waste should be encouraged, and the amount of waste that goes to landfills should be kept to a minimum so that the effects of landfill emissions, such as CO_2, CH_4, and NMVOCs, can be lessened.

8.3.4. There should be an increase in the recycling target of at least 51 % from the current waste generation and recycling practises at UoL, as well as in higher educational institutions in Nigeria, to enhance environmental sustainability.

8.3.5. In the state of Lagos, the amount of time between waste pickups should be shortened to enhance efficient waste collection, so that less waste ends up on the roads (littering). To improve public health, it is important to educate the public about the benefits and risks of improper waste disposal, to encourage waste reduction and more recycling, and to enforce environmental laws in the state, such as not letting people go near high-risk waste disposal sites like landfills.

8.3.6. There is also a need to find the best shorter routes for collecting and transporting waste using GIS, which could help the state lower the high environmental and economic costs of waste management. This means that more money will be saved or used for other projects, operations will take less time, and haulage trucks will use less fuel. This will save energy, time, and money on waste management in the state.

8.4: Further Works: Below are the anticipated research areas for further studies:

8.4.1. Monitoring of underground water pollutants within 0.5 km of the Olushosun landfill site and Patersona of Greenoakhill landfill site. This will also enable a better understanding of the impact of landfills on the water ecosystem within the case study areas.

8.4.2. Assessment of leachate within the case studies and evaluating it's effect on public health. Other pollutants in leachate, except chemical emissions of landfill were not considered, so there is room for more research in those areas.

8.4.3. Further analysis of the recycling cost-benefit analysis, including more environmental costs in the evaluation process, to consider not only the greenhouse gas emissions costs but also other intangible values and environmental costs, such as the monetary value of health risks or other issues associated with the practice.

8.4.4. Evaluation of the financial budgeting of the waste management authorities. This will involve interviews with key waste management stakeholders to further balance the rationale behind the ineffective waste management, especially in the waste collection services, and further understand whether the allegation of corruption in service delivery is true or false, hence an area for future study.

8.4.5. Waste service delivery perceptions of the private waste contractors. This will entail gathering opinions from private waste contractors in charge of waste collection services, as well as their employees, to balance the rationale behind ineffective waste management, particularly in waste collection services, which is an area for future research.

8.4.6. Optimisation of waste collection transport routes to enhance waste collection delivery: This potential research area will enable the minimization of waste haulage costs as a high percentage of the waste management budget goes to the fuelling of waste collection trucks.

CHAPTER 9

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APPENDICES

Below are supplementary information supporting the Thesis

Appendix 3.1. Ethics Application Form for data collection to understand the service level, the participants' recycling performance and attitude towards solid waste management (see Chapter 3).

Ethics Application Form

Please answer all questions

1. Title of the investigation
Attitudinal effects on recycling performance and solid waste management in Nigeria
Please state the title on the PIS and Consent Form, if different:

2. Chief Investigator (must be at least a Grade 7 member of staff or equivalent)
Name: **Dr Tara K Beattie** ☐ Professor ☐ Reader ☐ Senior Lecturer ☑ Lecturer ☐ Senior Teaching Fellow ☐ Teaching Fellow Department: **Civil and Environmental Engineering** Telephone: **0141 548 3437** E-mail: **t.k.beattie@strath.ac.uk**

3. Other Strathclyde investigator(s)
Name: Charles Mbama Status (e.g. lecturer, post-/undergraduate): Postgraduate (PhD Research Student) Department: Civil and Environmental Engineering Telephone: E-mail: Charles.mbama@strath.ac.uk

4. Non-Strathclyde collaborating investigator(s) (where applicable) N/A
Name: Austin Otegbulu Status (e.g. lecturer, post-/undergraduate): Associate Professor Department/Institution: University of Lagos, Nigeria If student(s), name of supervisor: Telephone: E-mail: austinotegbulu@yahoo.com Please provide details for all investigators involved in the study:

5. Overseas Supervisor(s) (where applicable) N/A
Name(s): Status:

Department/Institution:
Telephone:
Email:
I can confirm that the local supervisor has obtained a copy of the Code of Practice: Yes ☐ No ☐
Please provide details for all supervisors involved in the study:

6. Location of the investigation

At what place(s) will the investigation be conducted

The investigation will take place in Ikeja town which is located at Lagos State Nigeria. Questionnaires will be distributed to few residents of the area by hand

If this is not on University of Strathclyde premises, how have you satisfied yourself that adequate Health and Safety arrangements are in place to prevent injury or harm?

Appropriate risk assessments have been carried out.

7. Duration of the investigation

Duration(years/months): 6 weeks

Start date (expected): 20/11/16 Completion date (expected): 09/01/17

8. Sponsor
Please note that this is not the funder; refer to Section C and Annexes 1 and 3 of the Code of Practice for a definition and the key responsibilities of the sponsor.

Will the sponsor be the University of Strathclyde: Yes ☑ No ☐
If not, please specify who is the sponsor:

9. Funding body or proposed funding body (if applicable) N/A

Name of funding body:
Status of proposal – if seeking funding (please click appropriate box):
☐ In preparation
☐ Submitted
☐ Accepted
Date of submission of proposal: Date of start of funding:

10. Ethical issues

Describe the main ethical issues and how you propose to address them:

The main ethical issue in this project is on the dealing/ or handling people's data. This research has taken measures to carry out the surveys in which limited personal data will be sampled (as such, participants will NOT be able to be identified from the information they provide) e.g.: age range, gender, profession etc.

Opportunity will be given to participants to either go ahead with the completion of the work or to discontinue.

11. Objectives of investigation (including the academic rationale and justification for the investigation) Please use plain English.

This investigation is inspired by the need to gain more understanding of the solid waste management (SWM) situation (which includes understanding the service level, the participants' recycling performance and attitude towards solid waste management) the cause and effects to human health in Nigeria. Improper SWM practice can pose environmental hazard, hence, exposing people to health risk. Nigeria is characterised by inefficiency in waste collection and improper disposal. Nigeria is characterised by unsanitary landfill/ open dumping of solid waste. This is believed to be representative of the actual situation of municipal solid waste management practices in the country, without knowing the implication of such practices to human health.

The main benefit of understanding the cause of improper waste disposal is in environmental planning which can help to improve sustainable waste management. Therefore, this investigation which uses questionnaire, will sample people's opinion to understand more on the waste management situation in the case study area (Lagos) and people's recycling performance including their attitude towards solid waste.

Additionally, the waste audit to be carried out at the University of Lagos is important for proper decision making in waste management approach to undertake, because it is based on the knowledge of generated solid waste composition that better cost effective waste technological treatment option can be chosen.

12. Participants

Please detail the nature of the participants:
Participants will be residents of Lagos state, Nigeria
Summarise the number and age (range) of each group of participants:
Number: **maximum of 600 available participants** Age (range) **18 Yrs. & over**
Please detail any inclusion/exclusion criteria and any further screening procedures to be used:
Only people living in the case study areas will be targeted for this research

13. Nature of the participants
Please note that investigations governed by the Code of Practice that involve any of the types of

participants listed in B1(b) must be submitted to the University Ethics Committee (UEC) rather than DEC/SEC for approval.

Do any of the participants fall into a category listed in Section B1(b) (participant considerations) applicable in this investigation? Yes ☐ No ☑
If yes, please detail which category (and submit this application to the UEC):

14. Method of recruitment

Describe the method of recruitment (see section B4 of the Code of Practice), providing information on any payments, expenses, or other incentives.

The participation of the participants for the questionnaire will be voluntary as the participants will be given the opportunity to complete or discontinue. However, for the waste audit, there is also opportunity given to seven (7) students of Waste Management Department, University of Lagos, been the second case study, to voluntarily participate, at no payment (s), although care will be taken to provide participants' lunch.

The student's participation will also help them to build their skill in waste management more especially in waste auditing.

15. Participant consent

Please state the groups from whom consent/assent will be sought (please refer to the Guidance Document). The PIS and Consent Form(s) to be used should be attached to this application form.

Before the participation of participants, the aim and objective of the research will be read to them and made them understand that the research is voluntary and that every information/ answer provided will be confidential. This will also be stated on the PIS and Consent form.

16. Methodology

Investigations governed by the Code of Practice which involve any of the types of projects listed in B1(a) must be submitted to the University Ethics Committee rather than DEC/SEC for approval.

Are any of the categories mentioned in the Code of Practice Section B1(a) (project considerations) applicable in this investigation? Yes ☐ No ☑
If 'yes' please detail:

Describe the research methodology and procedure, providing a timeline of activities where possible. Please use plain English.

1. Development of research questionnaire. This has been completed (see attached questions)

2. The questionnaire will be disseminated to people in the case study areas. This will be carried out in Lagos state by face-to-face distribution and collection of completed questionnaires will be done simultaneously.

3. The results will be transferred to a safe storage device, and after which analysed. Note: No participants can be identified through the information they provided.

4. Waste audit: Seven volunteered students of waste management department, University of Lagos will aid in waste audit. This will also help the students gain waste management skill especially in waste audit.

5. Results will be inputted into a safe electronic storage device and analysed afterward.

6. The students who participated during the waste audit will be asked to evaluate the project.

7. Using Origin Pro software, the data will be analysed.

What specific techniques will be employed and what exactly is asked of the participants? Please identify any non-validated scale or measure and include any scale and measures charts as an Appendix to this application. Please include questionnaires, interview schedules or any other non-standardised method of data collection as appendices to this application.

The investigational technique used is questionnaire which involves sampling of people's opinion in respect to waste management practice in the study area to understand service level, the participants' recycling performance and attitude towards solid waste management.

Where an independent reviewer is not used, then the UEC, DEC or SEC reserves the right to scrutinise the methodology. Has this methodology been subject to independent scrutiny? Yes ☐ No ☑

If yes, please provide the name and contact details of the independent reviewer:

17. Previous experience of the investigator(s) with the procedures involved. Experience should demonstrate an ability to carry out the proposed research in accordance with the written methodology.

The Chief Investigator, Dr Tara Beattie has over 20 years of experience managing student projects requiring collection of interview data.

18. Data collection, storage, and security

How and where are data handled? Please specify whether it will be fully anonymous (i.e. the identity unknown even to the researchers) or pseudo-anonymised (i.e. the raw data is anonymised and given a code name, with the key for code names being stored in a separate location from the raw data) - if neither please justify.

The questionnaire will be collated and safely handled by the researcher an ideal location. No participant can be identified based of the information they provided; this makes the presentation of the data anonymous.

Explain how and where it will be stored, who has access to it, how long it will be stored and whether it will be securely destroyed after use:

All the information from paper questionnaires will be collected and stored safely in an electronic format (a copy in the researchers computer, another in an external hard drive which will be backed up in a virtual storage e.g. icloud or google store) accessible by the researchers only. The data will then be inputted in Origin Pro for qualitative analysis. After the period of six (6) months of the data usage, it will be destroyed.

Will anyone other than the named investigators have access to the data? Yes No ☑
If 'yes' please explain:

19. Potential risks or hazards

Describe the potential risks and hazards associated with the investigation:

This investigation via questionnaire does not require personal information and as such pose no potential risks or hazards. However, for the waste audit, risk assessment has been completed and measure to address identified potential risks strictly handled.

Has a specific Risk Assessment been completed for the research in accordance with the University's Risk Management Framework (http://www.strath.ac.uk/safetyservices/aboutus/riskmanagement/)? Yes ☑ No ☐
If yes, please attach risk form (S20) to your ethics application. If 'no,' please explain why not:

20. What method will you use to communicate the outcomes and any additional relevant details of the study to the participants?

Participants will not be contacted directly with the outcomes. This is because of the anonymous nature of the questionnaire. However, the result of the waste audit will be communicated to University of Lagos via an official email address.

21. How will the outcomes of the study be disseminated (e.g. will you seek to publish the results and, if relevant, how will you protect the identities of your participants in said dissemination)?
The outcome of the investigation will be published and made publicly available at the University of Strathclyde. Meanwhile, participants cannot be identified by any way, because all respondents are anonymous.

Checklist	Enclosed	N/A
Participant Information Sheet(s)	☑	☐
Consent Form(s)	☑	☐
Sample questionnaire(s)	☑	☐
Sample interview format(s)	☐	☐
Sample advertisement(s)	☐	☐
Any other documents (please specify below)	☐	☐
		☐
	☐	☐
	☐	☐
	☐	☐
	☐	
	☐	

22. Chief Investigator and Head of Department Declaration
Please note that unsigned applications will not be accepted and both signatures are required

I have read the University's Code of Practice on Investigations Involving Human Beings and have completed this application accordingly. By signing below, I acknowledge that I am aware of and accept my responsibilities as Chief Investigator under Clauses 3.11 – 3.13 of the Research Governance Framework and that this investigation cannot proceed before all approvals required have been obtained.

Signature of Chief Investigator	Tara K. Beattie
Please also type name here:	Tara K Beattie

I confirm I have read this application, I am happy that the study is consistent with departmental strategy, that the staff and/or students involved have the appropriate expertise to undertake the study and that adequate arrangements are in place to supervise any students that might be acting as investigators, that the study has access to the resources needed to conduct the proposed research successfully, and that there are no other departmental-specific issues relating to the study of which I am aware.

Signature of Head of Department	
Please also type name here	
Date:	/ /

23. Only for University sponsored projects under the remit of the DEC/SEC, with no external funding and no NHS involvement

Head of Department statement on Sponsorship
This application requires the University to sponsor the investigation. This is done by the Head of Department for all DEC applications with exception of those that are externally funded and those which are connected to the NHS (those exceptions should be submitted to R&KES). I am aware of the implications of university sponsorship of the investigation and have assessed this investigation with respect to sponsorship and management risk. As this investigation is within the remit of the DEC and has no external funding and no NHS involvement, I agree on behalf of the University that the University is the appropriate sponsor of the investigation and there are no management risks posed by the investigation.

If not applicable, tick here ☐

Signature of Head of Department	
Please also type name here	

Date:	/ /

For applications to the University Ethics Committee, the completed form should be sent to ethics@strath.ac.uk with the relevant electronic signatures.

24. Insurance
The questionnaire below must be completed and included in your submission to the UEC/DEC/SEC:

Is the proposed research an investigation or series of investigations conducted on any person for a Medicinal Purpose? Medicinal Purpose means: ▪ treating or preventing disease or diagnosing disease or ▪ ascertaining the existence degree of or extent of a physiological condition or ▪ assisting with or altering in any way the process of conception or ▪ investigating or participating in methods of contraception or ▪ inducing anaesthesia or ▪ otherwise preventing or interfering with the normal operation of a physiological function or ▪ altering the administration of prescribed medication.	No

If "**Yes**" please go to **Section A (Clinical Trials)** – all questions must be completed
If "**No**" please go to **Section B (Public Liability)** – all questions must be completed

Section A (Clinical Trials)

Does the proposed research involve subjects who are either: i. under the age of 5 years at the time of the trial; ii. known to be pregnant at the time of the trial	No

*If "**Yes**" the UEC should refer to Finance*

Is the proposed research limited to: iii. Questionnaires, interviews, psychological activity including CBT; iv. Venepuncture (withdrawal of blood); v. Muscle biopsy; vi. Measurements or monitoring of physiological processes including scanning; vii. Collections of body secretions by non-invasive methods; viii. Intake of foods or nutrients or variation of diet (excluding administration of drugs).	No

*If "**No**" the UEC should refer to Finance*

Will the proposed research take place within the UK?	No

*If "**No**" the UEC should refer to Finance*

Title of Research		
Chief Investigator		
Sponsoring Organisation		
Does the proposed research involve:		
a) investigating or participating in methods of contraception?		Yes / No
b) assisting with or altering the process of conception?		Yes / No
c) the use of drugs?		Yes / No
d) the use of surgery (other than biopsy)?		Yes / No
e) genetic engineering?		Yes / No
f) participants under 5 years of age(other than activities i-vi above)?		Yes / No
g) participants known to be pregnant (other than activities i-vi above)?		Yes / No
h) pharmaceutical product/appliance designed or manufactured by the institution?		Yes / No
i) work outside the United Kingdom?		Yes / No

If **"YES"** to **any** of the questions a-i please also complete the **Employee Activity Form** (attached).
If **"YES"** to **any** of the questions a-i, and this is a follow-on phase, please provide details of SUSARs on a separate sheet.
*If "**Yes**" to any of the questions a-i then the UEC/DEC/SEC should refer to Finance (aileen.stevenson@strath.ac.uk).*

Section B (Public Liability)

Does the proposed research involve :	
a) aircraft or any aerial device	No
b) hovercraft or any water borne craft	No
c) ionising radiation	No
d) asbestos	No
e) participants under 5 years of age	No
f) participants known to be pregnant	No
g) pharmaceutical product/appliance designed or manufactured by the institution?	No
h) work outside the United Kingdom?	YES

*If **"YES"** to any of the questions the UEC/DEC/SEC should refer to Finance(aileen.stevenson@strath.ac.uk).*

For NHS applications only - Employee Activity Form

Has NHS Indemnity been provided?	Yes / No
Are Medical Practitioners involved in the project?	Yes / No
If YES, will Medical Practitioners be covered by the MDU or other body?	Yes / No

This section aims to identify the staff involved, their employment contract and the extent of their involvement in the research (in some cases it may be more appropriate to refer to a group of persons rather than individuals).

Chief Investigator		
Name	**Employer**	**NHS Honorary Contract?**
		Yes / No
Others		
Name	**Employer**	**NHS Honorary Contract?**
		Yes / No
		Yes / No
		Yes / No
		Yes / No

Please provide any further relevant information here:

Appendix 3.2. List of questions asked to operation manager at the Olushosun, which centers on solid waste management plan, policy, communication, and treatment (see Chapter 3).

DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING

INTERVIEW QUESTIONS FOR THE WASTE MANAGEMENT AGENCY, INCLUDING THE LANDFILL OPERATION MANAGER (S)

Municipal solid waste management plan

1. How are waste reduction integrated in the waste management plan and what role does landfill play in the plan?
2. What are the successes recorded in waste management in Glasgow especially in Landfilling of waste?

Waste management policy and communication

3. I think the government may have waste management policy, for which objectives or targets must be listed, if yes, what is the status of some of the targets?
   i.e. i. Service coverage
   ii. Waste collection efficiency
4. How is the efficiency and resourceful is the landfill as waste treatment option?

Waste management funding

5. How is the waste management funded?
6. How much money is usually allocated to the management of waste annually from the national budget? What of funding for landfill?
7. What are the challenges regarding funding?

Technological treatment & human resources

8. How is the collaboration of the government with private sector? Is there any challenge to this?
9. How is the health and safety of workers ensured?
10. Is there any capacity building for staff? How often is this done?
11. In your opinion, how is the public's level of awareness on solid waste management especially at household level based on the type of waste receives on site?

Landfill Emissions

12. What method is used to ascertain the emissions from the landfill site?
13. On what bases are the emission threshold set?
14. I need publish copy (link) of reference threshold limit of gas emissions for landfill site, please.
15. How are the emissions monitored to ensure it meet with the permissible limits or standards?

ADDITIONAL QUESTIONS FOR LANDFILL OPERATORS

16. What year was the Landfill opened and started accepting waste?
17. What is the anticipated close date?
18. What is the amount of daily waste receiving by the landfill site/ waste acceptance rate?
19. What is the waste design capacity?

Appendix 3.3. LandGEM model which has an excel interface that automatically calculate the chemical emission estimates from Olushosun landfill site (see Chapter 3).

INVENTORY

Landfill Name or Identifier: Olushosun

Enter year of emissions inventory: 2011

Gas / Pollutant	Emission Rate				
	(Mg/year)	*(m^3/year)*	*(av ft^3/min)*	*(ft^3/year)*	*(short tons/year)*
Total landfill gas	5.377E+04	4.305E+07	2.893E+03	1.520E+09	5.914E+04
Methane	1.436E+04	2.153E+07	1.446E+03	7.602E+08	1.580E+04
Carbon dioxide	3.940E+04	2.153E+07	1.446E+03	7.602E+08	4.334E+04
NMOC	9.259E+01	2.583E+04	1.736E+00	9.122E+05	1.019E+02
1,1,1-Trichloroethane (methyl chloroform) - HAP	1.147E-01	2.067E+01	1.388E-03	7.298E+02	1.261E-01
1,1,2,2-Tetrachloroethane - HAP/VOC	3.306E-01	4.736E+01	3.182E-03	1.672E+03	3.637E-01
1,1-Dichloroethane (ethylidene dichloride) - HAP/VOC	4.253E-01	1.033E+02	6.942E-03	3.649E+03	4.679E-01
1,1-Dichloroethene (vinylidene chloride) - HAP/VOC	3.472E-02	8.611E+00	5.785E-04	3.041E+02	3.819E-02
1,2-Dichloroethane (ethylene dichloride) - HAP/VOC	7.265E-02	1.765E+01	1.186E-03	6.234E+02	7.992E-02
1,2-Dichloropropane (propylene dichloride) - HAP/VOC	3.642E-02	7.749E+00	5.207E-04	2.737E+02	4.006E-02
2-Propanol (isopropyl alcohol) - VOC	5.382E+00	2.153E+03	1.446E-01	7.602E+04	5.920E+00
Acetone	7.280E-01	3.014E+02	2.025E-02	1.064E+04	8.008E-01
Acrylonitrile - HAP/VOC	5.986E-01	2.712E+02	1.822E-02	9.579E+03	6.584E-01
Benzene - No or Unknown Co-disposal - HAP/VOC	2.658E-01	8.180E+01	5.496E-03	2.889E+03	2.923E-01
Benzene - Co-disposal - HAP/VOC	1.539E+00	4.736E+02	3.182E-02	1.672E+04	1.692E+00
Bromodichloromethane - VOC	9.094E-01	1.335E+02	8.967E-03	4.713E+03	1.000E+00
Butane - VOC	5.204E-01	2.153E+02	1.446E-02	7.602E+03	5.724E-01

Carbon disulfide - HAP/VOC	7.907E-02	2.497E+01	1.678E-03	8.818E+02	8.697E-02
Carbon monoxide	7.022E+00	6.027E+03	4.050E-01	2.129E+05	7.724E+00
Carbon tetrachloride - HAP/VOC	1.102E-03	1.722E-01	1.157E-05	6.082E+00	1.212E-03
Carbonyl sulfide - HAP/VOC	5.271E-02	2.110E+01	1.417E-03	7.450E+02	5.798E-02
Chlorobenzene - HAP/VOC	5.039E-02	1.076E+01	7.232E-04	3.801E+02	5.543E-02
Chlorodifluoromethane	2.013E-01	5.597E+01	3.761E-03	1.977E+03	2.214E-01
Chloroethane (ethyl chloride) - HAP/VOC	1.502E-01	5.597E+01	3.761E-03	1.977E+03	1.652E-01
Chloroform - HAP/VOC	6.414E-03	1.292E+00	8.678E-05	4.561E+01	7.055E-03
Chloromethane - VOC	1.085E-01	5.166E+01	3.471E-03	1.824E+03	1.193E-01
Dichlorobenzene - (HAP for para isomer/VOC)	5.528E-02	9.041E+00	6.075E-04	3.193E+02	6.081E-02
Dichlorodifluoromethane	3.464E+00	6.888E+02	4.628E-02	2.433E+04	3.811E+00
Dichlorofluoromethane - VOC	4.792E-01	1.119E+02	7.521E-03	3.953E+03	5.271E-01
Dichloromethane (methylene chloride) - HAP	2.129E+00	6.027E+02	4.050E-02	2.129E+04	2.342E+00
Dimethyl sulfide (methyl sulfide) - VOC	8.678E-01	3.358E+02	2.256E-02	1.186E+04	9.546E-01
Ethane	4.792E+01	3.832E+04	2.575E+00	1.353E+06	5.271E+01
Ethanol - VOC	2.228E+00	1.162E+03	7.810E-02	4.105E+04	2.451E+00
Ethyl mercaptan (ethanethiol) - VOC	2.559E-01	9.902E+01	6.653E-03	3.497E+03	2.815E-01
Ethylbenzene - HAP/VOC	8.745E-01	1.980E+02	1.331E-02	6.994E+03	9.619E-01
Ethylene dibromide - HAP/VOC	3.364E-04	4.305E-02	2.893E-06	1.520E+00	3.701E-04
Fluorotrichloromethane - VOC	1.870E-01	3.272E+01	2.198E-03	1.156E+03	2.057E-01
Hexane - HAP/VOC	1.019E+00	2.841E+02	1.909E-02	1.003E+04	1.120E+00
Hydrogen sulfide	2.197E+00	1.550E+03	1.041E-01	5.473E+04	2.417E+00
Mercury (total) - HAP	1.042E-04	1.249E-02	8.389E-07	4.409E-01	1.146E-04
Methyl ethyl ketone - HAP/VOC	9.168E-01	3.057E+02	2.054E-02	1.079E+04	1.008E+00
Methyl isobutyl ketone - HAP/VOC	3.408E-01	8.180E+01	5.496E-03	2.889E+03	3.749E-01
Methyl mercaptan - VOC	2.154E-01	1.076E+02	7.232E-03	3.801E+03	2.369E-01
Pentane - VOC	4.264E-01	1.421E+02	9.546E-03	5.017E+03	4.690E-01
Perchloroethylene (tetrachloroethylene) - HAP	1.099E+00	1.593E+02	1.070E-02	5.625E+03	1.209E+00
Propane - VOC	8.685E-01	4.736E+02	3.182E-02	1.672E+04	9.553E-01
t-1,2-Dichloroethene - VOC	4.860E-01	1.205E+02	8.100E-03	4.257E+03	5.347E-01
Toluene - No or Unknown Co-disposal - HAP/VOC	6.434E+00	1.679E+03	1.128E-01	5.930E+04	7.077E+00
Toluene - Co-disposal - HAP/VOC	2.805E+01	7.319E+03	4.918E-01	2.585E+05	3.085E+01
Trichloroethylene (trichloroethene) - HAP/VOC	6.588E-01	1.205E+02	8.100E-03	4.257E+03	7.247E-01
Vinyl chloride - HAP/VOC	8.170E-01	3.143E+02	2.112E-02	1.110E+04	8.987E-01
Xylenes - HAP/VOC	2.281E+00	5.166E+02	3.471E-02	1.824E+04	2.509E+00

*M^3/year was converted to Kg/per year using Traditional Oven, 2023.

Appendix 3.4. Chemical Emissions from Patterson Greenoakhill landfill site, Glasgow (Chapter 3).

Air Pollutants	2011 (Kg/yr)	SPRI-RT (kg/yr)
Formaldehyde	BRT	10
Ethylene dichloride	BRT	1000
Ethylene	BRT	1000
Ethyl toluene	BRT	10
Para-Dichlorobenzene	BRT	1
Chloroform	BRT	100
Carbon tetrachloride	BRT	10
Butene – all isomers	BRT	1,000
Butadiene	BRT	100
Benzo(a) pyrene	BRT	1
Benzene	BRT	1,000
Acetaldehyde	BRT	100
Hydrogen chloride	BRT	10,000
Carbon monoxide	167,000	100,000
Carbon disulphide	BRT	1,000
Carbon dioxide	49,300,000	10,000,000
Hexachlorocyclohexane – all isomers	BRT	1
Sulphur oxides, SO2 and SO3 as SO2	BRT	100,000
Perflurocarbons (PGCs)	BRT	10
Particulate matter – PM10 and smaller	BRT	10,000
Non-methane volatile organic compounds (NMVOCs)	BRT	10,000
Nitrogen oxides, NO and NO2	142,000	100,000
Hydrofluorocarbons (HFCs)	BRT	100

Appendix 4.1. General Risk Assessment Form for Travelling to Nigeria for Data Collection.

Appendix 4.1. General Risk Assessment Form for Travelling to Nigeria for Data Collection

University of Strathclyde Glasgow

GENERAL RISK ASSESSMENT FORM (S20)

Persons who undertake risk assessments must have a level of competence commensurate with the significance of the risks they are assessing. It is the responsibility of each Head of Department or Director of Service to ensure that all staff are adequately trained in the techniques of risk assessment. The University document "Guidance on Carrying Out Risk Assessments" will be available, in due course, to remind assessors of the current practice used by the University. However, reading the aforementioned document will not be a substitute for suitable training.

Prior to the commencement of any work involving non-trivial hazards, a suitable and sufficient assessment of risks should be made and where necessary, effective measures taken to control those risks.

Individuals working under this risk assessment have a legal responsibility to ensure they follow the control measures stipulated to safeguard the health and safety of themselves and others.

SECTION 1

1.1 OPERATION / ACTIVITY	Complete the relevant details of the activity being assessed.		
Title:	*Field trip to Nigeria for data collection*		
Department:	Civil and Environmental Engineering		
Location(s) of work:	Nigeria	**Ref No.**	
Brief description: *The trip involves going to Abuja and University of Lagos State, Nigeria. The purpose of the trip is for data verification and collaborative work from Prof Austin Otagbulu*			

1.2 PERSON RESPONSIBLE FOR MANAGING THIS WORK

Name:	Dr Tara K. Beattie	**Position:**	Academic Supervisor
Signature:	Tara K. Beattie	**Date:**	31/01/2020
Department:	Civil and Environmental Engineering		

1.3 PERSON CONDUCTING THIS ASSESSMENT			
Name:	Charles Mbama	**Signature:**	[signature]
Name:		**Signature:**	
Name:		**Signature:**	
Date risk assessment undertaken:	January 2020.		

1.4 ASSESSMENT REVIEW HISTORY

This assessment should be reviewed immediately if there is any reason to suppose that the original assessment is no longer valid. Otherwise, the assessment should be reviewed annually. The responsible person must ensure that this risk assessment remains valid.

	Review 1	Review 2	Review 3	Review 4
Due date:	31/01/2020			
Date conducted:				
Conducted by:				

SECTION 2

Work Task Identification and Evaluation of Associated Risks			Page 2 of 7	Ref No.					
Component Task / Situation	**Hazards Identified**	**Hazard Ref No.**	**Who Might be Harmed and How?**	**Existing Risk Control Measures (RCM)**	**Likelihood**	**Severity**	**Risk Rating**	**Risk**	**RCM' s**
Flight to Nigeria	*Swollen ankles and occasionally Deep Vein Thrombosis (DVT).*	*1*	*Mbama C (Researcher) – from sitting still for a longer time (over 5 hours) in a cramped aircrafts during journey.*	*Regular stretching and walking around the cabin during flight time. To avoid contrition of vein, loose-fitting clothing will be worn.*	*1*	*3*	*3*	*L*	*Y*
Transportation within Nigeria	*Low quality roads with local drivers*	*2*	*Mbama C. – when utilizing public transport within the country*	*Travel only during daylight hours. Use flight were applicable.* *Use reputable companies for transportation. Wear seat belts. Plan travel according to local weather.*	*2*	*4*	*8*	*M*	*Y*
	Malaria	*3*	*Mbama C. – when exposed to mosquitoes insects*	*Consult GP (General Practitioner) for appropriate advice and for proper immunisations and travel with good anti malaria drugs.* *More importantly, is to sleep in a netted room.*	*2*	*4*	*8*	*M*	*Y*
				Avoid staying close to stagnant water and use insect repellent.					
	Typhoid fever	*4*	*Mbama C- when consumed contaminated water*	*Only drink bottled water and practice good hygiene regularly.*					
	Cholera	*5*	*Mbama C - from consuming contaminated food or water / drink*	*Only drink bottled water. Avoid eating salad and items of food that could be prepared with unsafe water. Avoid eating cold foods and avoid street vendors.*	*4*	*3*	*12*	*M*	*Y*
	Exposure to criminal activity	*6*	*Mbama C – Mugging, theft etc.*	*Keep essential items/ documents secure. Rent a safe and secured hotel accommodation. Avoid staying late outside (never stay outside your accommodation after 6:30 pm)*	*4*	*3*	*12*	*M*	*Y*
	Exposure to terrorist group known as bokoharam	*7*	*Mbama C - terrorism activities*	*Never travel to the northern part of the country which includes Kano, Borno, Gombe, Jigawa, Bauchi and Adamawa States, where the violence is high. Concentrate on*	*2*	*3*	*6*	*M*	*Y*

				your study area which is in the eastern part of the country.					
Activities within Nigeria	*Cuts and scrapes*	*8*	*Mbama C – during movement and handling objects in Nigeria*	*Be careful of surroundings. Keep first aid kit available and under your reach at all times. Be mindful with handling sharp objects*	*2*	*1*	*2*	*L*	*Y*

SECTION 2 – continuation sheet

Work Task Identification and Evaluation of Associated Risks				**Page 3 of 7**	**Ref No.**				
Component Task / Situation	**Hazards Identified**	**Hazard Ref No.**	**Who Might be Harmed and how?**	**Existing Risk Control Measures (RCM)**	**Likelihood**	**Severity**	**Risk Rating**	**Risk**	**RCM' s**
	Sunburn and dehydration	*9*	*Mbama C – when exposed to the sun*	*Drink enough fluids every day. Use sunscreen and wear light and loose clothing to protect skin from sunburn.*	*3*	*2*	*6*	*M*	*Y*
	Schistosomiasis	*10*	*Mbama C – when exposed to fresh water in Africa.*	*Never paddle nor swim in any waterways.*	*2*	*4*	*8*	*M*	*Y*

SECTION 3

Identified Actions to Improve Control of Unacceptable Risks (as evaluated in Section 2)				**Page 4 of 7**	**Ref No.**						
							Revised Risk				
Hazard Ref No.	**Risk**	**Recommended Additional Risk Control Measures**	**Implemented Y/N**	**Action By**	**Target Date**	**Completion Date**	**Likelihood**	**Severity**	**Risk Rating**	**Risk**	**Revision of Risk Signed Off**

SECTION 4

RECORD OF SIGNIFICANT FINDINGS	**Page 6 of 7**
	Ref No.

Where this Section is to be given to staff etc., without Sections 2 & 3,

please attach to the front of this page, a copy of the relevant Section 1 details.

The significant findings of the risk assessment should include details of the following:

- The identified hazards
- Groups of persons who may be affected
- An evaluation of the risks
- The precautions that are in place (or should be taken) with comments on their effectiveness
- Identified actions to improve control of risks, where necessary

Alternatively, where the work activity/procedure is complex or hazardous, then a written Safe System of Work (SSOW) or Standard Operating Procedure (SOP) is advised that should incorporate the significant findings. Such documents should again, have the relevant Section 1 attached. Please state below whether either a SSOW or SOP is available in this case.

Relevant SSOW available Yes ☐ No X	Relevant SOP available Yes ☐ No X

Significant Findings: (Please use additional pages if further space is required)

The hazards identified in this risk assessment are understood to be such that are faced when travelling to typical developing nations of Africa. Such hazards are potential risk to the research. These include; suffering from malaria, typhoid, or cholera etc. of which good measures have been taken to mitigate them. Such measures are staying under netted apartment, avoid drinking untreated water or / drinking bottled water and warm food. More importantly ensuring the practice of personal hygiene.

Another hazard identified is road accident which is mostly because of poor-quality roads, however, measured are taken to prevent such strictly travelling only under daylights. Terrorism is another hazard in Nigeria, although this is only prevalence in the core northern States, therefore, care is taken not to visit the northern part of the country. Only the case study area will be visited which is in the southern Nigeria. More so, movement from Abuja to Lagos will be by flight to minimise the risk.

Nigeria is known for her harsh weather condition, most at times, the temperature reaches more than 30^{o}C of which long term exposure could result to dehydration and sunburn. Cares have been taken to prevent its occurrence by wearing light clothing materials and taking more fluid.

For the incidence of crime identified as a hazard, care has also been taken to ensure that safe and secured accommodations are rented and avoiding keeping late each day.

As a result of the risk assessment been categorised as low or medium, it was rated satisfactory and acceptable, if all precautionary measures are adhered to. Based on the above, no further action is required to improve the control of Unacceptable Risks.

Personal Contact Details

Email contact – Charles.mbama@strath.ac.uk or charllyzbomma@yahoo.com (both will be checked regularly)

Mobile Phone – +44 (0) 7771098695 (UK number) and +234 34606065 (Nigeria number) Both will be functional.

Skype –

SECTION 5

RECEIPT OF SIGNIFICANT FINDINGS OF RISK ASSESSMENT **Page 7 of 7**

Please copy this page if further space is required. **Ref No.**

All individuals working to the risk assessment with the Ref. No. as shown, must sign and date this Section to acknowledge that they have read the relevant risk assessment and are aware of its contents, plus the measures taken (or to be taken by them) to safeguard their health and safety and that of others.

If following review of the assessment revisions are minor, signatories may initial these where they occur in the documentation, to indicate they are aware of the changes made. If revisions are major, it is advisable to produce a new risk assessment and signature page.

NAME (Print)	SIGNATURE	DATE
Charles Mbama		30/01/2020
Delete this page		

Appendix 4.2. Interview questions used on the waste management coordinators to gain insight into the universities' waste management approach and the Lagos waste management agency (see Chapter 4).

University of Strathclyde Engineering

DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING

INTERVIEW QUESTIONS FOR THE WASTE MANAGEMENT AGENCY, INCLUDING THE LANDFILL OPERATION MANAGER (S)

Municipal solid waste management plan

1. Given a mass deposit of waste in public areas, how does the agency remove such material and alleviate the current situation?
2. Does the federal Government have an integrated waste management plan? What of the State?
3. How is waste reduction integrated in the waste management plan? **[Need a copy of the plan]**
4. What are the successes or achievements recorded in waste management in the state?

Waste management policy and communication

5. Does the fed/state government have any waste management policy? If yes, what are the objectives or targets? **[Need a copy of this].** What are the statuses of some of these targets?
   i.e. i. Service coverage
   ii. Waste collection efficiency
6. What are the communication strategies used by the agency to the public and what is been communicated?
7. What is the efficiency in waste collection, treatment, and disposal? **[Need a copy of this, if any].**

Waste management funding

8. How is the waste management funded?
9. How much money is allocated to the management of waste annually from the national budget? What percentage?
10. What are the challenges with regards to funding?

Technological treatment & human resources

11. How many numbers of staff are employed by the agency and their roles? **[Need a breakdown pls]**
12. What is the primary method of waste management used in the State?
13. Is there collaboration between the government and the private sector? Is there any challenge to this?
14. What is the significant of scavengers in the waste management of the State?
15. How is the health and safety of official workers ensured? What of the scavengers?
16. Is there any capacity building/ formal trainings for staff and when last was it done?

17. In your opinion, how is the public's level of awareness on solid waste management especially at household level?
18. How much complains does the agency receive from the public monthly?
    What complain?

ADDITIONAL QUESTIONS FOR BOTH LAWMA AND LANDFILL OPERATORS

19. What year was the Landfill opened and started accepting waste?
20. What is the anticipated close date?
21. What is the amount of daily waste receiving by the landfill site (waste acceptance rate)?
22. What is the waste/ landfill site design capacity?
23. What are the types of waste accepted by the landfills and the health & safety of the workplace?
24. What is the level of your awareness of pollution in the site?
25. Are there any pollution mitigation strategies for the landfill operation?
26. Also is there any design element that focused on mitigating environmental/human health risk?

Appendix 4.3a. Time Series Analysis for University of Lagos Waste Generation data to generate seasonal index and waste generation trend line or pattern.

S/n	Time Period	Quarter	X Code	Y	4QMA	Centred Average	% of Average
	2014	Q4	1	2097.9156			
1	2015	Q1	2	3338.742			
2					2780.79615		
3	2015	Q2	3	2968.383		2850.9822	104.1179072
4					2921.16825		
5	2015	Q3	4	2718.144		2884.666125	94.22733454
6					2848.164		
7	2015	Q4	5	2659.404		2748.108	96.77217926
8					2648.052		
9	2016	Q1	6	3046.725		2581.2215	118.034233
10					2514.391		
11	2016	Q2	7	2167.935			

S/n	Time Period	Quarter	X Code	Y	4QMA	Centred Average	% of Average
	2014	Q4	1	2097.9156			
1	2015	Q1	2	3338.742			
2					2780.79615		
3	2015	Q2	3	2968.383		2850.9822	104.1179072
4					2921.16825		
5	2015	Q3	4	2718.144		2884.666125	94.22733454
6					2848.164		
7	2015	Q4	5	2659.404		2748.108	96.77217926
8					2648.052		
9	2016	Q1	6	3046.725		2581.2215	118.034233
10					2514.391		
11	2016	Q2	7	2167.935			
12	2016	Q3	8	2183.5			

S/n	Year	Q1	Q2	Q3	Q4	Total
1	2014					
2	2015		104.12%	94.23%	96.77%	
3	2016	118.03%				
4	MEAN	118.03%	104.12%	94.23%	96.77%	**413.15%**
5	X adj Factor	0.9682	0.9682	0.9682	0.9682	0.9682
6	**Seasonal Index**	114.2766	100.809	91.23%	93.69%	**400**

	x code	y	xy	x^2
	1	2097.9156	2097.9156	1
	2	3338.742	6677.484	4
	3	2968.383	8905.149	9
	4	2718.144	10872.576	16
	5	2659.404	13297.02	25
	6	3046.725	18280.35	36
	7	2167.935	15175.545	49
	8	2183.5	17468	64
Total	**36**	**21180.7486**	**92774.0396**	**204**
MEAN	**4.5**	**2647.593575**	**11596.75495**	**25.5**

B To obtain a regression trend line representing the above data, the trend equation is used as shown below:

$Y = a + bx$

However,

$$b = \frac{n\sum xy - \sum x \sum y}{n\sum x^2 - (\sum x)^2}$$

While,

$$a = \frac{\sum y/n - b(\sum x/n)}{}$$

There, $a = \bar{y} - bx$

Therefore substituting the trend values from the above equation

$$b = \frac{n\sum xy - \sum x \sum y}{n\sum x^2 - (\sum x)^2}$$

$$b = \frac{8(92774.0396) - (36)(21180.7486)}{8(204) - (36)^2}$$

$$\mathbf{b = -60.46022}$$

There,

$a = \bar{y} - bx = 2647.593575 - (-60.46022)(4.5)$

$$\mathbf{a = 2919.665}$$

Y = a + bx

Y= 2919.665 + (-60.46022) x

Seasonal adjusted trend estimate (**forecast**) for the **4th Quarter of 2016**

Y = a + bx

Y= 2919.665 + (-60.46022) (9)

Y = 2919.665 + (-544.14198)

Y = 2375.52302 Then this value multiply by the seasonal index of Q4 gives the Y. (ie 2375.52302 * 93.69%)

Y = 2,225.63 tonnes

S/n	Time Period	X Code	Y
	4th Quarter, 2014	1	2097.9156
1	1st Quarter, 2015	2	3338.742
3	2nd Quarter, 2015	3	2968.383
5	3rd Quarter, 2015	4	2718.144
7	4th Quarter, 2015	5	2659.404
9	1st Quarter, 2016	6	3046.725
11	2nd Quarter, 2016	7	2167.935
13	3rd Quarter, 2016	8	2183.5
15	4th Quarter, 2016	9	2225.63
17	1st Quarter, 2017	10	2645.5751
19	2nd Quarter, 2017	11	2272.8423
21	3rd Quarter, 2017	12	2001.7161
22	4th Quarter, 2017	13	1999.0468

S/n	Time Period	Y	4QMA	X Code
	4th Quarter, 2014	2097.9156		1
1	1st Quarter, 2015	3338.742		2
3	2nd Quarter, 2015	2968.383	2780.79615	3
5	3rd Quarter, 2015	2718.144	2921.16825	4
7	4th Quarter, 2015	2659.404	2848.164	5
9	1st Quarter, 2016	3046.725	2648.052	6
11	2nd Quarter, 2016	2167.935	2514.391	7
13	3rd Quarter, 2016	2183.5	2225.63	8
15	4th Quarter, 2016	2225.63	2645.5751	9

17	1st Quarter, 2017	2645.5751	2272.842	10
19	2nd Quarter, 2017	2272.8423	2001.7161	11
21	3rd Quarter, 2017	2001.7161	1999.0468	12
22	4th Quarter, 2017	1999.0468		13

Appendix 4.3b: Time Series Analysis for University of Strathclyde Waste Generation data generate seasonal index and waste generation trend line or pattern.

S/n	Month	Quantity of waste disposed (tonnes)	Quarterly Total for waste disposed (t)
1	Feb-11	53.73	
2	Mar-11	63.29	
3	Apr-11	48.978	165.998
4	May-11	53.142	
5	Jun-11	59.097	
6	Jul-11	51.392	163.631
7	Aug-11	51.445	
8	Sep-11	48.692	
9	Oct-11	55.563	155.7
10	Nov-11	57.976	
11	Dec-11	46.457	
12	Jan-12	51.252	155.685
13	Feb-12	55.634	
14	Mar-12	60.693	
15	Apr-12	52.563	168.89
16	May-12	61.872	
17	Jun-12	51.185	
18	Jul-12	65.323	178.38
19	Aug-12	55.47	
20	Sep-12	44.583	
21	Oct-12	51.894	151.947
22	Nov-12	50.736	
23	Dec-12	34.777	
24	Jan-13	48.924	134.437

25	Feb-13	44.194	
26	Mar-13	43.716	136.834
27	Apr-13	44.669	
28	May-13	45.526	
29	Jun-13	43.927	134.122
30	Jul-13	5.359	
31	Aug-13	48.75	
32	Sep-13	46.133	100.242
33	Oct-13	52.029	
34	Nov-13	46.413	
35	Dec-13	36.48	134.922
36	Jan-14	47.823	
37	Feb-14	44.585	
38	Mar-14	46.541	138.949
39	Apr-14	45.228	
40	May-14	49.015	
41	Jun-14	46.81	141.053
42	Jul-14	45.306	
43	Aug-14	44.988	137.104
44	Sep-14	47.11	
45	Oct-14	51.393	
46	Nov-14	43.699	142.202
47	Dec-14	37.899	
48	Jan-15	43.995	
49	Feb-15	47.792	129.686
50	Mar-15	56.002	
51	Apr-15	55.569	
52	May-15	48.453	
53	Jun-15	56.747	160.769

Time Series Analysis for University

Waste Generation

S/n	Time Period	Quarter	X Code	Y	4QMA	Centred Average	% of Average
	2011	Q1	1	165.998			
1	2011	Q2	2	163.631			
2					160.2535		
3	2011	Q3	3	155.7		160.615	96.93988731
4					160.9765		
5	2011	Q4	4	155.685		162.820125	95.61778681
6					164.66375		

7	2012	Q1	5	168.89		164.194625	102.8596399
8					163.7255		
9	2012	Q2	6	178.38		144.264875	123.6475615
10					124.80425		
11	2012	Q3	7	151.947		137.601875	110.4250941
12					150.3995		
13	2012	Q4	8	134.437		144.86725	92.80013254
14					139.335		
15	2013	Q1	9	136.834		132.871875	102.981914
16					126.40875		
17	2013	Q2	10	134.122		126.469375	106.0509708
18					126.53		
19	2013	Q3	11	100.242		126.794375	79.05871219
20					127.05875		
21	2013	Q4	12	134.922		127.925125	105.469508
22					128.7915		
23	2014	Q1	13	138.949		133.39925	104.1602558
24					138.007		
25	2014	Q2	14	141.053		138.917	101.5376088
26					139.827		
27	2014	Q3	15	137.104		138.669125	98.8713241
28					137.51125		
29	2014	Q4	16	142.202		139.97575	101.5904541
30					142.44025		
31	2015	Q1	17	129.686			
32	2015	Q2	18	160.769			

S/n	Year	Q1	Q2	Q3	Q4	Total
1	2011			96.9398873	95.61778681	
2	2012	102.85964	123.647561	110.425094	92.80013254	
	2013	102.981914	106.050971	79.0587122	105.469508	
	2014	104.160256	101.537609	98.8713241	101.5904541	
3	2015					
4	MEAN	103.33	110.41	96.32	98.87	408.94
5	X adj Factor	0.98	0.98	0.98	0.98	0.98
6	Seasonal Index	101.08	108.00	94.22	96.71	**400.00**

B To obtain a regression trend line representing the above data, the trend equation is used as shown below:

$Y = a + bx$

However,

b = $\dfrac{n\sum xy - \sum x \sum y}{n\sum x^2 - (\sum x)^2}$

While,

a = $\sum y/n - b(\sum x/n)$

There, $a = \bar{y} - bx$

Therefore substituting the trend values from the above equation

b = $\dfrac{n\sum xy - \sum x \sum y}{n\sum x^2 - (\sum x)^2}$

b = $\dfrac{18(24142.782) - (171)(2630.551)}{18(2109) - (171)^2}$

b = -1.749

There,

a = $\bar{y} - bx$ = 146.1417 - (-1.749) (9.5)

a = 162.7577

$Y = a + bx$

Y= 162.7577 + (-1.749) x

This equation can be further used to make forcast to see the pattern for further years

	x code	y	xy	x^2
	1	165.998	165.998	1
	2	163.631	327.262	4
	3	155.7	467.1	9
	4	155.685	622.74	16
	5	168.89	844.45	25
	6	178.38	1070.28	36
	7	151.947	1063.629	49
	8	134.437	1075.496	64
	9	136.834	1231.506	81
	10	134.122	1341.22	100
	11	100.242	1102.662	121
	12	134.922	1619.064	144
	13	138.949	1806.337	169
	14	141.053	1974.742	196
	15	137.104	2056.56	225
	16	142.202	2275.232	256
	17	129.686	2204.662	289
	18	160.769	2893.842	324
Total	**171**	**2630.551**	**24142.78**	**2109**
MEAN	**9.5**	**146.1417222**	**1341.266**	**117.1666667**

162.7577

Time Period	Y	4QMA	X Code
1st Quarter, 2011	165.998		1
2nd Quarter, 2011	163.631	160.2535	2
3rd Quarter, 2011	155.7	160.9765	3
4th Quarter, 2011	155.685	164.66375	4
1st Quarter, 2012	168.89	163.7255	5
2nd Quarter, 2012	178.38	124.80425	6
3rd Quarter, 2012	151.947	150.3995	7
4th Quarter, 2012	134.437	139.335	8
1st Quarter, 2013	136.834	126.40875	9
2nd Quarter, 2013	134.122	126.53	10
3rd Quarter, 2013	100.242	127.05875	11
4th Quarter, 2013	134.922	128.7915	12
1st Quarter, 2014	138.949	138.007	13
2nd Quarter, 2014	141.053	139.827	14
3rd Quarter, 2014	137.104	137.51125	15
4th Quarter, 2014	142.202	142.44025	16
1st Quarter, 2015	129.686		17
2nd Quarter, 2015	160.769		18

Appendix 5.1. Costs and benefits including the greenhouse gas based on landfilling and recycling of waste at the university of Lagos.

	Construction cost (£)	Borehole drilling cost (£)	826 Waste Bins @ 2000 each (£)	Weighing Balance cost (£)	Technical staff training cost (£)	Total Waste Generated & reduction target	Total Waste Generated (tonnes)	Quantity of waste disposed (tonnes)	GHGs (Landfilled)	GHGs diverted from landfill	Quantity of waste recycled at 1% rate (tonnes)	Cost of haulage (£)	Cost of Sorting Recyclables (£)	Environmental Cost (from GHGs in £)	Benefit (from mixed Plastic at 28%	Benefit (mixed paper) at 24% composition	Environmental Saving (from (GHGs diverted from landfill in £)	TOTAL COST	TOTAL BENEFIT
Oct-14	3,000.00	4,000.00	3,304.00	40.00	-	496.57	491.60	486.68	96.85	0.98	4.92	2,566.15	315.66	6,682,651.86	55.06	70.79	67,501.53	6,695,877.67	67,627.38
Nov-14	-	-	-	-	-	584.22	578.38	572.59	113.95	1.15	5.78	3,019.12	371.38	7,862,260.25	64.78	83.29	79,416.77	7,865,650.75	79,564.83
Dec-14	-	-	-	-	-	1,025.21	1,014.96	1,004.81	199.96	2.02	10.15	5,298.09	651.71	13,797,043.24	113.68	146.15	139,364.07	13,802,993.04	139,623.90
Jan-15	-	-	-	-	-	1,040.50	1,030.09	1,019.79	202.94	2.05	10.30	5,377.07	661.42	14,002,724.81	115.37	148.33	141,441.66	14,008,763.30	141,705.37
Feb-15	-	-	-	-	-	1,067.53	1,056.86	1,046.29	208.21	2.10	10.57	5,516.79	678.61	14,366,582.08	118.37	152.19	145,116.99	14,372,777.48	145,387.55
Mar-15	-	-	-	-	-	1,250.47	1,237.96	1,225.58	243.89	2.46	12.38	6,462.16	794.90	16,828,476.15	138.65	178.27	169,984.61	16,835,733.20	170,301.53
Apr-15	-	-	-	-	-	1,048.07	1,037.59	1,027.21	204.42	2.06	10.38	5,416.22	666.24	14,104,680.75	116.21	149.41	142,471.52	14,110,763.21	142,737.15
May-15	-	-	-	-	-	1,063.03	1,052.40	1,041.87	207.33	2.09	10.52	5,493.52	675.75	14,305,981.82	117.87	151.55	144,504.87	14,312,151.09	144,774.28
Jun-15	-	-	-	-	-	879.01	870.22	861.52	171.44	1.73	8.70	4,542.54	558.77	11,829,472.64	97.46	125.31	119,489.62	11,834,573.94	119,712.40
Jul-15	-	-	-	-	-	999.83	989.83	979.93	195.01	1.97	9.90	5,166.90	635.57	13,455,411.45	110.86	142.54	135,913.25	13,461,213.92	136,166.64
Aug-15	-	-	-	-	-	926.70	917.43	908.25	180.74	1.83	9.17	4,788.97	589.08	12,471,232.51	102.75	132.11	125,972.05	12,476,610.56	126,206.91
Sep-15	-	-	-	-	-	823.95	815.71	807.55	160.70	1.62	8.16	4,257.98	523.76	11,088,448.38	91.36	117.46	112,004.53	11,093,230.13	112,213.35
Oct-15	-	-	-	-	-	920.02	910.82	901.71	179.44	1.81	9.11	4,754.49	584.84	12,381,428.92	102.01	131.16	125,064.94	12,386,768.25	125,298.11
Nov-15	-	-	-	-	-	862.56	853.94	845.40	168.23	1.70	8.54	4,457.55	548.31	11,608,146.43	95.64	122.97	117,254.00	11,613,152.29	117,472.61
Dec-15	-	-	-	-	-	909.71	900.61	891.60	177.43	1.79	9.01	4,701.18	578.28	12,242,612.20	100.87	129.69	123,662.75	12,247,891.66	123,893.31
Jan-16	-	-	-	-	-	934.74	925.39	916.13	182.31	1.84	9.25	4,830.52	594.19	12,579,432.84	103.64	133.26	127,064.98	12,584,857.56	127,301.88
Feb-16	-	-	-	-	-	994.88	984.93	975.08	194.04	1.96	9.85	5,141.33	632.42	13,388,809.03	110.31	141.83	135,240.50	13,394,582.78	135,492.64
Mar-16	-	-	-	-	-	1,164.22	1,152.58	1,141.05	227.07	2.29	11.53	6,016.46	740.07	15,667,798.77	129.09	165.97	158,260.59	15,674,555.30	158,555.65
Apr-16	-	-	-	-	-	752.90	745.37	737.92	146.85	1.48	7.45	3,890.83	478.60	10,132,328.85	83.48	107.33	102,346.76	10,136,698.28	102,537.57
May-16	-	-	-	-	-	795.78	787.83	779.95	155.21	1.57	7.88	4,112.45	505.86	10,709,451.14	88.24	113.45	108,176.27	10,714,069.45	108,377.96
Jun-16	-	-	-	-	-	650.92	644.41	637.97	126.96	1.28	6.44	3,363.83	413.78	8,759,947.56	72.17	92.80	88,484.32	8,763,725.18	88,649.29
Jul-16	-	-	-	-	-	658.80	652.21	645.69	128.49	1.30	6.52	3,404.55	418.79	8,865,967.74	73.05	93.92	89,555.23	8,869,791.07	89,722.20
Aug-16	-	-	-	-	-	822.70	814.47	806.33	160.46	1.62	8.14	4,251.55	522.97	11,071,693.48	91.22	117.28	111,835.29	11,076,468.00	112,043.79
Sep-16	-	-	-	-	-	733.46	726.13	718.87	143.05	1.44	7.26	3,790.38	466.25	9,870,737.05	81.33	104.56	99,704.41	9,874,993.67	99,890.30
Oct-16	-	-	-	-	-	767.83	760.15	752.55	149.76	1.51	7.60	3,967.99	488.09	10,333,266.56	85.14	109.46	104,376.43	10,337,722.65	104,571.03
														298,406,586.52	2,458.61	3,161.07		298,545,614.43	3,019,827.62

Appendix 5.2. Costs and benefits including the greenhouse gas based on landfilling and recycling of waste at the university of Strathclyde.

	Construction cost (€)	Borehole drilling cost (€)	826 Waste Bins @ 2000 each (€)	Weighing Balance cost (€)	Technical staff training cost (€)	Waste Generated & reduction target	Total Waste Generated (tonnes)	Quantity of waste Landfilled (tonnes)	GHGs (Landfilled)	GHGs diverted from landfill	Quantity of waste recycled at 100% rate (tonnes)	Cost of haulage (£)	Cost of Sorting Recyclables (£)	Cost of Awareness Creation (€)	Environmental Cost (from GHGs in €)	Benefit (from mixed Plastic at 21%	Benefit (mixed paper) at 24% compositio	Environmental Saving (from (GHGs diverted from landfill in £)	TOTAL COST	TOTAL BENEFIT
Feb-11	3,000.00	4,000.00	3,304.00	40.00	-	53.73	53.19	-	-	10.59	53.19	277.67	3,415.50	-	-	446.82	1,244.71	730,388.96	14,037.17	732,080.49
Mar-11	-	-	-	-	-	63.29	62.66	-	-	12.47	62.66	327.07	4,023.21	-	-	526.32	1,466.18	860,344.64	4,350.28	862,337.14
Apr-11	-	-	-	-	-	48.978	48.49	-	-	9.65	48.49	253.11	3,113.43	-	-	407.30	1,134.62	665,791.75	3,366.54	667,333.67
May-11	-	-	-	-	-	53.142	52.61	-	-	10.47	52.61	274.63	3,378.13	-	-	441.93	1,231.09	722,395.87	3,652.75	724,068.89
Jun-11	-	-	-	-	-	59.097	58.51	-	-	11.64	58.51	305.40	3,756.67	-	-	491.45	1,369.04	803,346.30	4,062.07	805,206.79
Jul-11	-	-	-	-	-	51.392	50.88	-	-	10.12	50.88	265.58	3,266.88	-	-	427.38	1,190.55	698,606.92	3,532.47	700,224.84
Aug-11	-	-	-	-	-	51.445	50.93	-	-	10.14	50.93	265.86	3,270.25	-	-	427.82	1,191.77	699,327.38	3,536.11	700,946.97
Sep-11	-	-	-	-	-	48.692	48.21	-	-	9.59	48.21	251.63	3,095.25	-	-	404.92	1,128.00	661,903.95	3,346.88	663,436.88
Oct-11	-	-	-	-	-	55.563	55.01	-	-	10.95	55.01	287.14	3,532.02	-	-	462.06	1,287.17	755,306.20	3,819.16	757,055.43
Nov-11	-	-	-	-	-	57.976	57.40	-	-	11.42	57.40	299.61	3,685.41	-	-	482.13	1,343.07	788,107.77	3,985.02	789,932.97
Dec-11	-	-	-	-	-	46.457	45.99	-	-	9.15	45.99	240.08	2,953.17	-	-	386.34	1,076.22	631,522.06	3,193.25	632,984.62
Jan-12	-	-	-	-	-	51.252	50.74	-	-	10.10	50.74	264.86	3,257.98	-	-	426.21	1,187.30	696,703.80	3,522.84	698,317.32
Feb-12	-	-	-	-	-	55.634	55.08	-	-	10.96	55.08	287.51	3,536.54	-	-	462.65	1,288.82	756,271.35	3,824.04	758,022.82
Mar-12	-	-	-	-	-	60.693	60.09	-	-	11.96	60.09	313.65	3,858.13	-	-	504.72	1,406.01	825,041.83	4,171.78	826,952.56
Apr-12	-	-	-	-	-	52.563	52.04	-	-	10.36	52.04	271.64	3,341.32	-	-	437.11	1,217.67	714,525.13	3,612.95	716,179.92
May-12	-	-	-	-	-	61.872	61.25	-	-	12.19	61.25	319.74	3,933.07	-	-	514.53	1,433.33	841,068.79	4,252.82	843,016.64
Jun-12	-	-	-	-	-	51.185	50.67	-	-	10.08	50.67	264.51	3,253.72	-	-	425.65	1,185.75	695,793.02	3,518.24	697,404.43
Jul-12	-	-	-	-	-	65.323	64.67	-	-	12.87	64.67	337.58	4,152.45	-	-	543.23	1,513.27	887,980.61	4,490.02	890,037.11
Aug-12	-	-	-	-	-	55.47	54.92	-	-	10.93	54.92	286.66	3,526.11	-	-	461.29	1,285.02	754,041.98	3,812.77	755,788.29
Sep-12	-	-	-	-	-	44.583	44.14	-	-	8.78	44.14	230.40	2,834.05	-	-	370.75	1,032.81	606,047.48	3,064.44	607,451.04
Oct-12	-	-	-	-	-	51.894	51.38	-	-	10.22	51.38	268.18	3,298.79	-	-	431.55	1,202.18	705,430.95	3,566.97	707,064.68
Nov-12	-	-	-	-	-	50.736	50.23	-	-	10.00	50.23	262.19	3,225.18	-	-	421.92	1,175.35	689,689.46	3,487.37	691,286.73
Dec-12	-	-	-	-	-	34.777	34.43	-	-	6.85	34.43	179.72	2,210.70	-	-	289.21	805.64	472,747.76	2,390.42	473,842.61
Jan-13	-	-	-	-	-	48.924	48.43	-	-	9.64	48.43	252.83	3,110.00	-	-	406.85	1,133.37	665,057.69	3,362.83	666,597.91
Feb-13	-	-	-	-	-	44.194	43.75	-	-	8.71	43.75	228.39	2,809.32	-	-	367.52	1,023.80	600,759.54	3,037.71	602,150.85
Mar-13						43.716	43.28	-	-	8.61	43.28	225.92	2,778.93	-	-	363.54	1,012.72	594,261.75	3,004.85	595,638.02
Apr-13						44.669	44.22	-	-	8.80	44.22	230.84	2,839.51	-	-	371.47	1,034.80	607,216.54	3,070.35	608,622.81
May-13						45.526	45.07	-	-	8.97	45.07	235.27	2,893.99	-	-	378.59	1,054.66	618,866.33	3,129.26	620,299.58
Jun-13						43.927	43.49	-	-	8.65	43.49	227.01	2,792.35	-	-	365.30	1,017.61	597,130.02	3,019.35	598,512.93
Jul-13						5.359	5.31	-	-	1.06	5.31	27.69	340.66	-	-	44.57	124.15	72,848.58	368.35	73,017.30
Aug-13						48.75	48.26	-	-	9.60	48.26	251.93	3,098.94	-	-	405.41	1,129.34	662,692.39	3,350.87	664,227.14
Sep-13						46.133	45.67	-	-	9.09	45.67	238.41	2,932.58	-	-	383.64	1,068.72	627,117.70	3,170.98	628,570.06
Oct-13						52.029	51.51	-	-	10.25	51.51	268.88	3,307.37	-	-	432.67	1,205.30	707,266.10	3,576.25	708,904.07
Nov-13						46.413	45.95	-	-	9.14	45.95	239.85	2,950.38	-	-	385.97	1,075.20	630,923.93	3,190.23	632,385.11
Dec-13						36.48	36.12	-	-	7.19	36.12	188.52	2,318.96	-	-	303.37	845.10	495,897.81	2,507.48	497,046.27
Jan-14						47.823	47.34	-	-	9.42	47.34	247.14	3,040.01	-	-	397.70	1,107.87	650,091.04	3,287.15	651,596.60
Feb-14						44.585	44.14	-	-	8.78	44.14	230.41	2,834.17	-	-	370.77	1,032.86	606,074.67	3,064.58	607,478.29
Mar-14						46.541	46.08	-	-	9.17	46.08	240.51	2,958.51	-	-	387.03	1,078.17	632,663.93	3,199.03	634,129.13
Apr-14						45.228	44.78	-	-	8.91	44.78	233.73	2,875.05	-	-	376.12	1,047.75	614,815.41	3,108.78	616,239.28
May-14						49.015	48.52	-	-	9.66	48.52	253.30	3,115.78	-	-	407.61	1,135.48	666,294.72	3,369.08	667,837.81
Jun-14						46.81	46.34	-	-	9.22	46.34	241.90	2,975.61	-	-	389.27	1,084.40	636,320.63	3,217.52	637,794.30
Jul-14						45.306	44.85	-	-	8.93	44.85	234.13	2,880.01	-	-	376.76	1,049.56	615,875.72	3,114.14	617,302.04
Aug-14						44.988	44.54	-	-	8.86	44.54	232.49	2,859.79	-	-	374.12	1,042.19	611,552.93	3,092.28	612,969.24
Sep-14						47.11	46.64	-	-	9.28	46.64	243.46	2,994.68	-	-	391.77	1,091.35	640,398.74	3,238.14	641,881.85
Oct-14						51.393	50.88	-	-	10.12	50.88	265.59	3,266.95	-	-	427.38	1,190.57	698,620.51	3,532.53	700,238.46
Nov-14						43.699	43.26	-	-	8.61	43.26	225.83	2,777.85	-	-	363.40	1,012.33	594,030.66	3,003.68	595,406.39
Dec-14						37.899	37.52	-	-	7.47	37.52	195.85	2,409.16	-	-	315.17	877.97	515,187.26	2,605.01	516,380.39
Jan-15						43.995	43.56	-	-	8.67	43.56	227.36	2,796.67	-	-	365.86	1,019.19	598,054.39	3,024.03	599,439.44
Feb-15						47.792	47.31	-	-	9.42	47.31	246.98	3,038.04	-	-	397.44	1,107.15	649,669.63	3,285.02	651,174.22
Mar-15						56.002	55.44	-	-	11.03	55.44	289.41	3,559.93	-	-	465.71	1,297.34	761,273.83	3,849.34	763,036.88
Apr-15						55.569	55.01	-	-	10.95	55.01	287.17	3,532.40	-	-	462.11	1,287.31	755,387.76	3,819.57	757,137.18
May-15						48.453	47.97	-	-	9.55	47.97	250.40	3,080.06	-	-	402.94	1,122.46	658,655.06	3,330.45	660,180.46
Jun-15						56.747	56.18	-	-	11.18	56.18	293.26	3,607.29	-	-	471.91	1,314.60	771,401.13	3,900.54	773,187.64
																21,545.25	60,018.91		**188,425.76**	**35,300,354.50**

Appendix 6.1: Waste management questionniare distributed to households and business owners in Lagos State (see Chapter 6).

DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING

University of Strathclyde Engineering

WASTE MANAGEMENT

1. How much waste is generated in your home? One polythene bag dai[ ] one polythene bag every two days [ ]
   one polythene bag every week [ ] one polythene bag every two weeks [ ] one polythene bag every month [ ]
   others [ ]
2. How do you feel about waste management in the state [ ]
3. Do you think there is a problem with waste management in the state? Ye[ ] No [ ]
4. If yes, what are the problems [ ]
5. How can these problems be solved [ ]

SERVICES AWARENESS & PRACTICE

6. **Do** you separate your wastes? Yes [ ] No [ ]
7. **If** yes, how do you separate your waste [ ]
8. What do you do with your following wastes?
   Plastic wastes [ ]
   Electronic waste [ ]
   Battery wastes [ ]
   Computer wastes [ ]
   Food wastes [ ]

Garden waste

9. In the last 4 months, which of the practices have you often used as a means of waste disposal?

   Dumping on the road ☐ Bury waste ☐ Disposal through private waste collector ☐

   Burning waste ☐ Disposal through government authority ☐ Waste recycling ☐

   Others

10. **Do** you pay for your monthly environmental fees? Yes ☐ No ☐
11. Do you understand what recycling means? Yes ☐ No ☐

    What does recycling mean?

12. **Are** you aware of e-waste? Yes ☐ No ☐
13. **How** do you dispose your e-waste
14. **Do** you see waste on roadside while going to your work? Yes ☐ No ☐
15. Is there an official waste management system in the state (i.e. official waste collection)? ☐ ☐

    Yes No

16. If yes, why do people not engage with the official waste management system?

17. **Do** you know that improper waste disposal is a threat to environment and health? ☐ ☐

    No

18. **If** yes, how is improper waste disposal a threat to environment and health?

COMMUNICATION

19. Have you been in communication with the waste management agency regarding waste and recycling? Yes ☐ No ☐
20. What could be your preferred method of communication for waste and recycling?

    Leaflets posted to your house ☐ message sent to your phone ☐ face to face ☐

    Social network *e.g.* Facebook ☐ through the agency website ☐

GENERAL (waste management and attitude scale)

21. For each of the questions below, tick or mark the response that best characterise how you feel about the given statement. From very poor to very good and strongly disagree to strongly agree, which are also coded with 1 - 5 for analytic purpose:

Please rate the following statement.	Very Poor	Poor	Neither Poor or	Good	Very

Commented [should this be

			Good		
- General waste collection service in your area	1	2	3	4	5
- Communication from waste management authority on collection of waste days	1	2	3	4	5
- Weekly recyclable waste collection service	1	2	3	4	5
- People's knowledge on segregation at source	1	2	3	4	5
- Weekly food waste collection service	1	2	3	4	5
- Knowledge of people on health issues associated with improper waste disposal.	1	2	3	4	5
- People's awareness of danger to living close to dump sites	1	2	3	4	5

	Strongly Disagree	Disagree	Neither Agree no Disagree	Agree	Strongly Agree
-All household wastes are put in the single bin container before disposal.	1	2	3	4	5
-People understand what RECYCLING means.	1	2	3	4	5
-Corruption can be one of the reasons why there is poor management of waste.	1	2	3	4	5
- The waste management agency engages all relevant stakeholders including residents on their waste management strategy, including how to recycle their waste	1	2	3	4	5
- If the collection of waste is done efficiently in the country, people will willingly pay their environmental levy.	1	2	3	4	5
- The country needs better environmental management structure	1	2	3	4	5
- Government is not doing enough to fix the wastes problem.	1	2	3	4	5
- People throw wastes on the street because they don't see government waste collectors	1	2	3	4	5
- Regular collection of waste is a solution to waste problem.	1	2	3	4	5
- Waste management should be taught in all schools.	1	2	3	4	5
- It is very important Nigeria government put recycling laws and programmes in place.	1	2		4	5

<u>DEMOGRAHIC CHARACTERISTICS</u>

22. Which area do you live?
23. What is your gender? Male Female
24. What is your age? Under 25 25-34 35-49 50-64 65 and above
25. What is your employment status? Employed unemployed student retired trader

    Others

26. What is your educational level? Illiterate Primary Secondary University Other

27. Who is responsible for disposing waste from your house?

28. Which describes the type of your house? Concrete wood zinc Concrete and zinc others

29. Is the house owned or rented? Owned Rented

30. General comment on the above topic?

THANK YOU for your time.

Appendix 6.2. The consent form for participants to accept or decline completing the questionnaire.

University of Strathclyde Engineering

DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING

Participant Information Sheet

Area/ Location: __________________ Interviewer: _____________________

Title of the study: People's perception on municipal solid waste management in Lagos State, Nigeria

Introduction

Good day. My name is Charles Mbama, a Nigerian research student attending the University of Strathclyde, UK, where I am conducting research on sustainable waste management. As part of my studies I wish to gather data from the public on their waste habits and perception towards municipal solid waste management in Lagos State. This survey centres on waste generation and other waste management issues. For proper assessment of this research, you are kindly invited to take part in a questionnaire about your current waste management practice, attitude and public health. It will ONLY take 15 minutes to complete this questionnaire. You have the right to decline your participation. Your personal detail such as name (s) or house address are not needed, therefore, you CANNOT be identified through the information you provided. Your answers will help proffer recommendation towards sustainable waste management in our country. I sincerely appreciate for your time.

Why have you been invited to take part?

You are invited to participate in the study because you are one of the vital stakeholders in waste management who has a great role to play in sustainable waste management. We would like your participation in order to gain understanding on your waste habits and perception towards municipal solid waste management and your view towards better waste management in the country. The outcome of this research will recommend a better sustainable waste management for the State, which can be replicated to other parts of the country. This will have a great positive impact on the environment and human health.

Do you have to take part?

Your participation is very important to us. However, participation in this study is voluntary and you have the right to withdraw your participation at any point. If you feel uncomfortable answering any of the questions, please let the interviewer know and the question can be missed or the discussion stopped. Also note that ALL information that you provide will be kept anonymous by the researchers. Therefore, you CANNOT be identified through the information you provided.

What happens to the information in the project?

Your participation is anonymous: we will not include any names or other personally identifying information in any subsequent reports or publications. Thus, you CANNOT be identified through the information you provided.
The University of Strathclyde is registered with the Information Commissioner's Office who implements the Data Protection Act 1998. All personal data on participants will be processed in accordance with the provisions of the Data Protection Act 1998. This means that the data will be obtained and processed fairly for the purpose of Charles Mbama's doctoral thesis and all the information collected today will be in line and relevant to that purpose. The information will be accurate and kept up to date, will not be kept any longer than necessary and will be processed in accordance with the data subject's rights. The data will be kept safe from unauthorised access, accidental loss or destruction.

What happens next?

We appreciate your time to read the above information. If you are happy to participate, please sign the attached consent form and we will begin the discussion. If you have any questions, please do not hesitate to contact me, using the contact details provided below.

Information you provide today will be included in my doctoral thesis, which when complete will be publicly available at the University of Strathclyde. Any personal information, identifying you or any other participants will not be included in publicly available or published material. If you would like to receive a copy of the report from the discussions here today, please contact me, using the details provided below.

Researcher contact details:
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This investigation was granted ethical approval by the Department of Civil and Environmental Engineering Ethics Committee.

If you have any questions/concerns, during or after the investigation, or wish to contact an independent person to whom any questions may be directed or further information may be sought from, please contact:

Participant Consent Form

Title of the study: People's perception on municipal solid waste management in Lagos State, Nigeria

- I confirm that I understand the information provided for the above study and have had the opportunity to ask questions and raise any concerns.
- I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason and without any consequences.
- I understand that my responses will be made anonymous and that I will not be identified in any written report or publication.
- I agree to take part in this study.

Print Name of Participant: ____

Signature of Participant/Witness (if illiterate): ____________________________

Date: ____________________________

Day/month/year

Appendix 6.3. Ethical application form for the Lagos State questionnaire.

OFFICE USE ONLY
UEC
//13
Paper

Ethics Application Form

Please answer all questions

1. Title of the investigation
Attitudinal effects on recycling performance and solid waste management in Nigeria
Please state the title on the PIS and Consent Form, if different:

2. Chief Investigator (must be at least a Grade 7 member of staff or equivalent)
Name: **Dr Tara K Beattie** ☐ Professor ☐ Reader ☐ Senior Lecturer ☑ Lecturer ☐ Senior Teaching Fellow ☐ Teaching Fellow Department: **Civil and Environmental Engineering** Telephone: **0141 548 3437** E-mail: **t.k.beattie@strath.ac.uk**

3. Other Strathclyde investigator(s)
Name: Charles Mbama Status (e.g. lecturer, post-/undergraduate): Post graduate (PhD Research Student) Department: Civil and Environmental Engineering Telephone: E-mail: Charles.mbama@strath.ac.uk

4. Non-Strathclyde collaborating investigator(s) (where applicable) N/A
Name: Austin Otegbulu Status (e.g. lecturer, post-/undergraduate): Associate Professor Department/Institution: University of Lagos, Nigeria If student(s), name of supervisor: Telephone: E-mail: austinotegbulu@yahoo.com Please provide details for all investigators involved in the study:

5. Overseas Supervisor(s) (where applicable) N/A

Name(s):
Status:
Department/Institution:
Telephone:
Email:
I can confirm that the local supervisor has obtained a copy of the Code of Practice: Yes ☐ No ☐
Please provide details for all supervisors involved in the study:

6. Location of the investigation

At what place(s) will the investigation be conducted

The investigation will take place in Ikeja town which is located at Lagos State Nigeria. Questionnaires will be distributed to few residents of the area by hand

If this is not on University of Strathclyde premises, how have you satisfied yourself that adequate Health and Safety arrangements are in place to prevent injury or harm?

Appropriate risk assessments have been carried out.

7. Duration of the investigation

Duration(years/months) : 6 weeks

Start date (expected): 20/11/16 Completion date (expected): 09/01/17

8. Sponsor
Please note that this is not the funder; refer to Section C and Annexes 1 and 3 of the Code of Practice for a definition and the key responsibilities of the sponsor.

Will the sponsor be the University of Strathclyde: Yes ☑ No ☐
If not, please specify who is the sponsor:

9. Funding body or proposed funding body (if applicable) N/A

Name of funding body:
Status of proposal – if seeking funding (please click appropriate box):
☐ In preparation
☐ Submitted
☐ Accepted
Date of submission of proposal: Date of start of funding:

10. Ethical issues

Describe the main ethical issues and how you propose to address them:

The main ethical issues in this project is on the dealing/ or handling people's data. This research has taken measures to carry out the surveys in which limited personal data will be sampled (as such, participants will NOT be able to be identified from the information they provide) e.g.: age range, gender, profession etc.

Opportunity will be given to participants to either go ahead with the completion of the work or to discontinue.

11. Objectives of investigation (including the academic rationale and justification for the investigation)
Please use plain English.

This investigation is inspired by the need to gain more understanding of the solid waste management (SWM) situation (which includes understanding the service level, the participants' recycling performance and attitude towards solid waste management) the cause and effects to human health in Nigeria. Improper SWM practice can pose environmental hazard, hence, exposing people to health risk. Nigeria is characterised by inefficiency in waste collection and improper disposal. Nigeria is characterised by unsanitary landfill/ open dumping of solid waste. This is believed to be representative of the actual situation of municipal solid waste management practices in the country, without knowing the implication of such practices to human health.

The main benefit of understanding the cause of improper waste disposal is in environmental planning which can help to improve sustainable waste management. Therefore, this investigation which uses questionnaire, will sample peoples opinion to understand more on the waste management situation in the case study area (Lagos) and people's recycling performance including their attitude towards solid waste.

Additionally, the waste audit to be carried out at the University of Lagos is important for proper decision making in waste management approach to undertake, because it is based on the knowledge of generated solid waste composition that better cost effective waste technological treatment option can be chosen.

12. Participants

Please detail the nature of the participants:
Participants will be residents of Lagos state, Nigeria
Summarise the number and age (range) of each group of participants:
Number: **maximum of 600 available participants** Age (range) **18 Yrs. & over**
Please detail any inclusion/exclusion criteria and any further screening procedures to be used:
Only people living in the case study areas will be targeted for this research

13. Nature of the participants
Please note that investigations governed by the Code of Practice that involve any of the types of participants listed in B1(b) must be submitted to the University Ethics Committee (UEC) rather than DEC/SEC for approval.

Do any of the participants fall into a category listed in Section B1(b) (participant considerations) applicable in this investigation?: Yes ☐ No ☑

If yes, please detail which category (and submit this application to the UEC):

14. Method of recruitment

Describe the method of recruitment (see section B4 of the Code of Practice), providing information on any payments, expenses or other incentives.

The participation of the participants for the questionnaire will be voluntary as the participants will be given the opportunity to complete or discontinue. However, for the waste audit, there is also opportunity given to seven (7) students of Waste Management Department, University of Lagos, been the second case study, to voluntarily participate, at no payment (s), although care will be taken to provide participants lunch.

The student's participation will also help them to build their skill in waste management more especially in waste auditing.

15. Participant consent

Please state the groups from whom consent/assent will be sought (please refer to the Guidance Document). The PIS and Consent Form(s) to be used should be attached to this application form.

Before the participation of participants, the aim and objective of the research will be read to them and also made them understand that the research is voluntary and that every information/ answers provided will be confidential. This will also be stated on the PIS and Consent form.

16. Methodology

Investigations governed by the Code of Practice which involve any of the types of projects listed in B1(a) must be submitted to the University Ethics Committee rather than DEC/SEC for approval.

Are any of the categories mentioned in the Code of Practice Section B1(a) (project considerations) applicable in this investigation? Yes ☐ No ☑

If 'yes' please detail:

Describe the research methodology and procedure, providing a timeline of activities where possible. Please use plain English.

1. Development of research questionnaire. This has been completed (see attached questions)

2. The questionnaire will be disseminated to people in the case study areas. This will be carried out in Lagos state by face to face distribution and collection of completed questionnaires will be done simultaneously.

3. The results will be transferred to a safe storage device and after which analysed. Note: No participants can be identified through the information they provided.

4. Waste audit: Seven volunteered students of waste management department, University of Lagos will aid in waste audit. This will also help the students gain waste management skill especially in waste audit.

5. Results will be inputted into a safe electronic storage device and analysed afterward.

6. The students who participated during the waste audit will be asked to evaluate the project.

7. Using Origin Pro software, the data will be analysed.

What specific techniques will be employed and what exactly is asked of the participants? Please identify any non-validated scale or measure and include any scale and measures charts as an Appendix to this application. Please include questionnaires, interview schedules or any other non-standardised method of data collection as appendices to this application.

The investigational technique used is questionnaire which involves sampling of people's opinion in respect to waste management practice in the study area in order to understand service level, the participants' recycling performance and attitude towards solid waste management.

Where an independent reviewer is not used, then the UEC, DEC or SEC reserves the right to scrutinise the methodology. Has this methodology been subject to independent scrutiny? Yes ☐ No ☑
If yes, please provide the name and contact details of the independent reviewer:

17. Previous experience of the investigator(s) with the procedures involved. Experience should demonstrate an ability to carry out the proposed research in accordance with the written methodology.

The Chief Investigator, Dr Tara Beattie has over 20 years of experience managing student projects requiring collection of interview data.

18. Data collection, storage and security

How and where are data handled? Please specify whether it will be fully anonymous (i.e. the identity unknown even to the researchers) or pseudo-anonymised (i.e. the raw data is anonymised and given a code name, with the key for code names being stored in a separate location from the raw data) - if neither please justify.
The questionnaire will be collated and safely handled by the researcher an ideal location. No participant can be identified based of the information they provided, this makes the presentation of the data anonymous.

Explain how and where it will be stored, who has access to it, how long it will be stored and whether it will be securely destroyed after use:

All the information from paper questionnaires will be collected and stored safely in an electronic format (a copy in the researchers computer, another in an external hard drive which will be backed up in a virtual storage e.g. icloud or google store) accessible by the researchers only. The data will then be inputted in Origin Pro for qualitative analysis. After the period of six (6) months of the data usage, it will be destroyed.

Will anyone other than the named investigators have access to the data? Yes No ☑ If 'yes' please explain:

19. Potential risks or hazards
Describe the potential risks and hazards associated with the investigation: This investigation via questionnaire does not require personal information and as such pose no potential risks or hazards. However, for the waste audit, risk assessment has been completed and measure to address identified potential risks strictly handled.
Has a specific Risk Assessment been completed for the research in accordance with the University's Risk Management Framework (http://www.strath.ac.uk/safetyservices/aboutus/riskmanagement/)? Yes ☑ No ☐ If yes, please attach risk form (S20) to your ethics application. If 'no', please explain why not:

20. What method will you use to communicate the outcomes and any additional relevant details of the study to the participants?
Participants will not be contacted directly with the outcomes. This is because of the anonymous nature of the questionnaire. However, the result of the waste audit will be communicated to University of Lagos via an official email address.

21. How will the outcomes of the study be disseminated (e.g. will you seek to publish the results and, if relevant, how will you protect the identities of your participants in said dissemination)?
The outcome of the investigation will be published and made publicly available at the University of Strathclyde. Meanwhile, participants cannot be identified by any way, because, all respondents are anonymous.

Checklist	Enclosed	N/A
Participant Information Sheet(s)	☑	☐
Consent Form(s)	☑	☐
Sample questionnaire(s)	☑	☐
Sample interview format(s)	☐	☐
Sample advertisement(s)	☐	☐
Any other documents (please specify below)	☐	☐
		☐
	☐	☐
	☐	☐
	☐	☐
	☐	
	☐	

22. Chief Investigator and Head of Department Declaration
Please note that unsigned applications will not be accepted and both signatures are required

I have read the University's Code of Practice on Investigations involving Human Beings and have completed this application accordingly. By signing below, I acknowledge that I am aware of and accept my responsibilities as Chief Investigator under Clauses 3.11 – 3.13 of the Research Governance Framework and that this investigation cannot proceed before all approvals required have been obtained.

Signature of Chief Investigator: Tara K. Beattie

Please also type name here: Tara K Beattie

I confirm I have read this application, I am happy that the study is consistent with departmental strategy, that the staff and/or students involved have the appropriate expertise to undertake the study and that adequate arrangements are in place to supervise any students that might be acting as investigators, that the study has access to the resources needed to conduct the proposed research successfully, and that there are no other departmental-specific issues relating to the study of which I am aware.

Signature of Head of Department

Please also type name here

Date: / /

23. Only for University sponsored projects under the remit of the DEC/SEC, with no external funding and no NHS involvement

Head of Department statement on Sponsorship
This application requires the University to sponsor the investigation. This is done by the Head of Department for all DEC applications with exception of those that are externally funded and those which are connected to the NHS (those exceptions should be submitted to R&KES). I am aware of the implications of University sponsorship of the investigation and have assessed this investigation with respect to sponsorship and management risk. As this particular investigation is within the remit of the DEC and has no external funding and no NHS involvement, I agree on behalf of the University that the University is the appropriate sponsor of the investigation and there are no management risks posed by the investigation.

If not applicable, tick here ☐

Signature of Head of Department

Please also type name here

Date: / /

For applications to the University Ethics Committee, the completed form should be sent to ethics@strath.ac.uk with the relevant electronic signatures.

24. Insurance
The questionnaire below must be completed and included in your submission to the UEC/DEC/SEC:

Is the proposed research an investigation or series of investigations conducted on any person for a Medicinal Purpose? Medicinal Purpose means: ▪ treating or preventing disease or diagnosing disease or ▪ ascertaining the existence degree of or extent of a physiological condition or ▪ assisting with or altering in any way the process of conception or ▪ investigating or participating in methods of contraception or ▪ inducing anaesthesia or ▪ otherwise preventing or interfering with the normal operation of a physiological function or ▪ altering the administration of prescribed medication.	No

If "**Yes**" please go to **Section A (Clinical Trials)** – all questions must be completed
If "**No**" please go to **Section B (Public Liability)** – all questions must be completed

Section A (Clinical Trials)

Does the proposed research involve subjects who are either: i. under the age of 5 years at the time of the trial; ii. known to be pregnant at the time of the trial	No

*If "**Yes**" the UEC should refer to Finance*

Is the proposed research limited to: iii. Questionnaires, interviews, psychological activity including CBT; iv. Venepuncture (withdrawal of blood); v. Muscle biopsy; vi. Measurements or monitoring of physiological processes including scanning; vii. Collections of body secretions by non-invasive methods; viii. Intake of foods or nutrients or variation of diet (excluding administration of drugs).	No

*If "**No**" the UEC should refer to Finance*

Will the proposed research take place within the UK?	No

*If "**No**" the UEC should refer to Finance*

Title of Research		
Chief Investigator		
Sponsoring Organisation		
Does the proposed research involve:		
a) investigating or participating in methods of contraception?		Yes / No
b) assisting with or altering the process of conception?		Yes / No
c) the use of drugs?		Yes / No
d) the use of surgery (other than biopsy)?		Yes / No
e) genetic engineering?		Yes / No
f) participants under 5 years of age(other than activities i-vi above)?		Yes / No
g) participants known to be pregnant (other than activities i-vi above)?		Yes / No
h) pharmaceutical product/appliance designed or manufactured by the institution?		Yes / No
i) work outside the United Kingdom?		Yes / No

If **"YES"** to **any** of the questions a-i please also complete the **Employee Activity Form** (attached).
If **"YES"** to **any** of the questions a-i, <u>and this is a follow-on phase</u>, please provide details of SUSARs on a separate sheet.
*If "**Yes**" to any of the questions a-i then the UEC/DEC/SEC should refer to Finance (aileen.stevenson@strath.ac.uk).*

Section B (Public Liability)	
Does the proposed research involve :	
a) aircraft or any aerial device	No
b) hovercraft or any water borne craft	No
c) ionising radiation	No
d) asbestos	No
e) participants under 5 years of age	No
f) participants known to be pregnant	No
g) pharmaceutical product/appliance designed or manufactured by the institution?	No
h) work outside the United Kingdom?	YES

*If **"YES"** to any of the questions the UEC/DEC/SEC should refer to Finance(aileen.stevenson@strath.ac.uk).*

For NHS applications only - Employee Activity Form

Has NHS Indemnity been provided?	Yes / No
Are Medical Practitioners involved in the project?	Yes / No
If YES, will Medical Practitioners be covered by the MDU or other body?	Yes / No

This section aims to identify the staff involved, their employment contract and the extent of their involvement in the research (in some cases it may be more appropriate to refer to a group of persons rather than individuals).

Chief Investigator		
Name	**Employer**	**NHS Honorary Contract?**
		Yes / No
Others		
Name	**Employer**	**NHS Honorary Contract?**
		Yes / No
		Yes / No
		Yes / No
		Yes / No

Please provide any further relevant information here:

Appendix 6.5: Explanation of Correlation Coefficient.

Correlation coefficient is a statistical measure that indicates the degree to which two or more variables are related or tend to vary or occur together in a manner that is not likely due to chance (Puth et al., 2014; Akoglu 2018; Patrick et al., 2018). Correlated data involves a relationship where a change in one variable is linked to a change in another variable, either positively or negatively (Akoglu 2018). Therefore, correlation coefficient remains a dimensionless quantity that ranges from -1 to +1. A correlation coefficient of 0 signifies the absence of a linear relationship between two continuous variables, while a correlation coefficient of −1 or +1 shows a perfect linear relationship. However, a correlation coefficient approaches ±1 as the strength of the association increases. A close to a positive coefficient indicates a close to direct relationship between variables, meaning that if one variable increases, the other variable likewise tends to increase. Conversely, if the coefficient is negative, the variables exhibit an inverse relationship, meaning when one variable increases, the other variable tends to decrease, hence, two variables can be moderately or strongly correlated either in a positive or negative direction (Mukaka 2012; Akoglu 2018; Patrick et al., 2018).

SUPPLEMENTARY INFORMATION

Supplementary 4.4. Waste samples showing the distribution across the waste generating area at UoL.

SIXTY FOUR REPRESENTATIVE WASTE SAMPLES WERE COLLECTED							
S/N	x (kg)	$\bar{x}$	$(x - \bar{x})$	$(x - \bar{x})^2$	STDEV	SQRT OF n	Marginal Error
Adminstration Area							
1	3.2	4.042969	-0.842969	0.710596313	2.771219	8	0.678948576
2	3.43		-0.612969	0.375730688			
3	2.93		-1.112969	1.238699438			
4	3.88		-0.162969	0.026558813			
5	1.11		-2.932969	8.602305688			
6	2.64		-1.402969	1.968321313			
7	1.6		-2.442969	5.968096313			
8	1.42		-2.622969	6.879965063			
9	1.76		-2.282969	5.211946313			
10	5.19		1.1470313	1.315680688			
11	5.07		1.0270313	1.054793188			
12	1.85		-2.192969	4.809111938			
13	3.07		-0.972969	0.946668188			
14	3.77		-0.272969	0.074511938			
15	2.89		-1.152969	1.329336938			
16	2.23		-1.812969	3.286855688			
17	2.33		-1.712969	2.934261938			
18	1.34		-2.702969	7.306040063			
19	2.12		-1.922969	3.697808813			
20	2.8		-1.242969	1.544971313			
21	1.65		-2.392969	5.726299438			
22	6.41		2.3670313	5.602836938			
23	2.02		-2.022969	4.092402563			
24	3.52		-0.522969	0.273496313			
25	1.97		-2.072969	4.297199438			
26	3.41		-0.632969	0.400649438			
27	3.04		-1.002969	1.005946313			
28	3.14		-0.902969	0.815352563			
	79.79						
Commercial Area							
29	2.6		-1.442969	2.082158813			
30	1.66		-2.382969	5.678540063			
31	3.3		-0.742969	0.552002563			
32	6.1		2.0570313	4.231377563			
33	11.51		7.4670313	55.75655569			
34	3.87		-0.172969	0.029918188			
35	8.57		4.5270313	20.49401194			
36	10.6		6.5570313	42.99465881			
37	12.8		8.7570313	76.68559631			
38	5		0.9570313	0.915908813			
39	2.51		-1.532969	2.349993188			
40	5.32		1.2770313	1.630808813			
41	5.97		1.9270313	3.713449438			
42	4.27		0.2270313	0.051543188			
43	3.05		-0.992969	0.985986938			
44	2.06		-1.982969	3.932165063			
45	4.19		0.1470313	0.021618188			
46	5.54		1.4970313	2.241102563			
47	3.52		-0.522969	0.273496313			
48	1.75		-2.292969	5.257705688			
49	11.49		7.4470313	55.45827444			
50	7.38		3.3370313	11.13577756			
51	2.62		-1.422969	2.024840063			
52	2.63		-1.412969	1.996480688			
	128.31						
Residential Area							
53	6.5		2.4570313	6.037002563			
54	3.9		-0.142969	0.020440063			
55	1.37		-2.672969	7.144761938			
56	1.28		-2.762969	7.633996313			
57	12.12		8.0770313	65.23843381			
58	2.15		-1.892969	3.583330688			
59	5.65		1.6070313	2.582549438			
60	1.21		-2.832969	8.025711938			
61	3.47		-0.572969	0.328293188			
62	5.04		0.9970313	0.994071313			
63	3.64		-0.402969	0.162383813			
64	4.32		0.2770313	0.076746313			
	50.65						
TOTAL	**258.75**			**483.8181359**			
Standard deviation, S							
	$s = \sqrt{\frac{\sum(x - \bar{x})^2}{n - 1}}$	=	7.679653				
S	**2.771218676**						
Variance							
S^2	7.679652951						
Marginal error							
	$z * S/\sqrt{n}$						
where							
Z = confidence coefficent =			1.96				
S = Standard deviation							
n = sample size							
Substituting the equation =			0.6789486				
INTEPRETATION							

Standard deviation of 2.77 shows that the data value is staistically significant as the data is shown to be closely clustered to the mean, 4.023 which indicates that the sample size is standard well distributed.

Supplementary 4.5. Results of ONEWAY ANOVA for the waste categories of University of Lagos.

Supplementary 4.5. Results of ONEWAY ANOVA for the waste categories of University of Lagos

```
ONEWAY MixedPaperBlueBin BY WasteCategories
  /STATISTICS DESCRIPTIVES HOMOGENEITY
  /MISSING ANALYSIS.
```

Oneway

Descriptives

MixedPaperBlueBin

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Mixed Paper	3	4.0967	1.78542	1.03081	-.3386	8.5319	2.51	6.03
Can	3	.4867	.45181	.26085	-.6357	1.6090	.06	.96
Mixed Plastic	3	6.7867	8.03366	4.63823	-13.1700	26.7434	.73	15.90
Other Waste	3	5.6733	6.27898	3.62517	-9.9245	21.2712	1.85	12.92
Total	12	4.2608	5.06910	1.46332	1.0401	7.4816	.06	15.90

Test of Homogeneity of Variances

MixedPaperBlueBin

Levene Statistic	df1	df2	Sig.
6.383	3	8	.016

ANOVA

MixedPaperBlueBin

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	67.939	3	22.646	.844	.507
Within Groups	214.714	8	26.839		
Total	282.653	11			

```
ONEWAY MixedPlasticGreenBin BY WasteCategories
  /STATISTICS DESCRIPTIVES HOMOGENEITY
  /MISSING ANALYSIS.
```

Oneway

Descriptives

MixedPlasticGreenBin

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Mixed Paper	3	7.2867	6.53720	3.77426	-8.9526	23.5260	.21	13.10
Can	3	1.8767	2.88282	1.66440	-5.2846	9.0380	.05	5.20
Mixed Plastic	3	5.3300	3.34319	1.93019	-2.9749	13.6349	1.65	8.18
Other Waste	3	6.0300	4.53982	2.62107	-5.2475	17.3075	2.43	11.13
Total	12	5.1308	4.40992	1.27303	2.3289	7.9328	.05	13.10

Test of Homogeneity of Variances

MixedPlasticGreenBin

Levene Statistic	df1	df2	Sig.
.985	3	8	.447

ANOVA

MixedPlasticGreenBin

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	48.256	3	16.085	.777	.539
Within Groups	165.665	8	20.708		
Total	213.921	11			

```
ONEWAY CanRedBin BY WasteCategories
  /STATISTICS DESCRIPTIVES HOMOGENEITY
  /MISSING ANALYSIS.
```

Oneway

Descriptives

CanRedBin

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Mixed Paper	3	.9533	.87506	.50522	-1.2204	3.1271	.00	1.72
Can	3	.1367	.17214	.09939	-.2910	.5643	.00	.33
Mixed Plastic	3	2.0200	2.64960	1.52975	-4.5620	8.6020	.00	5.02
Other Waste	3	2.8167	3.20896	1.85269	-5.1548	10.7882	.00	6.31
Total	12	1.4817	2.10426	.60745	.1447	2.8186	.00	6.31

Test of Homogeneity of Variances

CanRedBin

Levene Statistic	df1	df2	Sig.
4.014	3	8	.051

ANOVA

CanRedBin

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	12.481	3	4.160	.919	.474
Within Groups	36.226	8	4.528		
Total	48.707	11			

```
ONEWAY GeneralBlackBin BY WasteCategories
  /STATISTICS DESCRIPTIVES HOMOGENEITY
  /MISSING ANALYSIS.
```

Oneway

Descriptives

GeneralBlackBin

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Mixed Paper	3	8.0833	2.73412	1.57855	1.2914	14.8753	5.44	10.90
Can	3	.6900	.22650	.13077	.1274	1.2526	.48	.93
Mixed Plastic	3	9.6833	1.59412	.92037	5.7233	13.6434	7.90	10.97
Other Waste	3	22.8867	8.98530	5.18767	.5659	45.2074	14.89	32.61
Total	12	10.3358	9.29224	2.68244	4.4318	16.2398	.48	32.61

Test of Homogeneity of Variances

GeneralBlackBin

Levene Statistic	df1	df2	Sig.
4.608	3	8	.037

ANOVA

GeneralBlackBin

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	768.195	3	256.065	11.280	.003
Within Groups	181.607	8	22.701		
Total	949.802	11			

```
ONEWAY GeneralBlackBin BY WasteCategories /STATISTICS DESCRIPTIVES
HOMOGENEITY/MISSING ANALYSIS /POSTHOC=TUKEY ALPHA(0.05).
```

Oneway

Descriptives

GeneralBlackBin

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Mixed Paper	3	8.0833	2.73412	1.57855	1.2914	14.8753	5.44	10.90
Can	3	.6900	.22650	.13077	.1274	1.2526	.48	.93
Mixed Plastic	3	9.6833	1.59412	.92037	5.7233	13.6434	7.90	10.97
Other Waste	3	22.8867	8.98530	5.18767	.5659	45.2074	14.89	32.61
Total	12	10.3358	9.29224	2.68244	4.4318	16.2398	.48	32.61

Test of Homogeneity of Variances

GeneralBlackBin

Levene Statistic	df1	df2	Sig.
4.608	3	8	.037

ANOVA

GeneralBlackBin

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	768.195	3	256.065	11.280	.003
Within Groups	181.607	8	22.701		
Total	949.802	11			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: GeneralBlackBin

Tukey HSD

(I) WasteCategories	(J) WasteCategories	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Mixed Paper	Can	7.39333	3.89024	.300	-5.0646	19.8512
	Mixed Plastic	-1.60000	3.89024	.975	-14.0579	10.8579
	Other Waste	-14.80333*	3.89024	.022	-27.2612	-2.3454
Can	Mixed Paper	-7.39333	3.89024	.300	-19.8512	5.0646
	Mixed Plastic	-8.99333	3.89024	.174	-21.4512	3.4646

	Other Waste	-22.19667*	3.89024	.002	-34.6546	-9.7388
Mixed Plastic	Mixed Paper	1.60000	3.89024	.975	-10.8579	14.0579
	Can	8.99333	3.89024	.174	-3.4646	21.4512
	Other Waste	-13.20333*	3.89024	.038	-25.6612	-.7454
Other Waste	Mixed Paper	14.80333*	3.89024	.022	2.3454	27.2612
	Can	22.19667*	3.89024	.002	9.7388	34.6546
	Mixed Plastic	13.20333*	3.89024	.038	.7454	25.6612

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets

GeneralBlackBin

Tukey HSD[a]

WasteCategories	N	Subset for alpha = 0.05	
		1	2
Can	3	.6900	
Mixed Paper	3	8.0833	
Mixed Plastic	3	9.6833	
Other Waste	3		22.8867
Sig.		.174	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Supplementary 4.6. Result of University of Strathclyde Waste Audit Statistical Analysis; One Way ANOVA

Supplementary 4.6. Result of University of Strathclyde Waste Audit Statistical Analysis; One Way ANOVA

```
ONEWAY MixedPaperComposition BY Group
  /STATISTICS DESCRIPTIVES HOMOGENEITY
  /MISSING ANALYSIS
  /POSTHOC=TUKEY ALPHA(0.05).
```

Oneway

Descriptives

MixedPaperComposition

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound
Mixed Paper	5	1.7180	2.94279	1.31606	-1.9360
Mixed Plastic	5	.1080	.14856	.06644	-.0765
Cans	5	.0000	.00000	.00000	.0000
Glass	5	.0000	.00000	.00000	.0000
Organic waste	5	.0660	.14758	.06600	-.1172
Non Recyclables	5	.4080	.35088	.15692	-.0277
Total	30	.3833	1.26722	.23136	-.0899

Descriptives

MixedPaperComposition

	95% Confidence Interval for Mean		
	Upper Bound	Minimum	Maximum
Mixed Paper	5.3720	.06	6.94
Mixed Plastic	.2925	.00	.32
Cans	.0000	.00	.00
Glass	.0000	.00	.00
Organic waste	.2492	.00	.33
Non Recyclables	.8437	.05	.99
Total	.8565	.00	6.94

Test of Homogeneity of Variances

MixedPaperComposition

Levene Statistic	df1	df2	Sig.
6.158	5	24	.001

ANOVA

MixedPaperComposition

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	11.262	5	2.252	1.531	.218
Within Groups	35.308	24	1.471		
Total	46.570	29			

Homogeneous Subsets

MixedPaperComposition

Tukey HSD[a]

Group	N	Subset for alpha = 0.05
		1
Cans	5	.0000
Glass	5	.0000
Organic waste	5	.0660
Mixed Plastic	5	.1080
Non Recyclables	5	.4080
Mixed Paper	5	1.7180
Sig.		.257

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 5.000.

```
ONEWAY MixedPlasticComposition BY Group
  /STATISTICS DESCRIPTIVES HOMOGENEITY
  /MISSING ANALYSIS
  /POSTHOC=TUKEY ALPHA(0.05).
```

Oneway

Descriptives

MixedPlasticComposition

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean
					Lower Bound
Mixed Paper	5	.1420	.15802	.07067	-.0542
Mixed Plastic	5	.7912	.41797	.18692	.2722
Cans	5	.0120	.02168	.00970	-.0149
Glass	5	.0000	.00000	.00000	.0000
Organic waste	5	.0240	.03362	.01503	-.0177
Non Recyclables	5	.5160	.30517	.13648	.1371
Total	30	.2475	.36696	.06700	.1105

Descriptives

MixedPlasticComposition

	95% Confidence Interval for Mean	Minimum	Maximum

	Upper Bound		
Mixed Paper	.3382	.00	.39
Mixed Plastic	1.3102	.18	1.28
Cans	.0389	.00	.05
Glass	.0000	.00	.00
Organic waste	.0657	.00	.08
Non Recyclables	.8949	.17	.88
Total	.3846	.00	1.28

Test of Homogeneity of Variances

MixedPlasticComposition

Levene Statistic	df1	df2	Sig.
5.733	5	24	.001

ANOVA

MixedPlasticComposition

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.728	5	.546	11.118	.000
Within Groups	1.178	24	.049		

Total	3.905	29			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: MixedPlasticComposition

Tukey HSD

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Mixed Paper	Mixed Plastic	-.64920*	.14009	.001	-1.0824	-.2160
	Cans	.13000	.14009	.935	-.3032	.5632
	Glass	.14200	.14009	.909	-.2912	.5752
	Organic waste	.11800	.14009	.956	-.3152	.5512
	Non Recyclables	-.37400	.14009	.119	-.8072	.0592
Mixed Plastic	Mixed Paper	.64920*	.14009	.001	.2160	1.0824
	Cans	.77920*	.14009	.000	.3460	1.2124
	Glass	.79120*	.14009	.000	.3580	1.2244
	Organic waste	.76720*	.14009	.000	.3340	1.2004
	Non Recyclables	.27520	.14009	.390	-.1580	.7084
Cans	Mixed Paper	-.13000	.14009	.935	-.5632	.3032

	Mixed Plastic	-.77920*	.14009	.000	-1.2124	-.3460
	Glass	.01200	.14009	1.000	-.4212	.4452
	Organic waste	-.01200	.14009	1.000	-.4452	.4212
	Non Recyclables	-.50400*	.14009	.016	-.9372	-.0708
Glass	Mixed Paper	-.14200	.14009	.909	-.5752	.2912
	Mixed Plastic	-.79120*	.14009	.000	-1.2244	-.3580
	Cans	-.01200	.14009	1.000	-.4452	.4212
	Organic waste	-.02400	.14009	1.000	-.4572	.4092
	Non Recyclables	-.51600*	.14009	.013	-.9492	-.0828
Organic waste	Mixed Paper	-.11800	.14009	.956	-.5512	.3152
	Mixed Plastic	-.76720*	.14009	.000	-1.2004	-.3340
	Cans	.01200	.14009	1.000	-.4212	.4452
	Glass	.02400	.14009	1.000	-.4092	.4572
	Non Recyclables	-.49200*	.14009	.020	-.9252	-.0588
Non Recyclables	Mixed Paper	.37400	.14009	.119	-.0592	.8072
	Mixed Plastic	-.27520	.14009	.390	-.7084	.1580
	Cans	.50400*	.14009	.016	.0708	.9372
	Glass	.51600*	.14009	.013	.0828	.9492
	Organic waste	.49200*	.14009	.020	.0588	.9252

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets

MixedPlasticComposition

Tukey HSD[a]

		Subset for alpha = 0.05		
Group	N	1	2	3
Glass	5	.0000		
Cans	5	.0120		
Organic waste	5	.0240		
Mixed Paper	5	.1420	.1420	
Non Recyclables	5		.5160	.5160
Mixed Plastic	5			.7912
Sig.		.909	.119	.390

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 5.000.

```
ONEWAY CansComposition BY Group
  /STATISTICS DESCRIPTIVES HOMOGENEITY
  /MISSING ANALYSIS
  /POSTHOC=TUKEY ALPHA(0.05).
```

Oneway

Descriptives

CansComposition

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound
Mixed Paper	5	1.9200	4.05447	1.81322	-3.1143
Mixed Plastic	5	1.0192	1.68567	.75385	-1.0738
Cans	5	.2680	.30850	.13796	-.1150
Glass	5	.0000	.00000	.00000	.0000
Organic waste	5	.2420	.35088	.15692	-.1937
Non Recyclables	5	1.1680	1.60346	.71709	-.8230
Total	30	.7695	1.87186	.34175	.0706

Descriptives

CansComposition

	95% Confidence Interval for Mean		
	Upper Bound	Minimum	Maximum
Mixed Paper	6.9543	.00	9.17
Mixed Plastic	3.1122	.00	3.98
Cans	.6510	.00	.70
Glass	.0000	.00	.00
Organic waste	.6777	.00	.80
Non Recyclables	3.1590	.17	3.90
Total	1.4685	.00	9.17

Test of Homogeneity of Variances

CansComposition

Levene Statistic	df1	df2	Sig.
4.327	5	24	.006

ANOVA

CansComposition

	Sum of Squares	df	Mean Square	F	Sig.

Between Groups	13.333	5	2.667	.725	.611
Within Groups	88.278	24	3.678		
Total	101.612	29			

Homogeneous Subsets

CansComposition

Tukey HSD[a]

		Subset for alpha = 0.05
Group	N	1
Glass	5	.0000
Organic waste	5	.2420
Cans	5	.2680
Mixed Plastic	5	1.0192
Non Recyclables	5	1.1680
Mixed Paper	5	1.9200
Sig.		.617

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 5.000.

```
ONEWAY GeneralWasteComposition BY Group
  /STATISTICS DESCRIPTIVES HOMOGENEITY
  /MISSING ANALYSIS
  /POSTHOC=TUKEY ALPHA(0.05).
```

Oneway

Descriptives

GeneralWasteComposition

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean
					Lower Bound
Mixed Paper	4	.3950	.68432	.34216	-.6939
Mixed Plastic	4	.3550	.48031	.24016	-.4093
Cans	4	.0800	.11314	.05657	-.1000
Glass	4	.0200	.04000	.02000	-.0436
Organic waste	4	.4550	.39569	.19784	-.1746
Non Recyclables	4	1.4750	1.12914	.56457	-.3217
Total	24	.4633	.72137	.14725	.1587

Descriptives

GeneralWasteComposition

	95% Confidence Interval for Mean		
	Upper Bound	Minimum	Maximum
Mixed Paper	1.4839	.01	1.42
Mixed Plastic	1.1193	.01	1.06
Cans	.2600	.00	.24
Glass	.0836	.00	.08
Organic waste	1.0846	.14	1.03
Non Recyclables	3.2717	.16	2.84
Total	.7679	.00	2.84

Test of Homogeneity of Variances

GeneralWasteComposition

Levene Statistic	df1	df2	Sig.
3.765	5	18	.017

ANOVA

GeneralWasteComposition

	Sum of Squares	df	Mean Square	F	Sig.

Between Groups	5.534	5	1.107	3.096	.034
Within Groups	6.435	18	.357		
Total	11.969	23			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: GeneralWasteComposition

Tukey HSD

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound
Mixed Paper	Mixed Plastic	.04000	.42278	1.000	-1.3036
	Cans	.31500	.42278	.973	-1.0286
	Glass	.37500	.42278	.945	-.9686
	Organic waste	-.06000	.42278	1.000	-1.4036
	Non Recyclables	-1.08000	.42278	.160	-2.4236
Mixed Plastic	Mixed Paper	-.04000	.42278	1.000	-1.3836
	Cans	.27500	.42278	.985	-1.0686
	Glass	.33500	.42278	.965	-1.0086
	Organic waste	-.10000	.42278	1.000	-1.4436
	Non Recyclables	-1.12000	.42278	.136	-2.4636

Cans	Mixed Paper	-.31500	.42278	.973	-1.6586
	Mixed Plastic	-.27500	.42278	.985	-1.6186
	Glass	.06000	.42278	1.000	-1.2836
	Organic waste	-.37500	.42278	.945	-1.7186
	Non Recyclables	-1.39500*	.42278	.039	-2.7386
Glass	Mixed Paper	-.37500	.42278	.945	-1.7186
	Mixed Plastic	-.33500	.42278	.965	-1.6786
	Cans	-.06000	.42278	1.000	-1.4036
	Organic waste	-.43500	.42278	.902	-1.7786
	Non Recyclables	-1.45500*	.42278	.029	-2.7986
Organic waste	Mixed Paper	.06000	.42278	1.000	-1.2836
	Mixed Plastic	.10000	.42278	1.000	-1.2436
	Cans	.37500	.42278	.945	-.9686
	Glass	.43500	.42278	.902	-.9086
	Non Recyclables	-1.02000	.42278	.204	-2.3636
Non Recyclables	Mixed Paper	1.08000	.42278	.160	-.2636
	Mixed Plastic	1.12000	.42278	.136	-.2236
	Cans	1.39500*	.42278	.039	.0514
	Glass	1.45500*	.42278	.029	.1114
	Organic waste	1.02000	.42278	.204	-.3236

Multiple Comparisons

Dependent Variable: GeneralWasteComposition

Tukey HSD

(I) Group	(J) Group	95% Confidence Interval Upper Bound
Mixed Paper	Mixed Plastic	1.3836
	Cans	1.6586
	Glass	1.7186
	Organic waste	1.2836
	Non Recyclables	.2636
Mixed Plastic	Mixed Paper	1.3036
	Cans	1.6186
	Glass	1.6786
	Organic waste	1.2436
	Non Recyclables	.2236
Cans	Mixed Paper	1.0286
	Mixed Plastic	1.0686
	Glass	1.4036
	Organic waste	.9686
	Non Recyclables	-.0514
Glass	Mixed Paper	.9686
	Mixed Plastic	1.0086
	Cans	1.2836
	Organic waste	.9086
	Non Recyclables	-.1114
Organic waste	Mixed Paper	1.4036

	Mixed Plastic	1.4436
	Cans	1.7186
	Glass	1.7786
	Non Recyclables	.3236
Non Recyclables	Mixed Paper	2.4236
	Mixed Plastic	2.4636
	Cans	2.7386
	Glass	2.7986
	Organic waste	2.3636

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets

GeneralWasteComposition

Tukey HSD[a]

Group	N	Subset for alpha = 0.05 1	2
Glass	4	.0200	
Cans	4	.0800	
Mixed Plastic	4	.3550	.3550
Mixed Paper	4	.3950	.3950
Organic waste	4	.4550	.4550
Non Recyclables	4		1.4750
Sig.		.902	.136

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 4.000.

Supplementary 5.1. Cost benefit analysis showing the environmental costs and savings at the University of Lagos based on the current waste management practice at University of Lagos.

	Waste Reduction Target				1%
	Scenario				1
	Market price of plastic/ ton (£))				40.00
	Market price of paper/tonne (£)				60.00
	Emission Cost per (kg) - CO2, CH4, and N2O (£)				69,000.00
	Cost of Sorting waste per tonne £				64.21
	% of Waste Recycled				1%
	Cost of Haulage/ tonne (£)				5.22
	Environmental Cost per Kg (₦)				34,500.00
	Cost of Awareness				100.00
	Cost of Awareness (1, 2 or 3)				1.00
Emission factor	Material (mixed) recycling				21.00
Emission factor	Refuse Commercial & Industrial to Landfill				199.00
	Discount rate per annum				8%
	Total Cost	Total Benefits	Net Cash Flow	Discount Factor	Net Discounted Cash Flow
Oct-14	6,693,416.65	67,501.79	-£ 6,625,914.86	1.000	-£ 6,625,914.86
Nov-14	7,862,637.67	79,417.07	-£ 7,783,220.60	0.993	-£ 7,731,676.09
Dec-14	13,797,705.54	139,364.59	-£ 13,658,340.95	0.987	-£ 13,478,034.80
Jan-15	14,003,496.99	141,442.19	-£ 13,862,054.79	0.980	-£ 13,588,469.58
Feb-15	14,367,271.72	145,117.53	-£ 14,222,154.19	0.974	-£ 13,849,134.40

Mar-15	16,829,283.97	169,985.24	-£ 16,659,298.72	0.967	-£ 16,114,924.48
Apr-15	14,105,457.82	142,472.05	-£ 13,962,985.76	0.961	-£ 13,417,270.20
May-15	14,306,668.55	144,505.41	-£ 14,162,163.15	0.955	-£ 13,518,539.53
Jun-15	11,830,040.49	119,490.07	-£ 11,710,550.42	0.948	-£ 11,104,315.75
Jul-15	13,456,157.35	135,913.75	-£ 13,320,243.60	0.942	-£ 12,547,031.06
Aug-15	12,471,831.17	125,972.52	-£ 12,345,858.65	0.936	-£ 11,552,192.52
Sep-15	11,088,980.66	112,004.95	-£ 10,976,975.71	0.930	
Oct-15	12,382,123.27	125,065.40	-£ 12,257,057.87	0.923	-£ 11,317,694.78
Nov-15	11,608,703.66	117,254.44	-£ 11,491,449.22	0.917	-£ 10,540,491.32
Dec-15	12,243,199.88	123,663.21	-£ 12,119,536.67	0.911	-£ 11,042,982.45
Jan-16	12,580,136.70	127,065.45	-£ 12,453,071.24	0.905	-£ 11,271,744.84
Feb-16	13,389,451.74	135,241.00	-£ 13,254,210.74	0.899	-£ 11,917,436.86
Mar-16	15,668,550.88	158,261.18	-£ 15,510,289.69	0.893	-£ 13,853,618.04
Apr-16	10,132,915.23	102,347.14	-£ 10,030,568.10	0.887	-£ 8,899,859.33
May-16	10,709,965.22	108,176.68	-£ 10,601,788.55	0.881	-£ 9,344,392.27
Jun-16	8,760,368.07	88,484.65	-£ 8,671,883.42	0.876	-£ 7,592,759.89

Jul-16	8,866,493.34	89,555.56	-£ 8,776,937.77	0.870	-£ 7,633,849.02
Aug-16	11,072,224.95	111,835.70	-£ 10,960,389.25	0.864	-£ 9,469,800.65
Sep-16	9,871,210.87	99,704.79	-£ 9,771,506.09	0.858	-£ 8,386,691.68
Oct-16	10,333,862.59	104,376.82	-£ 10,229,485.77	0.853	-£ 8,721,622.50
	Net Present Value				-£ 263,520,446.90

Scenario Number	NPV	% of Waste Recycled	Cost of Haulage/ tonne (₦)	Cost of Sorting waste per tonne £	Waste Reduction Target
	-£263,520,447	0	0	0	0
1	-£263,520,447	1%	5.22	64.21	1%
2	-£239,565,059	1%	5.22	64.21	10%
3	-£212,947,961	1%	5.22	64.21	20%
4	-£186,330,863	1%	5.22	64.21	30%
5	-£53,245,372	1%	5.22	64.21	80%
6	-£263,519,190	1%	5.22	57.789	1%
7	-£239,563,916	1%	5.22	57.789	10%
8	-£212,946,945	1%	5.22	57.789	20%
9	-£186,329,974	1%	5.22	57.789	30%
10	-£53,245,118	1%	5.22	57.789	80%
11	-£263,517,932	1%	5.22	51.368	1%
12	-£239,562,773	1%	5.22	51.368	10%
13	-£212,945,929	1%	5.22	51.368	20%
14	-£186,329,084	1%	5.22	51.368	30%
15	-£53,244,864	1%	5.22	51.368	80%
16	-£263,516,675	1%	5.22	44.947	1%
17	-£239,561,630	1%	5.22	44.947	10%
18	-£212,944,913	1%	5.22	44.947	20%
19	-£186,328,195	1%	5.22	44.947	30%
20	-£53,244,610	1%	5.22	44.947	80%
21	-£263,515,418	1%	5.22	38.526	1%
22	-£239,560,487	1%	5.22	38.526	10%
23	-£212,943,896	1%	5.22	38.526	20%
24	-£186,327,306	1%	5.22	38.526	30%
25	-£53,244,356	1%	5.22	38.526	80%
26	-£263,520,426	1%	4.698	64.21	1%
27	-£239,565,040	1%	4.698	64.21	10%
28	-£212,947,944	1%	4.698	64.21	20%
29	-£186,330,848	1%	4.698	64.21	30%
30	-£53,245,368	1%	4.698	64.21	80%
31	-£263,519,169	1%	4.698	57.789	1%
32	-£239,563,897	1%	4.698	57.789	10%
33	-£212,946,928	1%	4.698	57.789	20%
34	-£186,329,959	1%	4.698	57.789	30%
35	-£53,245,114	1%	4.698	57.789	80%
36	-£263,517,912	1%	4.698	51.368	1%
37	-£239,562,754	1%	4.698	51.368	10%
38	-£212,945,912	1%	4.698	51.368	20%

39	-£186,329,070	1%	4.698	51.368	30%
40	-£53,244,860	1%	4.698	51.368	80%
41	-£263,516,654	1%	4.698	44.947	1%
42	-£239,561,611	1%	4.698	44.947	10%
43	-£212,944,896	1%	4.698	44.947	20%
44	-£186,328,181	1%	4.698	44.947	30%
45	-£53,244,606	1%	4.698	44.947	80%
46	-£263,515,397	1%	4.698	38.526	1%
47	-£239,560,468	1%	4.698	38.526	10%
48	-£212,943,880	1%	4.698	38.526	20%
49	-£186,327,292	1%	4.698	38.526	30%
50	-£53,244,352	1%	4.698	38.526	80%
51	-£263,520,406	1%	4.18	64.21	1%
52	-£239,565,021	1%	4.18	64.21	10%
53	-£212,947,928	1%	4.18	64.21	20%
54	-£186,330,834	1%	4.18	64.21	30%
55	-£53,245,364	1%	4.18	64.21	80%
56	-£263,519,149	1%	4.18	57.789	1%
57	-£239,563,878	1%	4.18	57.789	10%
58	-£212,946,912	1%	4.18	57.789	20%
59	-£186,329,945	1%	4.18	57.789	30%
60	-£53,245,110	1%	4.18	57.789	80%
61	-£263,517,891	1%	4.18	51.368	1%
62	-£239,562,735	1%	4.18	51.368	10%
63	-£212,945,896	1%	4.18	51.368	20%
64	-£186,329,056	1%	4.18	51.368	30%
65	-£53,244,856	1%	4.18	51.368	80%
66	-£263,516,634	1%	4.18	44.947	1%
67	-£239,561,592	1%	4.18	44.947	10%
68	-£212,944,879	1%	4.18	44.947	20%
69	-£186,328,167	1%	4.18	44.947	30%
70	-£53,244,602	1%	4.18	44.947	80%
71	-£263,515,377	1%	4.18	38.526	1%
72	-£239,560,449	1%	4.18	38.526	10%
73	-£212,943,863	1%	4.18	38.526	20%
74	-£186,327,278	1%	4.18	38.526	30%
75	-£53,244,348	1%	4.18	38.526	80%
76	-£263,520,386	1%	3.654	64.21	1%
77	-£239,565,003	1%	3.654	64.21	10%
78	-£212,947,911	1%	3.654	64.21	20%
79	-£186,330,819	1%	3.654	64.21	30%
80	-£53,245,360	1%	3.654	64.21	80%
81	-£263,519,128	1%	3.654	57.789	1%

82	-£239,563,860	1%	3.654	57.789	10%
83	-£212,946,895	1%	3.654	57.789	20%
84	-£186,329,930	1%	3.654	57.789	30%
85	-£53,245,106	1%	3.654	57.789	80%
86	-£263,517,871	1%	3.654	51.368	1%
87	-£239,562,717	1%	3.654	51.368	10%
88	-£212,945,879	1%	3.654	51.368	20%
89	-£186,329,041	1%	3.654	51.368	30%
90	-£53,244,852	1%	3.654	51.368	80%
91	-£263,516,614	1%	3.654	44.947	1%
92	-£239,561,574	1%	3.654	44.947	10%
93	-£212,944,863	1%	3.654	44.947	20%
94	-£186,328,152	1%	3.654	44.947	30%
95	-£53,244,598	1%	3.654	44.947	80%
96	-£263,515,356	1%	3.654	38.526	1%
97	-£239,560,431	1%	3.654	38.526	10%
98	-£212,943,847	1%	3.654	38.526	20%
99	-£186,327,263	1%	3.654	38.526	30%
100	-£53,244,344	1%	3.654	38.526	80%
101	-£263,520,365	1%	3.132	64.21	1%
102	-£239,564,984	1%	3.132	64.21	10%
103	-£212,947,895	1%	3.132	64.21	20%
104	-£186,330,805	1%	3.132	64.21	30%
105	-£53,245,356	1%	3.132	64.21	80%
106	-£263,519,108	1%	3.132	57.789	1%
107	-£239,563,841	1%	3.132	57.789	10%
108	-£212,946,878	1%	3.132	57.789	20%
109	-£186,329,916	1%	3.132	57.789	30%
110	-£53,245,102	1%	3.132	57.789	80%
111	-£263,517,850	1%	3.132	51.368	1%
112	-£239,562,698	1%	3.132	51.368	10%
113	-£212,945,862	1%	3.132	51.368	20%
114	-£186,329,027	1%	3.132	51.368	30%
115	-£53,244,848	1%	3.132	51.368	80%
116	-£263,516,593	1%	3.132	44.947	1%
117	-£239,561,555	1%	3.132	44.947	10%
118	-£212,944,846	1%	3.132	44.947	20%
119	-£186,328,138	1%	3.132	44.947	30%
120	-£53,244,594	1%	3.132	44.947	80%
121	-£263,515,336	1%	3.132	38.526	1%
122	-£239,560,412	1%	3.132	38.526	10%
123	-£212,943,830	1%	3.132	38.526	20%
124	-£186,327,249	1%	3.132	38.526	30%

125	-£53,244,340	1%	3.132	38.526	80%
126	-£161,587,036	20%	5.22	64.21	1%
127	-£146,898,321	20%	5.22	64.21	10%
128	-£130,577,527	20%	5.22	64.21	20%
129	-£114,256,733	20%	5.22	64.21	30%
130	-£32,652,764	20%	5.22	64.21	80%
131	-£161,561,889	20%	5.22	57.789	1%
132	-£146,875,461	20%	5.22	57.789	10%
133	-£130,557,207	20%	5.22	57.789	20%
134	-£114,238,953	20%	5.22	57.789	30%
135	-£32,647,684	20%	5.22	57.789	80%
136	-£161,536,742	20%	5.22	51.368	1%
137	-£146,852,600	20%	5.22	51.368	10%
138	-£130,536,886	20%	5.22	51.368	20%
139	-£114,221,173	20%	5.22	51.368	30%
140	-£32,642,604	20%	5.22	51.368	80%
141	-£161,511,596	20%	5.22	44.947	1%
142	-£146,829,740	20%	5.22	44.947	10%
143	-£130,516,566	20%	5.22	44.947	20%
144	-£114,203,392	20%	5.22	44.947	30%
145	-£32,637,524	20%	5.22	44.947	80%
146	-£161,486,449	20%	5.22	38.526	1%
147	-£146,806,879	20%	5.22	38.526	10%
148	-£130,496,245	20%	5.22	38.526	20%
149	-£114,185,612	20%	5.22	38.526	30%
150	-£32,632,443	20%	5.22	38.526	80%
151	-£161,587,015	20%	4.698	64.21	1%
152	-£146,898,303	20%	4.698	64.21	10%
153	-£130,577,511	20%	4.698	64.21	20%
154	-£114,256,719	20%	4.698	64.21	30%
155	-£32,652,760	20%	4.698	64.21	80%
156	-£161,561,869	20%	4.698	57.789	1%
157	-£146,875,442	20%	4.698	57.789	10%
158	-£130,557,190	20%	4.698	57.789	20%
159	-£114,238,939	20%	4.698	57.789	30%
160	-£32,647,680	20%	4.698	57.789	80%
161	-£161,536,722	20%	4.698	51.368	1%
162	-£146,852,582	20%	4.698	51.368	10%
163	-£130,536,870	20%	4.698	51.368	20%
164	-£114,221,158	20%	4.698	51.368	30%
165	-£32,642,600	20%	4.698	51.368	80%
166	-£161,511,575	20%	4.698	44.947	1%
167	-£146,829,721	20%	4.698	44.947	10%

168	-£130,516,549	20%	4.698	44.947	20%
169	-£114,203,378	20%	4.698	44.947	30%
170	-£32,637,519	20%	4.698	44.947	80%
171	-£161,486,429	20%	4.698	38.526	1%
172	-£146,806,860	20%	4.698	38.526	10%
173	-£130,496,229	20%	4.698	38.526	20%
174	-£114,185,597	20%	4.698	38.526	30%
175	-£32,632,439	20%	4.698	38.526	80%
176	-£161,586,995	20%	4.18	64.21	1%
177	-£146,898,284	20%	4.18	64.21	10%
178	-£130,577,494	20%	4.18	64.21	20%
179	-£114,256,704	20%	4.18	64.21	30%
180	-£32,652,756	20%	4.18	64.21	80%
181	-£161,561,848	20%	4.18	57.789	1%
182	-£146,875,423	20%	4.18	57.789	10%
183	-£130,557,174	20%	4.18	57.789	20%
184	-£114,238,924	20%	4.18	57.789	30%
185	-£32,647,676	20%	4.18	57.789	80%
186	-£161,536,702	20%	4.18	51.368	1%
187	-£146,852,563	20%	4.18	51.368	10%
188	-£130,536,853	20%	4.18	51.368	20%
189	-£114,221,144	20%	4.18	51.368	30%
190	-£32,642,595	20%	4.18	51.368	80%
191	-£161,511,555	20%	4.18	44.947	1%
192	-£146,829,702	20%	4.18	44.947	10%
193	-£130,516,533	20%	4.18	44.947	20%
194	-£114,203,363	20%	4.18	44.947	30%
195	-£32,637,515	20%	4.18	44.947	80%
196	-£161,486,408	20%	4.18	38.526	1%
197	-£146,806,842	20%	4.18	38.526	10%
198	-£130,496,212	20%	4.18	38.526	20%
199	-£114,185,583	20%	4.18	38.526	30%
200	-£32,632,435	20%	4.18	38.526	80%
201	-£161,586,974	20%	3.654	64.21	1%
202	-£146,898,265	20%	3.654	64.21	10%
203	-£130,577,478	20%	3.654	64.21	20%
204	-£114,256,690	20%	3.654	64.21	30%
205	-£32,652,752	20%	3.654	64.21	80%
206	-£161,561,828	20%	3.654	57.789	1%
207	-£146,875,405	20%	3.654	57.789	10%
208	-£130,557,157	20%	3.654	57.789	20%
209	-£114,238,910	20%	3.654	57.789	30%
210	-£32,647,671	20%	3.654	57.789	80%

211	-£161,536,681	20%	3.654	51.368	1%
212	-£146,852,544	20%	3.654	51.368	10%
213	-£130,536,837	20%	3.654	51.368	20%
214	-£114,221,129	20%	3.654	51.368	30%
215	-£32,642,591	20%	3.654	51.368	80%
216	-£161,511,535	20%	3.654	44.947	1%
217	-£146,829,684	20%	3.654	44.947	10%
218	-£130,516,516	20%	3.654	44.947	20%
219	-£114,203,349	20%	3.654	44.947	30%
220	-£32,637,511	20%	3.654	44.947	80%
221	-£161,486,388	20%	3.654	38.526	1%
222	-£146,806,823	20%	3.654	38.526	10%
223	-£130,496,196	20%	3.654	38.526	20%
224	-£114,185,568	20%	3.654	38.526	30%
225	-£32,632,431	20%	3.654	38.526	80%
226	-£161,586,954	20%	3.132	64.21	1%
227	-£146,898,247	20%	3.132	64.21	10%
228	-£130,577,461	20%	3.132	64.21	20%
229	-£114,256,676	20%	3.132	64.21	30%
230	-£32,652,747	20%	3.132	64.21	80%
231	-£161,561,807	20%	3.132	57.789	1%
232	-£146,875,386	20%	3.132	57.789	10%
233	-£130,557,141	20%	3.132	57.789	20%
234	-£114,238,895	20%	3.132	57.789	30%
235	-£32,647,667	20%	3.132	57.789	80%
236	-£161,536,661	20%	3.132	51.368	1%
237	-£146,852,526	20%	3.132	51.368	10%
238	-£130,536,820	20%	3.132	51.368	20%
239	-£114,221,115	20%	3.132	51.368	30%
240	-£32,642,587	20%	3.132	51.368	80%
241	-£161,511,514	20%	3.132	44.947	1%
242	-£146,829,665	20%	3.132	44.947	10%
243	-£130,516,500	20%	3.132	44.947	20%
244	-£114,203,334	20%	3.132	44.947	30%
245	-£32,637,507	20%	3.132	44.947	80%
246	-£161,486,368	20%	3.132	38.526	1%
247	-£146,806,805	20%	3.132	38.526	10%
248	-£130,496,179	20%	3.132	38.526	20%
249	-£114,185,554	20%	3.132	38.526	30%
250	-£32,632,427	20%	3.132	38.526	80%
251	-£639,544	50%	5.22	64.21	1%
252	-£582,420	50%	5.22	64.21	10%
253	-£518,948	50%	5.22	64.21	20%

254	-£455,477	50%	5.22	64.21	30%
255	-£138,119	50%	5.22	64.21	80%
256	-£576,678	50%	5.22	57.789	1%
257	-£525,269	50%	5.22	57.789	10%
258	-£468,147	50%	5.22	57.789	20%
259	-£411,026	50%	5.22	57.789	30%
260	-£125,419	50%	5.22	57.789	80%
261	-£513,811	50%	5.22	51.368	1%
262	-£468,117	50%	5.22	51.368	10%
263	-£417,346	50%	5.22	51.368	20%
264	-£366,575	50%	5.22	51.368	30%
265	-£112,719	50%	5.22	51.368	80%
266	-£450,945	50%	5.22	44.947	1%
267	-£410,966	50%	5.22	44.947	10%
268	-£366,545	50%	5.22	44.947	20%
269	-£322,124	50%	5.22	44.947	30%
270	-£100,018	50%	5.22	44.947	80%
271	-£388,078	50%	5.22	38.526	1%
272	-£353,814	50%	5.22	38.526	10%
273	-£315,744	50%	5.22	38.526	20%
274	-£277,673	50%	5.22	38.526	30%
275	-£87,318	50%	5.22	38.526	80%
276	-£639,524	50%	4.698	64.21	1%
277	-£582,401	50%	4.698	64.21	10%
278	-£518,932	50%	4.698	64.21	20%
279	-£455,462	50%	4.698	64.21	30%
280	-£138,115	50%	4.698	64.21	80%
281	-£576,657	50%	4.698	57.789	1%
282	-£525,250	50%	4.698	57.789	10%
283	-£468,131	50%	4.698	57.789	20%
284	-£411,011	50%	4.698	57.789	30%
285	-£125,415	50%	4.698	57.789	80%
286	-£513,791	50%	4.698	51.368	1%
287	-£468,099	50%	4.698	51.368	10%
288	-£417,329	50%	4.698	51.368	20%
289	-£366,560	50%	4.698	51.368	30%
290	-£112,714	50%	4.698	51.368	80%
291	-£450,924	50%	4.698	44.947	1%
292	-£410,947	50%	4.698	44.947	10%
293	-£366,528	50%	4.698	44.947	20%
294	-£322,109	50%	4.698	44.947	30%
295	-£100,014	50%	4.698	44.947	80%
296	-£388,058	50%	4.698	38.526	1%

297	-£353,796	50%	4.698	38.526	10%
298	-£315,727	50%	4.698	38.526	20%
299	-£277,658	50%	4.698	38.526	30%
300	-£87,314	50%	4.698	38.526	80%
301	-£639,503	50%	4.18	64.21	1%
302	-£582,383	50%	4.18	64.21	10%
303	-£518,915	50%	4.18	64.21	20%
304	-£455,448	50%	4.18	64.21	30%
305	-£138,111	50%	4.18	64.21	80%
306	-£576,637	50%	4.18	57.789	1%
307	-£525,231	50%	4.18	57.789	10%
308	-£468,114	50%	4.18	57.789	20%
309	-£410,997	50%	4.18	57.789	30%
310	-£125,411	50%	4.18	57.789	80%
311	-£513,770	50%	4.18	51.368	1%
312	-£468,080	50%	4.18	51.368	10%
313	-£417,313	50%	4.18	51.368	20%
314	-£366,546	50%	4.18	51.368	30%
315	-£112,710	50%	4.18	51.368	80%
316	-£450,904	50%	4.18	44.947	1%
317	-£410,929	50%	4.18	44.947	10%
318	-£366,512	50%	4.18	44.947	20%
319	-£322,095	50%	4.18	44.947	30%
320	-£100,010	50%	4.18	44.947	80%
321	-£388,037	50%	4.18	38.526	1%
322	-£353,777	50%	4.18	38.526	10%
323	-£315,710	50%	4.18	38.526	20%
324	-£277,644	50%	4.18	38.526	30%
325	-£87,310	50%	4.18	38.526	80%
326	-£639,483	50%	3.654	64.21	1%
327	-£582,364	50%	3.654	64.21	10%
328	-£518,899	50%	3.654	64.21	20%
329	-£455,433	50%	3.654	64.21	30%
330	-£138,107	50%	3.654	64.21	80%
331	-£576,616	50%	3.654	57.789	1%
332	-£525,213	50%	3.654	57.789	10%
333	-£468,098	50%	3.654	57.789	20%
334	-£410,982	50%	3.654	57.789	30%
335	-£125,406	50%	3.654	57.789	80%
336	-£513,750	50%	3.654	51.368	1%
337	-£468,061	50%	3.654	51.368	10%
338	-£417,296	50%	3.654	51.368	20%
339	-£366,531	50%	3.654	51.368	30%

340	-£112,706	50%	3.654	51.368	80%
341	-£450,883	50%	3.654	44.947	1%
342	-£410,910	50%	3.654	44.947	10%
343	-£366,495	50%	3.654	44.947	20%
344	-£322,080	50%	3.654	44.947	30%
345	-£100,006	50%	3.654	44.947	80%
346	-£388,017	50%	3.654	38.526	1%
347	-£353,759	50%	3.654	38.526	10%
348	-£315,694	50%	3.654	38.526	20%
349	-£277,629	50%	3.654	38.526	30%
350	-£87,306	50%	3.654	38.526	80%
351	-£639,463	50%	3.132	64.21	1%
352	-£582,346	50%	3.132	64.21	10%
353	-£518,882	50%	3.132	64.21	20%
354	-£455,419	50%	3.132	64.21	30%
355	-£138,103	50%	3.132	64.21	80%
356	-£576,596	50%	3.132	57.789	1%
357	-£525,194	50%	3.132	57.789	10%
358	-£468,081	50%	3.132	57.789	20%
359	-£410,968	50%	3.132	57.789	30%
360	-£125,402	50%	3.132	57.789	80%
361	-£513,730	50%	3.132	51.368	1%
362	-£468,043	50%	3.132	51.368	10%
363	-£417,280	50%	3.132	51.368	20%
364	-£366,517	50%	3.132	51.368	30%
365	-£112,702	50%	3.132	51.368	80%
366	-£450,863	50%	3.132	44.947	1%
367	-£410,891	50%	3.132	44.947	10%
368	-£366,479	50%	3.132	44.947	20%
369	-£322,066	50%	3.132	44.947	30%
370	-£100,002	50%	3.132	44.947	80%
371	-£387,997	50%	3.132	38.526	1%
372	-£353,740	50%	3.132	38.526	10%
373	-£315,677	50%	3.132	38.526	20%
374	-£277,615	50%	3.132	38.526	30%
375	-£87,301	50%	3.132	38.526	80%
376	£4,725,372	51%	5.22	64.21	1%
377	£4,294,777	51%	5.22	64.21	10%
378	£3,816,338	51%	5.22	64.21	20%
379	£3,337,898	51%	5.22	64.21	30%
380	£945,702	51%	5.22	64.21	80%
381	£4,789,496	51%	5.22	57.789	1%
382	£4,353,071	51%	5.22	57.789	10%

383	£3,868,155	51%	5.22	57.789	20%
384	£3,383,238	51%	5.22	57.789	30%
385	£958,657	51%	5.22	57.789	80%
386	£4,853,620	51%	5.22	51.368	1%
387	£4,411,366	51%	5.22	51.368	10%
388	£3,919,972	51%	5.22	51.368	20%
389	£3,428,579	51%	5.22	51.368	30%
390	£971,611	51%	5.22	51.368	80%
391	£4,917,744	51%	5.22	44.947	1%
392	£4,469,660	51%	5.22	44.947	10%
393	£3,971,789	51%	5.22	44.947	20%
394	£3,473,919	51%	5.22	44.947	30%
395	£984,565	51%	5.22	44.947	80%
396	£4,981,867	51%	5.22	38.526	1%
397	£4,527,954	51%	5.22	38.526	10%
398	£4,023,607	51%	5.22	38.526	20%
399	£3,519,259	51%	5.22	38.526	30%
400	£997,520	51%	5.22	38.526	80%
401	£4,725,393	51%	4.698	64.21	1%
402	£4,294,795	51%	4.698	64.21	10%
403	£3,816,354	51%	4.698	64.21	20%
404	£3,337,913	51%	4.698	64.21	30%
405	£945,706	51%	4.698	64.21	80%
406	£4,789,516	51%	4.698	57.789	1%
407	£4,353,090	51%	4.698	57.789	10%
408	£3,868,171	51%	4.698	57.789	20%
409	£3,383,253	51%	4.698	57.789	30%
410	£958,661	51%	4.698	57.789	80%
411	£4,853,640	51%	4.698	51.368	1%
412	£4,411,384	51%	4.698	51.368	10%
413	£3,919,989	51%	4.698	51.368	20%
414	£3,428,593	51%	4.698	51.368	30%
415	£971,615	51%	4.698	51.368	80%
416	£4,917,764	51%	4.698	44.947	1%
417	£4,469,679	51%	4.698	44.947	10%
418	£3,971,806	51%	4.698	44.947	20%
419	£3,473,933	51%	4.698	44.947	30%
420	£984,569	51%	4.698	44.947	80%
421	£4,981,888	51%	4.698	38.526	1%
422	£4,527,973	51%	4.698	38.526	10%
423	£4,023,623	51%	4.698	38.526	20%
424	£3,519,273	51%	4.698	38.526	30%
425	£997,524	51%	4.698	38.526	80%

426	£4,725,413	51%	4.18	64.21	1%
427	£4,294,814	51%	4.18	64.21	10%
428	£3,816,371	51%	4.18	64.21	20%
429	£3,337,927	51%	4.18	64.21	30%
430	£945,711	51%	4.18	64.21	80%
431	£4,789,537	51%	4.18	57.789	1%
432	£4,353,108	51%	4.18	57.789	10%
433	£3,868,188	51%	4.18	57.789	20%
434	£3,383,267	51%	4.18	57.789	30%
435	£958,665	51%	4.18	57.789	80%
436	£4,853,661	51%	4.18	51.368	1%
437	£4,411,403	51%	4.18	51.368	10%
438	£3,920,005	51%	4.18	51.368	20%
439	£3,428,607	51%	4.18	51.368	30%
440	£971,619	51%	4.18	51.368	80%
441	£4,917,784	51%	4.18	44.947	1%
442	£4,469,697	51%	4.18	44.947	10%
443	£3,971,822	51%	4.18	44.947	20%
444	£3,473,948	51%	4.18	44.947	30%
445	£984,573	51%	4.18	44.947	80%
446	£4,981,908	51%	4.18	38.526	1%
447	£4,527,992	51%	4.18	38.526	10%
448	£4,023,640	51%	4.18	38.526	20%
449	£3,519,288	51%	4.18	38.526	30%
450	£997,528	51%	4.18	38.526	80%
451	£4,725,433	51%	3.654	64.21	1%
452	£4,294,833	51%	3.654	64.21	10%
453	£3,816,387	51%	3.654	64.21	20%
454	£3,337,942	51%	3.654	64.21	30%
455	£945,715	51%	3.654	64.21	80%
456	£4,789,557	51%	3.654	57.789	1%
457	£4,353,127	51%	3.654	57.789	10%
458	£3,868,204	51%	3.654	57.789	20%
459	£3,383,282	51%	3.654	57.789	30%
460	£958,669	51%	3.654	57.789	80%
461	£4,853,681	51%	3.654	51.368	1%
462	£4,411,421	51%	3.654	51.368	10%
463	£3,920,022	51%	3.654	51.368	20%
464	£3,428,622	51%	3.654	51.368	30%
465	£971,623	51%	3.654	51.368	80%
466	£4,917,805	51%	3.654	44.947	1%
467	£4,469,716	51%	3.654	44.947	10%
468	£3,971,839	51%	3.654	44.947	20%

469	£3,473,962	51%	3.654	44.947	30%
470	£984,578	51%	3.654	44.947	80%
471	£4,981,929	51%	3.654	38.526	1%
472	£4,528,010	51%	3.654	38.526	10%
473	£4,023,656	51%	3.654	38.526	20%
474	£3,519,302	51%	3.654	38.526	30%
475	£997,532	51%	3.654	38.526	80%
476	£4,725,454	51%	3.132	64.21	1%
477	£4,294,851	51%	3.132	64.21	10%
478	£3,816,404	51%	3.132	64.21	20%
479	£3,337,956	51%	3.132	64.21	30%
480	£945,719	51%	3.132	64.21	80%
481	£4,789,578	51%	3.132	57.789	1%
482	£4,353,146	51%	3.132	57.789	10%
483	£3,868,221	51%	3.132	57.789	20%
484	£3,383,296	51%	3.132	57.789	30%
485	£958,673	51%	3.132	57.789	80%
486	£4,853,702	51%	3.132	51.368	1%
487	£4,411,440	51%	3.132	51.368	10%
488	£3,920,038	51%	3.132	51.368	20%
489	£3,428,636	51%	3.132	51.368	30%
490	£971,627	51%	3.132	51.368	80%
491	£4,917,825	51%	3.132	44.947	1%
492	£4,469,734	51%	3.132	44.947	10%
493	£3,971,855	51%	3.132	44.947	20%
494	£3,473,976	51%	3.132	44.947	30%
495	£984,582	51%	3.132	44.947	80%
496	£4,981,949	51%	3.132	38.526	1%
497	£4,528,029	51%	3.132	38.526	10%
498	£4,023,673	51%	3.132	38.526	20%
499	£3,519,317	51%	3.132	38.526	30%
500	£997,536	51%	3.132	38.526	80%
501	£160,307,947	80%	5.22	64.21	1%
502	£145,733,481	80%	5.22	64.21	10%
503	£129,539,631	80%	5.22	64.21	20%
504	£113,345,780	80%	5.22	64.21	30%
505	£32,376,526	80%	5.22	64.21	80%
506	£160,408,534	80%	5.22	57.789	1%
507	£145,824,924	80%	5.22	57.789	10%
508	£129,620,912	80%	5.22	57.789	20%
509	£113,416,901	80%	5.22	57.789	30%
510	£32,396,846	80%	5.22	57.789	80%
511	£160,509,120	80%	5.22	51.368	1%

512	£145,916,366	80%	5.22	51.368	10%
513	£129,702,194	80%	5.22	51.368	20%
514	£113,488,023	80%	5.22	51.368	30%
515	£32,417,167	80%	5.22	51.368	80%
516	£160,609,706	80%	5.22	44.947	1%
517	£146,007,808	80%	5.22	44.947	10%
518	£129,783,476	80%	5.22	44.947	20%
519	£113,559,145	80%	5.22	44.947	30%
520	£32,437,487	80%	5.22	44.947	80%
521	£160,710,293	80%	5.22	38.526	1%
522	£146,099,250	80%	5.22	38.526	10%
523	£129,864,758	80%	5.22	38.526	20%
524	£113,630,266	80%	5.22	38.526	30%
525	£32,457,807	80%	5.22	38.526	80%
526	£160,307,968	80%	4.698	64.21	1%
527	£145,733,500	80%	4.698	64.21	10%
528	£129,539,647	80%	4.698	64.21	20%
529	£113,345,794	80%	4.698	64.21	30%
530	£32,376,530	80%	4.698	64.21	80%
531	£160,408,554	80%	4.698	57.789	1%
532	£145,824,942	80%	4.698	57.789	10%
533	£129,620,929	80%	4.698	57.789	20%
534	£113,416,916	80%	4.698	57.789	30%
535	£32,396,850	80%	4.698	57.789	80%
536	£160,509,140	80%	4.698	51.368	1%
537	£145,916,384	80%	4.698	51.368	10%
538	£129,702,211	80%	4.698	51.368	20%
539	£113,488,038	80%	4.698	51.368	30%
540	£32,417,171	80%	4.698	51.368	80%
541	£160,609,727	80%	4.698	44.947	1%
542	£146,007,827	80%	4.698	44.947	10%
543	£129,783,493	80%	4.698	44.947	20%
544	£113,559,159	80%	4.698	44.947	30%
545	£32,437,491	80%	4.698	44.947	80%
546	£160,710,313	80%	4.698	38.526	1%
547	£146,099,269	80%	4.698	38.526	10%
548	£129,864,775	80%	4.698	38.526	20%
549	£113,630,281	80%	4.698	38.526	30%
550	£32,457,812	80%	4.698	38.526	80%
551	£160,307,988	80%	4.18	64.21	1%
552	£145,733,519	80%	4.18	64.21	10%
553	£129,539,664	80%	4.18	64.21	20%
554	£113,345,809	80%	4.18	64.21	30%

555	£32,376,534	80%	4.18	64.21	80%
556	£160,408,574	80%	4.18	57.789	1%
557	£145,824,961	80%	4.18	57.789	10%
558	£129,620,946	80%	4.18	57.789	20%
559	£113,416,930	80%	4.18	57.789	30%
560	£32,396,854	80%	4.18	57.789	80%
561	£160,509,161	80%	4.18	51.368	1%
562	£145,916,403	80%	4.18	51.368	10%
563	£129,702,227	80%	4.18	51.368	20%
564	£113,488,052	80%	4.18	51.368	30%
565	£32,417,175	80%	4.18	51.368	80%
566	£160,609,747	80%	4.18	44.947	1%
567	£146,007,845	80%	4.18	44.947	10%
568	£129,783,509	80%	4.18	44.947	20%
569	£113,559,174	80%	4.18	44.947	30%
570	£32,437,495	80%	4.18	44.947	80%
571	£160,710,334	80%	4.18	38.526	1%
572	£146,099,287	80%	4.18	38.526	10%
573	£129,864,791	80%	4.18	38.526	20%
574	£113,630,295	80%	4.18	38.526	30%
575	£32,457,816	80%	4.18	38.526	80%
576	£160,308,008	80%	3.654	64.21	1%
577	£145,733,537	80%	3.654	64.21	10%
578	£129,539,680	80%	3.654	64.21	20%
579	£113,345,823	80%	3.654	64.21	30%
580	£32,376,538	80%	3.654	64.21	80%
581	£160,408,595	80%	3.654	57.789	1%
582	£145,824,979	80%	3.654	57.789	10%
583	£129,620,962	80%	3.654	57.789	20%
584	£113,416,945	80%	3.654	57.789	30%
585	£32,396,858	80%	3.654	57.789	80%
586	£160,509,181	80%	3.654	51.368	1%
587	£145,916,421	80%	3.654	51.368	10%
588	£129,702,244	80%	3.654	51.368	20%
589	£113,488,066	80%	3.654	51.368	30%
590	£32,417,179	80%	3.654	51.368	80%
591	£160,609,768	80%	3.654	44.947	1%
592	£146,007,864	80%	3.654	44.947	10%
593	£129,783,526	80%	3.654	44.947	20%
594	£113,559,188	80%	3.654	44.947	30%
595	£32,437,499	80%	3.654	44.947	80%
596	£160,710,354	80%	3.654	38.526	1%
597	£146,099,306	80%	3.654	38.526	10%

598	£129,864,808	80%	3.654	38.526	20%
599	£113,630,310	80%	3.654	38.526	30%
600	£32,457,820	80%	3.654	38.526	80%
601	£160,308,029	80%	3.132	64.21	1%
602	£145,733,556	80%	3.132	64.21	10%
603	£129,539,697	80%	3.132	64.21	20%
604	£113,345,838	80%	3.132	64.21	30%
605	£32,376,542	80%	3.132	64.21	80%
606	£160,408,615	80%	3.132	57.789	1%
607	£145,824,998	80%	3.132	57.789	10%
608	£129,620,979	80%	3.132	57.789	20%
609	£113,416,959	80%	3.132	57.789	30%
610	£32,396,863	80%	3.132	57.789	80%
611	£160,509,202	80%	3.132	51.368	1%
612	£145,916,440	80%	3.132	51.368	10%
613	£129,702,261	80%	3.132	51.368	20%
614	£113,488,081	80%	3.132	51.368	30%
615	£32,417,183	80%	3.132	51.368	80%
616	£160,609,788	80%	3.132	44.947	1%
617	£146,007,882	80%	3.132	44.947	10%
618	£129,783,542	80%	3.132	44.947	20%
619	£113,559,203	80%	3.132	44.947	30%
620	£32,437,504	80%	3.132	44.947	80%
621	£160,710,375	80%	3.132	38.526	1%
622	£146,099,324	80%	3.132	38.526	10%
623	£129,864,824	80%	3.132	38.526	20%
624	£113,630,324	80%	3.132	38.526	30%
625	£32,457,824	80%	3.132	38.526	80%

Supplementary 5.2. Cost benefit analysis showing the environmental costs and savings at the University of Strathclyde based on the current waste management practice a University of Strathclyde.

	Waste Reduction Target				**1%**
	Scenario				1
	Market price of plastic/ ton (£))				40.00
	Market price of paper/tonne (£)				60.00
	Emission Cost per (kg) - CO2, CH4, and N2O (£)				69,000.00
	Cost of Sorting waste per tonne £				64.21
	% of Waste Recycled				100%
	Cost of Haulage/ tonne (£)				5.22
	Environmental Cost per Kg (₦)				34,500.00
	Cost of Awareness				100.00
	Cost of Awareness (1, 2 or 3)				1.00
Emission factor	Material (mixed) recycling				21.00
Emission factor	Refuse Commercial & Industrial to Landfill				199.00
	Discount rate per annum				8%
	Total Cost	Total Benefits	Net Cash Flow	Discount Factor	Net Discounted Cash Flow
Feb-11	13,860.06	730,391.69	£ 716,531.63	1.000	£ 716,531.63
Mar-11	4,023.87	860,347.85	£ 856,323.98	0.993	£ 850,652.96
Apr-11	3,113.93	665,794.23	£ 662,680.30	0.987	£ 653,932.14
May-11	3,478.67	722,398.57	£ 718,919.89	0.980	£ 704,731.10

Jun-11	3,757.28	803,349.29	£ 799,592.01	0.974	£ 778,620.25
Jul-11	3,267.41	698,609.52	£ 695,342.11	0.967	£ 672,620.48
Aug-11	3,370.78	699,329.99	£ 695,959.21	0.961	£ 668,759.02
Sep-11	3,095.75	661,906.42	£ 658,810.67	0.955	£ 628,869.90
Oct-11	3,532.60	755,309.01	£ 751,776.42	0.948	£ 712,858.27
Nov-11	3,786.01	788,110.71	£ 784,324.70	0.942	£ 738,796.27
Dec-11	2,953.65	631,524.41	£ 628,570.76	0.936	£ 588,162.44
Jan-12	3,258.51	696,706.40	£ 693,447.89	0.930	£ 644,571.74
Feb-12	3,637.11	756,274.17	£ 752,637.06	0.923	£ 694,956.05
Mar-12	3,858.75	825,044.90	£ 821,186.15	0.917	£ 753,230.10
Apr-12	3,341.86	714,527.79	£ 711,185.93	0.911	£ 648,012.70
May-12	4,033.71	841,071.92	£ 837,038.21	0.905	£ 757,634.88
Jun-12	3,254.25	695,795.62	£ 692,541.37	0.899	£ 622,694.04
Jul-12	4,153.12	887,983.92	£ 883,830.80	0.893	£ 789,427.83
Aug-12	3,626.68	754,044.80	£ 750,418.11	0.887	£ 665,826.26

Sep-12	2,834.51	606,049.74	£ 603,215.23	0.881	£ 531,672.53
Oct-12	3,299.33	705,433.58	£ 702,134.25	0.876	£ 614,761.12
Nov-12	3,325.71	689,692.03	£ 686,366.32	0.870	£ 596,975.51
Dec-12	2,211.06	472,749.52	£ 470,538.46	0.864	£ 406,546.27
Jan-13	3,110.50	665,060.17	£ 661,949.67	0.858	£ 568,138.39
Feb-13	2,909.78	600,761.78	£ 597,852.00	0.853	£ 509,726.45
Mar-13	2,779.39	594,263.97	£ 591,484.58	1.000	£ 591,484.58
Apr-13	2,839.98	607,218.80	£ 604,378.83	1.000	£ 604,378.83
May-13	2,894.46	618,868.64	£ 615,974.18	1.000	£ 615,974.18
Jun-13	2,792.80	597,132.25	£ 594,339.45	1.000	£ 594,339.45
Jul-13	340.72	72,848.86	£ 72,508.14	1.000	£ 72,508.14
Aug-13	3,099.44	662,694.86	£ 659,595.42	1.000	£ 659,595.42
Sep-13	2,933.05	627,120.04	£ 624,186.98	1.000	£ 624,186.98
Oct-13	3,307.91	707,268.73	£ 703,960.82	1.000	£ 703,960.82
Nov-13	2,950.86	630,926.29	£ 627,975.43	1.000	£ 627,975.43

Dec-13	2,319.33	495,899.66	£ 493,580.33	1.000	£ 493,580.33
Jan-14	3,040.50	650,093.46	£ 647,052.96	1.000	£ 647,052.96
Feb-14	2,834.64	606,076.93	£ 603,242.29	1.000	£ 603,242.29
Mar-14	2,958.99	632,666.29	£ 629,707.29	1.000	£ 629,707.29
Apr-14	2,875.52	614,817.70	£ 611,942.19	1.000	£ 611,942.19
May-14	3,116.29	666,297.20	£ 663,180.91	1.000	£ 663,180.91
Jun-14	2,976.10	636,323.00	£ 633,346.90	1.000	£ 633,346.90
Jul-14	2,880.48	615,878.02	£ 612,997.54	1.000	£ 612,997.54
Aug-14	2,860.26	611,555.21	£ 608,694.95	1.000	£ 608,694.95
Sep-14	2,995.17	640,401.12	£ 637,405.95	1.000	£ 637,405.95
Oct-14	3,267.48	698,623.12	£ 695,355.64	1.000	£ 695,355.64
Nov-14	2,778.31	594,032.87	£ 591,254.57	1.000	£ 591,254.57
Dec-14	2,409.55	515,189.18	£ 512,779.63	1.000	£ 512,779.63
Jan-15	2,797.12	598,056.62	£ 595,259.50	1.000	£ 595,259.50
Feb-15	3,038.53	649,672.05	£ 646,633.52	1.000	£ 646,633.52

Mar-15	3,560.51	761,276.67	£ 757,716.16	1.000	£ 757,716.16
Apr-15	3,532.98	755,390.58	£ 751,857.60	1.000	£ 751,857.60
May-15	3,080.56	658,657.52	£ 655,576.96	1.000	£ 655,576.96
Jun-15	3,607.87	771,404.00	£ 767,796.13	1.000	£ 767,796.13
	Net Present Value				£ 33,728,493.18

Scenario Number	NPV	% of Waste Recycled	Cost of Haulage/ tonne (₦)	Cost of Sorting waste per tonne £	Waste Reduction Target
	£33,728,493	0	0	0	0
1	£33,728,493	1%	5.22	64.21	1%
2	£30,661,251	1%	5.22	64.21	10%
3	£27,253,203	1%	5.22	64.21	20%
4	£23,845,156	1%	5.22	64.21	30%
5	£6,804,919	1%	5.22	64.21	80%
6	£33,744,345	1%	5.22	57.789	1%
7	£30,675,661	1%	5.22	57.789	10%
8	£27,266,013	1%	5.22	57.789	20%
9	£23,856,364	1%	5.22	57.789	30%
10	£6,808,121	1%	5.22	57.789	80%
11	£33,760,197	1%	5.22	51.368	1%
12	£30,690,072	1%	5.22	51.368	10%
13	£27,278,822	1%	5.22	51.368	20%
14	£23,867,572	1%	5.22	51.368	30%
15	£6,811,323	1%	5.22	51.368	80%
16	£33,776,048	1%	5.22	44.947	1%
17	£30,704,482	1%	5.22	44.947	10%
18	£27,291,631	1%	5.22	44.947	20%
19	£23,878,781	1%	5.22	44.947	30%
20	£6,814,526	1%	5.22	44.947	80%
21	£33,791,900	1%	5.22	38.526	1%
22	£30,718,893	1%	5.22	38.526	10%
23	£27,304,441	1%	5.22	38.526	20%
24	£23,889,989	1%	5.22	38.526	30%
25	£6,817,728	1%	5.22	38.526	80%
26	£33,728,496	1%	4.698	64.21	1%
27	£30,661,253	1%	4.698	64.21	10%
28	£27,253,205	1%	4.698	64.21	20%
29	£23,845,158	1%	4.698	64.21	30%
30	£6,804,919	1%	4.698	64.21	80%
31	£33,744,347	1%	4.698	57.789	1%
32	£30,675,663	1%	4.698	57.789	10%
33	£27,266,015	1%	4.698	57.789	20%
34	£23,856,366	1%	4.698	57.789	30%
35	£6,808,122	1%	4.698	57.789	80%
36	£33,760,199	1%	4.698	51.368	1%
37	£30,690,074	1%	4.698	51.368	10%
38	£27,278,824	1%	4.698	51.368	20%

39	£23,867,574	1%	4.698	51.368	30%
40	£6,811,324	1%	4.698	51.368	80%
41	£33,776,051	1%	4.698	44.947	1%
42	£30,704,485	1%	4.698	44.947	10%
43	£27,291,634	1%	4.698	44.947	20%
44	£23,878,782	1%	4.698	44.947	30%
45	£6,814,526	1%	4.698	44.947	80%
46	£33,791,903	1%	4.698	38.526	1%
47	£30,718,895	1%	4.698	38.526	10%
48	£27,304,443	1%	4.698	38.526	20%
49	£23,889,991	1%	4.698	38.526	30%
50	£6,817,729	1%	4.698	38.526	80%
51	£33,728,498	1%	4.18	64.21	1%
52	£30,661,255	1%	4.18	64.21	10%
53	£27,253,207	1%	4.18	64.21	20%
54	£23,845,159	1%	4.18	64.21	30%
55	£6,804,920	1%	4.18	64.21	80%
56	£33,744,350	1%	4.18	57.789	1%
57	£30,675,666	1%	4.18	57.789	10%
58	£27,266,017	1%	4.18	57.789	20%
59	£23,856,368	1%	4.18	57.789	30%
60	£6,808,122	1%	4.18	57.789	80%
61	£33,760,202	1%	4.18	51.368	1%
62	£30,690,076	1%	4.18	51.368	10%
63	£27,278,826	1%	4.18	51.368	20%
64	£23,867,576	1%	4.18	51.368	30%
65	£6,811,324	1%	4.18	51.368	80%
66	£33,776,053	1%	4.18	44.947	1%
67	£30,704,487	1%	4.18	44.947	10%
68	£27,291,636	1%	4.18	44.947	20%
69	£23,878,784	1%	4.18	44.947	30%
70	£6,814,527	1%	4.18	44.947	80%
71	£33,791,905	1%	4.18	38.526	1%
72	£30,718,898	1%	4.18	38.526	10%
73	£27,304,445	1%	4.18	38.526	20%
74	£23,889,992	1%	4.18	38.526	30%
75	£6,817,729	1%	4.18	38.526	80%
76	£33,728,501	1%	3.654	64.21	1%
77	£30,661,258	1%	3.654	64.21	10%
78	£27,253,209	1%	3.654	64.21	20%
79	£23,845,161	1%	3.654	64.21	30%
80	£6,804,920	1%	3.654	64.21	80%
81	£33,744,353	1%	3.654	57.789	1%

82	£30,675,668	1%	3.654	57.789	10%
83	£27,266,019	1%	3.654	57.789	20%
84	£23,856,369	1%	3.654	57.789	30%
85	£6,808,123	1%	3.654	57.789	80%
86	£33,760,204	1%	3.654	51.368	1%
87	£30,690,079	1%	3.654	51.368	10%
88	£27,278,828	1%	3.654	51.368	20%
89	£23,867,578	1%	3.654	51.368	30%
90	£6,811,325	1%	3.654	51.368	80%
91	£33,776,056	1%	3.654	44.947	1%
92	£30,704,489	1%	3.654	44.947	10%
93	£27,291,638	1%	3.654	44.947	20%
94	£23,878,786	1%	3.654	44.947	30%
95	£6,814,527	1%	3.654	44.947	80%
96	£33,791,908	1%	3.654	38.526	1%
97	£30,718,900	1%	3.654	38.526	10%
98	£27,304,447	1%	3.654	38.526	20%
99	£23,889,994	1%	3.654	38.526	30%
100	£6,817,730	1%	3.654	38.526	80%
101	£33,728,503	1%	3.132	64.21	1%
102	£30,661,260	1%	3.132	64.21	10%
103	£27,253,211	1%	3.132	64.21	20%
104	£23,845,163	1%	3.132	64.21	30%
105	£6,804,921	1%	3.132	64.21	80%
106	£33,744,355	1%	3.132	57.789	1%
107	£30,675,671	1%	3.132	57.789	10%
108	£27,266,021	1%	3.132	57.789	20%
109	£23,856,371	1%	3.132	57.789	30%
110	£6,808,123	1%	3.132	57.789	80%
111	£33,760,207	1%	3.132	51.368	1%
112	£30,690,081	1%	3.132	51.368	10%
113	£27,278,830	1%	3.132	51.368	20%
114	£23,867,580	1%	3.132	51.368	30%
115	£6,811,325	1%	3.132	51.368	80%
116	£33,776,059	1%	3.132	44.947	1%
117	£30,704,492	1%	3.132	44.947	10%
118	£27,291,640	1%	3.132	44.947	20%
119	£23,878,788	1%	3.132	44.947	30%
120	£6,814,528	1%	3.132	44.947	80%
121	£33,791,910	1%	3.132	38.526	1%
122	£30,718,902	1%	3.132	38.526	10%
123	£27,304,449	1%	3.132	38.526	20%
124	£23,889,996	1%	3.132	38.526	30%

125	£6,817,730	1%	3.132	38.526	80%
126	£33,728,493	20%	5.22	64.21	1%
127	£30,661,251	20%	5.22	64.21	10%
128	£27,253,203	20%	5.22	64.21	20%
129	£23,845,156	20%	5.22	64.21	30%
130	£6,804,919	20%	5.22	64.21	80%
131	£33,744,345	20%	5.22	57.789	1%
132	£30,675,661	20%	5.22	57.789	10%
133	£27,266,013	20%	5.22	57.789	20%
134	£23,856,364	20%	5.22	57.789	30%
135	£6,808,121	20%	5.22	57.789	80%
136	£33,760,197	20%	5.22	51.368	1%
137	£30,690,072	20%	5.22	51.368	10%
138	£27,278,822	20%	5.22	51.368	20%
139	£23,867,572	20%	5.22	51.368	30%
140	£6,811,323	20%	5.22	51.368	80%
141	£33,776,048	20%	5.22	44.947	1%
142	£30,704,482	20%	5.22	44.947	10%
143	£27,291,631	20%	5.22	44.947	20%
144	£23,878,781	20%	5.22	44.947	30%
145	£6,814,526	20%	5.22	44.947	80%
146	£33,791,900	20%	5.22	38.526	1%
147	£30,718,893	20%	5.22	38.526	10%
148	£27,304,441	20%	5.22	38.526	20%
149	£23,889,989	20%	5.22	38.526	30%
150	£6,817,728	20%	5.22	38.526	80%
151	£33,728,496	20%	4.698	64.21	1%
152	£30,661,253	20%	4.698	64.21	10%
153	£27,253,205	20%	4.698	64.21	20%
154	£23,845,158	20%	4.698	64.21	30%
155	£6,804,919	20%	4.698	64.21	80%
156	£33,744,347	20%	4.698	57.789	1%
157	£30,675,663	20%	4.698	57.789	10%
158	£27,266,015	20%	4.698	57.789	20%
159	£23,856,366	20%	4.698	57.789	30%
160	£6,808,122	20%	4.698	57.789	80%
161	£33,760,199	20%	4.698	51.368	1%
162	£30,690,074	20%	4.698	51.368	10%
163	£27,278,824	20%	4.698	51.368	20%
164	£23,867,574	20%	4.698	51.368	30%
165	£6,811,324	20%	4.698	51.368	80%
166	£33,776,051	20%	4.698	44.947	1%
167	£30,704,485	20%	4.698	44.947	10%

168	£27,291,634	20%	4.698	44.947	20%
169	£23,878,782	20%	4.698	44.947	30%
170	£6,814,526	20%	4.698	44.947	80%
171	£33,791,903	20%	4.698	38.526	1%
172	£30,718,895	20%	4.698	38.526	10%
173	£27,304,443	20%	4.698	38.526	20%
174	£23,889,991	20%	4.698	38.526	30%
175	£6,817,729	20%	4.698	38.526	80%
176	£33,728,498	20%	4.18	64.21	1%
177	£30,661,255	20%	4.18	64.21	10%
178	£27,253,207	20%	4.18	64.21	20%
179	£23,845,159	20%	4.18	64.21	30%
180	£6,804,920	20%	4.18	64.21	80%
181	£33,744,350	20%	4.18	57.789	1%
182	£30,675,666	20%	4.18	57.789	10%
183	£27,266,017	20%	4.18	57.789	20%
184	£23,856,368	20%	4.18	57.789	30%
185	£6,808,122	20%	4.18	57.789	80%
186	£33,760,202	20%	4.18	51.368	1%
187	£30,690,076	20%	4.18	51.368	10%
188	£27,278,826	20%	4.18	51.368	20%
189	£23,867,576	20%	4.18	51.368	30%
190	£6,811,324	20%	4.18	51.368	80%
191	£33,776,053	20%	4.18	44.947	1%
192	£30,704,487	20%	4.18	44.947	10%
193	£27,291,636	20%	4.18	44.947	20%
194	£23,878,784	20%	4.18	44.947	30%
195	£6,814,527	20%	4.18	44.947	80%
196	£33,791,905	20%	4.18	38.526	1%
197	£30,718,898	20%	4.18	38.526	10%
198	£27,304,445	20%	4.18	38.526	20%
199	£23,889,992	20%	4.18	38.526	30%
200	£6,817,729	20%	4.18	38.526	80%
201	£33,728,501	20%	3.654	64.21	1%
202	£30,661,258	20%	3.654	64.21	10%
203	£27,253,209	20%	3.654	64.21	20%
204	£23,845,161	20%	3.654	64.21	30%
205	£6,804,920	20%	3.654	64.21	80%
206	£33,744,353	20%	3.654	57.789	1%
207	£30,675,668	20%	3.654	57.789	10%
208	£27,266,019	20%	3.654	57.789	20%
209	£23,856,369	20%	3.654	57.789	30%
210	£6,808,123	20%	3.654	57.789	80%

211	£33,760,204	20%	3.654	51.368	1%
212	£30,690,079	20%	3.654	51.368	10%
213	£27,278,828	20%	3.654	51.368	20%
214	£23,867,578	20%	3.654	51.368	30%
215	£6,811,325	20%	3.654	51.368	80%
216	£33,776,056	20%	3.654	44.947	1%
217	£30,704,489	20%	3.654	44.947	10%
218	£27,291,638	20%	3.654	44.947	20%
219	£23,878,786	20%	3.654	44.947	30%
220	£6,814,527	20%	3.654	44.947	80%
221	£33,791,908	20%	3.654	38.526	1%
222	£30,718,900	20%	3.654	38.526	10%
223	£27,304,447	20%	3.654	38.526	20%
224	£23,889,994	20%	3.654	38.526	30%
225	£6,817,730	20%	3.654	38.526	80%
226	£33,728,503	20%	3.132	64.21	1%
227	£30,661,260	20%	3.132	64.21	10%
228	£27,253,211	20%	3.132	64.21	20%
229	£23,845,163	20%	3.132	64.21	30%
230	£6,804,921	20%	3.132	64.21	80%
231	£33,744,355	20%	3.132	57.789	1%
232	£30,675,671	20%	3.132	57.789	10%
233	£27,266,021	20%	3.132	57.789	20%
234	£23,856,371	20%	3.132	57.789	30%
235	£6,808,123	20%	3.132	57.789	80%
236	£33,760,207	20%	3.132	51.368	1%
237	£30,690,081	20%	3.132	51.368	10%
238	£27,278,830	20%	3.132	51.368	20%
239	£23,867,580	20%	3.132	51.368	30%
240	£6,811,325	20%	3.132	51.368	80%
241	£33,776,059	20%	3.132	44.947	1%
242	£30,704,492	20%	3.132	44.947	10%
243	£27,291,640	20%	3.132	44.947	20%
244	£23,878,788	20%	3.132	44.947	30%
245	£6,814,528	20%	3.132	44.947	80%
246	£33,791,910	20%	3.132	38.526	1%
247	£30,718,902	20%	3.132	38.526	10%
248	£27,304,449	20%	3.132	38.526	20%
249	£23,889,996	20%	3.132	38.526	30%
250	£6,817,730	20%	3.132	38.526	80%
251	£33,728,493	50%	5.22	64.21	1%
252	£30,661,251	50%	5.22	64.21	10%
253	£27,253,203	50%	5.22	64.21	20%

254	£23,845,156	50%	5.22	64.21	30%
255	£6,804,919	50%	5.22	64.21	80%
256	£33,744,345	50%	5.22	57.789	1%
257	£30,675,661	50%	5.22	57.789	10%
258	£27,266,013	50%	5.22	57.789	20%
259	£23,856,364	50%	5.22	57.789	30%
260	£6,808,121	50%	5.22	57.789	80%
261	£33,760,197	50%	5.22	51.368	1%
262	£30,690,072	50%	5.22	51.368	10%
263	£27,278,822	50%	5.22	51.368	20%
264	£23,867,572	50%	5.22	51.368	30%
265	£6,811,323	50%	5.22	51.368	80%
266	£33,776,048	50%	5.22	44.947	1%
267	£30,704,482	50%	5.22	44.947	10%
268	£27,291,631	50%	5.22	44.947	20%
269	£23,878,781	50%	5.22	44.947	30%
270	£6,814,526	50%	5.22	44.947	80%
271	£33,791,900	50%	5.22	38.526	1%
272	£30,718,893	50%	5.22	38.526	10%
273	£27,304,441	50%	5.22	38.526	20%
274	£23,889,989	50%	5.22	38.526	30%
275	£6,817,728	50%	5.22	38.526	80%
276	£33,728,496	50%	4.698	64.21	1%
277	£30,661,253	50%	4.698	64.21	10%
278	£27,253,205	50%	4.698	64.21	20%
279	£23,845,158	50%	4.698	64.21	30%
280	£6,804,919	50%	4.698	64.21	80%
281	£33,744,347	50%	4.698	57.789	1%
282	£30,675,663	50%	4.698	57.789	10%
283	£27,266,015	50%	4.698	57.789	20%
284	£23,856,366	50%	4.698	57.789	30%
285	£6,808,122	50%	4.698	57.789	80%
286	£33,760,199	50%	4.698	51.368	1%
287	£30,690,074	50%	4.698	51.368	10%
288	£27,278,824	50%	4.698	51.368	20%
289	£23,867,574	50%	4.698	51.368	30%
290	£6,811,324	50%	4.698	51.368	80%
291	£33,776,051	50%	4.698	44.947	1%
292	£30,704,485	50%	4.698	44.947	10%
293	£27,291,634	50%	4.698	44.947	20%
294	£23,878,782	50%	4.698	44.947	30%
295	£6,814,526	50%	4.698	44.947	80%
296	£33,791,903	50%	4.698	38.526	1%

297	£30,718,895	50%	4.698	38.526	10%
298	£27,304,443	50%	4.698	38.526	20%
299	£23,889,991	50%	4.698	38.526	30%
300	£6,817,729	50%	4.698	38.526	80%
301	£33,728,498	50%	4.18	64.21	1%
302	£30,661,255	50%	4.18	64.21	10%
303	£27,253,207	50%	4.18	64.21	20%
304	£23,845,159	50%	4.18	64.21	30%
305	£6,804,920	50%	4.18	64.21	80%
306	£33,744,350	50%	4.18	57.789	1%
307	£30,675,666	50%	4.18	57.789	10%
308	£27,266,017	50%	4.18	57.789	20%
309	£23,856,368	50%	4.18	57.789	30%
310	£6,808,122	50%	4.18	57.789	80%
311	£33,760,202	50%	4.18	51.368	1%
312	£30,690,076	50%	4.18	51.368	10%
313	£27,278,826	50%	4.18	51.368	20%
314	£23,867,576	50%	4.18	51.368	30%
315	£6,811,324	50%	4.18	51.368	80%
316	£33,776,053	50%	4.18	44.947	1%
317	£30,704,487	50%	4.18	44.947	10%
318	£27,291,636	50%	4.18	44.947	20%
319	£23,878,784	50%	4.18	44.947	30%
320	£6,814,527	50%	4.18	44.947	80%
321	£33,791,905	50%	4.18	38.526	1%
322	£30,718,898	50%	4.18	38.526	10%
323	£27,304,445	50%	4.18	38.526	20%
324	£23,889,992	50%	4.18	38.526	30%
325	£6,817,729	50%	4.18	38.526	80%
326	£33,728,501	50%	3.654	64.21	1%
327	£30,661,258	50%	3.654	64.21	10%
328	£27,253,209	50%	3.654	64.21	20%
329	£23,845,161	50%	3.654	64.21	30%
330	£6,804,920	50%	3.654	64.21	80%
331	£33,744,353	50%	3.654	57.789	1%
332	£30,675,668	50%	3.654	57.789	10%
333	£27,266,019	50%	3.654	57.789	20%
334	£23,856,369	50%	3.654	57.789	30%
335	£6,808,123	50%	3.654	57.789	80%
336	£33,760,204	50%	3.654	51.368	1%
337	£30,690,079	50%	3.654	51.368	10%
338	£27,278,828	50%	3.654	51.368	20%
339	£23,867,578	50%	3.654	51.368	30%

340	£6,811,325	50%	3.654	51.368	80%
341	£33,776,056	50%	3.654	44.947	1%
342	£30,704,489	50%	3.654	44.947	10%
343	£27,291,638	50%	3.654	44.947	20%
344	£23,878,786	50%	3.654	44.947	30%
345	£6,814,527	50%	3.654	44.947	80%
346	£33,791,908	50%	3.654	38.526	1%
347	£30,718,900	50%	3.654	38.526	10%
348	£27,304,447	50%	3.654	38.526	20%
349	£23,889,994	50%	3.654	38.526	30%
350	£6,817,730	50%	3.654	38.526	80%
351	£33,728,503	50%	3.132	64.21	1%
352	£30,661,260	50%	3.132	64.21	10%
353	£27,253,211	50%	3.132	64.21	20%
354	£23,845,163	50%	3.132	64.21	30%
355	£6,804,921	50%	3.132	64.21	80%
356	£33,744,355	50%	3.132	57.789	1%
357	£30,675,671	50%	3.132	57.789	10%
358	£27,266,021	50%	3.132	57.789	20%
359	£23,856,371	50%	3.132	57.789	30%
360	£6,808,123	50%	3.132	57.789	80%
361	£33,760,207	50%	3.132	51.368	1%
362	£30,690,081	50%	3.132	51.368	10%
363	£27,278,830	50%	3.132	51.368	20%
364	£23,867,580	50%	3.132	51.368	30%
365	£6,811,325	50%	3.132	51.368	80%
366	£33,776,059	50%	3.132	44.947	1%
367	£30,704,492	50%	3.132	44.947	10%
368	£27,291,640	50%	3.132	44.947	20%
369	£23,878,788	50%	3.132	44.947	30%
370	£6,814,528	50%	3.132	44.947	80%
371	£33,791,910	50%	3.132	38.526	1%
372	£30,718,902	50%	3.132	38.526	10%
373	£27,304,449	50%	3.132	38.526	20%
374	£23,889,996	50%	3.132	38.526	30%
375	£6,817,730	50%	3.132	38.526	80%
376	£33,728,493	51%	5.22	64.21	1%
377	£30,661,251	51%	5.22	64.21	10%
378	£27,253,203	51%	5.22	64.21	20%
379	£23,845,156	51%	5.22	64.21	30%
380	£6,804,919	51%	5.22	64.21	80%
381	£33,744,345	51%	5.22	57.789	1%
382	£30,675,661	51%	5.22	57.789	10%

383	£27,266,013	51%	5.22	57.789	20%
384	£23,856,364	51%	5.22	57.789	30%
385	£6,808,121	51%	5.22	57.789	80%
386	£33,760,197	51%	5.22	51.368	1%
387	£30,690,072	51%	5.22	51.368	10%
388	£27,278,822	51%	5.22	51.368	20%
389	£23,867,572	51%	5.22	51.368	30%
390	£6,811,323	51%	5.22	51.368	80%
391	£33,776,048	51%	5.22	44.947	1%
392	£30,704,482	51%	5.22	44.947	10%
393	£27,291,631	51%	5.22	44.947	20%
394	£23,878,781	51%	5.22	44.947	30%
395	£6,814,526	51%	5.22	44.947	80%
396	£33,791,900	51%	5.22	38.526	1%
397	£30,718,893	51%	5.22	38.526	10%
398	£27,304,441	51%	5.22	38.526	20%
399	£23,889,989	51%	5.22	38.526	30%
400	£6,817,728	51%	5.22	38.526	80%
401	£33,728,496	51%	4.698	64.21	1%
402	£30,661,253	51%	4.698	64.21	10%
403	£27,253,205	51%	4.698	64.21	20%
404	£23,845,158	51%	4.698	64.21	30%
405	£6,804,919	51%	4.698	64.21	80%
406	£33,744,347	51%	4.698	57.789	1%
407	£30,675,663	51%	4.698	57.789	10%
408	£27,266,015	51%	4.698	57.789	20%
409	£23,856,366	51%	4.698	57.789	30%
410	£6,808,122	51%	4.698	57.789	80%
411	£33,760,199	51%	4.698	51.368	1%
412	£30,690,074	51%	4.698	51.368	10%
413	£27,278,824	51%	4.698	51.368	20%
414	£23,867,574	51%	4.698	51.368	30%
415	£6,811,324	51%	4.698	51.368	80%
416	£33,776,051	51%	4.698	44.947	1%
417	£30,704,485	51%	4.698	44.947	10%
418	£27,291,634	51%	4.698	44.947	20%
419	£23,878,782	51%	4.698	44.947	30%
420	£6,814,526	51%	4.698	44.947	80%
421	£33,791,903	51%	4.698	38.526	1%
422	£30,718,895	51%	4.698	38.526	10%
423	£27,304,443	51%	4.698	38.526	20%
424	£23,889,991	51%	4.698	38.526	30%
425	£6,817,729	51%	4.698	38.526	80%

426	£33,728,498	51%	4.18	64.21	1%
427	£30,661,255	51%	4.18	64.21	10%
428	£27,253,207	51%	4.18	64.21	20%
429	£23,845,159	51%	4.18	64.21	30%
430	£6,804,920	51%	4.18	64.21	80%
431	£33,744,350	51%	4.18	57.789	1%
432	£30,675,666	51%	4.18	57.789	10%
433	£27,266,017	51%	4.18	57.789	20%
434	£23,856,368	51%	4.18	57.789	30%
435	£6,808,122	51%	4.18	57.789	80%
436	£33,760,202	51%	4.18	51.368	1%
437	£30,690,076	51%	4.18	51.368	10%
438	£27,278,826	51%	4.18	51.368	20%
439	£23,867,576	51%	4.18	51.368	30%
440	£6,811,324	51%	4.18	51.368	80%
441	£33,776,053	51%	4.18	44.947	1%
442	£30,704,487	51%	4.18	44.947	10%
443	£27,291,636	51%	4.18	44.947	20%
444	£23,878,784	51%	4.18	44.947	30%
445	£6,814,527	51%	4.18	44.947	80%
446	£33,791,905	51%	4.18	38.526	1%
447	£30,718,898	51%	4.18	38.526	10%
448	£27,304,445	51%	4.18	38.526	20%
449	£23,889,992	51%	4.18	38.526	30%
450	£6,817,729	51%	4.18	38.526	80%
451	£33,728,501	51%	3.654	64.21	1%
452	£30,661,258	51%	3.654	64.21	10%
453	£27,253,209	51%	3.654	64.21	20%
454	£23,845,161	51%	3.654	64.21	30%
455	£6,804,920	51%	3.654	64.21	80%
456	£33,744,353	51%	3.654	57.789	1%
457	£30,675,668	51%	3.654	57.789	10%
458	£27,266,019	51%	3.654	57.789	20%
459	£23,856,369	51%	3.654	57.789	30%
460	£6,808,123	51%	3.654	57.789	80%
461	£33,760,204	51%	3.654	51.368	1%
462	£30,690,079	51%	3.654	51.368	10%
463	£27,278,828	51%	3.654	51.368	20%
464	£23,867,578	51%	3.654	51.368	30%
465	£6,811,325	51%	3.654	51.368	80%
466	£33,776,056	51%	3.654	44.947	1%
467	£30,704,489	51%	3.654	44.947	10%
468	£27,291,638	51%	3.654	44.947	20%

469	£23,878,786	51%	3.654	44.947	30%
470	£6,814,527	51%	3.654	44.947	80%
471	£33,791,908	51%	3.654	38.526	1%
472	£30,718,900	51%	3.654	38.526	10%
473	£27,304,447	51%	3.654	38.526	20%
474	£23,889,994	51%	3.654	38.526	30%
475	£6,817,730	51%	3.654	38.526	80%
476	£33,728,503	51%	3.132	64.21	1%
477	£30,661,260	51%	3.132	64.21	10%
478	£27,253,211	51%	3.132	64.21	20%
479	£23,845,163	51%	3.132	64.21	30%
480	£6,804,921	51%	3.132	64.21	80%
481	£33,744,355	51%	3.132	57.789	1%
482	£30,675,671	51%	3.132	57.789	10%
483	£27,266,021	51%	3.132	57.789	20%
484	£23,856,371	51%	3.132	57.789	30%
485	£6,808,123	51%	3.132	57.789	80%
486	£33,760,207	51%	3.132	51.368	1%
487	£30,690,081	51%	3.132	51.368	10%
488	£27,278,830	51%	3.132	51.368	20%
489	£23,867,580	51%	3.132	51.368	30%
490	£6,811,325	51%	3.132	51.368	80%
491	£33,776,059	51%	3.132	44.947	1%
492	£30,704,492	51%	3.132	44.947	10%
493	£27,291,640	51%	3.132	44.947	20%
494	£23,878,788	51%	3.132	44.947	30%
495	£6,814,528	51%	3.132	44.947	80%
496	£33,791,910	51%	3.132	38.526	1%
497	£30,718,902	51%	3.132	38.526	10%
498	£27,304,449	51%	3.132	38.526	20%
499	£23,889,996	51%	3.132	38.526	30%
500	£6,817,730	51%	3.132	38.526	80%
501	£33,728,493	80%	5.22	64.21	1%
502	£30,661,251	80%	5.22	64.21	10%
503	£27,253,203	80%	5.22	64.21	20%
504	£23,845,156	80%	5.22	64.21	30%
505	£6,804,919	80%	5.22	64.21	80%
506	£33,744,345	80%	5.22	57.789	1%
507	£30,675,661	80%	5.22	57.789	10%
508	£27,266,013	80%	5.22	57.789	20%
509	£23,856,364	80%	5.22	57.789	30%
510	£6,808,121	80%	5.22	57.789	80%
511	£33,760,197	80%	5.22	51.368	1%

512	£30,690,072	80%	5.22	51.368	10%
513	£27,278,822	80%	5.22	51.368	20%
514	£23,867,572	80%	5.22	51.368	30%
515	£6,811,323	80%	5.22	51.368	80%
516	£33,776,048	80%	5.22	44.947	1%
517	£30,704,482	80%	5.22	44.947	10%
518	£27,291,631	80%	5.22	44.947	20%
519	£23,878,781	80%	5.22	44.947	30%
520	£6,814,526	80%	5.22	44.947	80%
521	£33,791,900	80%	5.22	38.526	1%
522	£30,718,893	80%	5.22	38.526	10%
523	£27,304,441	80%	5.22	38.526	20%
524	£23,889,989	80%	5.22	38.526	30%
525	£6,817,728	80%	5.22	38.526	80%
526	£33,728,496	80%	4.698	64.21	1%
527	£30,661,253	80%	4.698	64.21	10%
528	£27,253,205	80%	4.698	64.21	20%
529	£23,845,158	80%	4.698	64.21	30%
530	£6,804,919	80%	4.698	64.21	80%
531	£33,744,347	80%	4.698	57.789	1%
532	£30,675,663	80%	4.698	57.789	10%
533	£27,266,015	80%	4.698	57.789	20%
534	£23,856,366	80%	4.698	57.789	30%
535	£6,808,122	80%	4.698	57.789	80%
536	£33,760,199	80%	4.698	51.368	1%
537	£30,690,074	80%	4.698	51.368	10%
538	£27,278,824	80%	4.698	51.368	20%
539	£23,867,574	80%	4.698	51.368	30%
540	£6,811,324	80%	4.698	51.368	80%
541	£33,776,051	80%	4.698	44.947	1%
542	£30,704,485	80%	4.698	44.947	10%
543	£27,291,634	80%	4.698	44.947	20%
544	£23,878,782	80%	4.698	44.947	30%
545	£6,814,526	80%	4.698	44.947	80%
546	£33,791,903	80%	4.698	38.526	1%
547	£30,718,895	80%	4.698	38.526	10%
548	£27,304,443	80%	4.698	38.526	20%
549	£23,889,991	80%	4.698	38.526	30%
550	£6,817,729	80%	4.698	38.526	80%
551	£33,728,498	80%	4.18	64.21	1%
552	£30,661,255	80%	4.18	64.21	10%
553	£27,253,207	80%	4.18	64.21	20%
554	£23,845,159	80%	4.18	64.21	30%

555	£6,804,920	80%	4.18	64.21	80%
556	£33,744,350	80%	4.18	57.789	1%
557	£30,675,666	80%	4.18	57.789	10%
558	£27,266,017	80%	4.18	57.789	20%
559	£23,856,368	80%	4.18	57.789	30%
560	£6,808,122	80%	4.18	57.789	80%
561	£33,760,202	80%	4.18	51.368	1%
562	£30,690,076	80%	4.18	51.368	10%
563	£27,278,826	80%	4.18	51.368	20%
564	£23,867,576	80%	4.18	51.368	30%
565	£6,811,324	80%	4.18	51.368	80%
566	£33,776,053	80%	4.18	44.947	1%
567	£30,704,487	80%	4.18	44.947	10%
568	£27,291,636	80%	4.18	44.947	20%
569	£23,878,784	80%	4.18	44.947	30%
570	£6,814,527	80%	4.18	44.947	80%
571	£33,791,905	80%	4.18	38.526	1%
572	£30,718,898	80%	4.18	38.526	10%
573	£27,304,445	80%	4.18	38.526	20%
574	£23,889,992	80%	4.18	38.526	30%
575	£6,817,729	80%	4.18	38.526	80%
576	£33,728,501	80%	3.654	64.21	1%
577	£30,661,258	80%	3.654	64.21	10%
578	£27,253,209	80%	3.654	64.21	20%
579	£23,845,161	80%	3.654	64.21	30%
580	£6,804,920	80%	3.654	64.21	80%
581	£33,744,353	80%	3.654	57.789	1%
582	£30,675,668	80%	3.654	57.789	10%
583	£27,266,019	80%	3.654	57.789	20%
584	£23,856,369	80%	3.654	57.789	30%
585	£6,808,123	80%	3.654	57.789	80%
586	£33,760,204	80%	3.654	51.368	1%
587	£30,690,079	80%	3.654	51.368	10%
588	£27,278,828	80%	3.654	51.368	20%
589	£23,867,578	80%	3.654	51.368	30%
590	£6,811,325	80%	3.654	51.368	80%
591	£33,776,056	80%	3.654	44.947	1%
592	£30,704,489	80%	3.654	44.947	10%
593	£27,291,638	80%	3.654	44.947	20%
594	£23,878,786	80%	3.654	44.947	30%
595	£6,814,527	80%	3.654	44.947	80%
596	£33,791,908	80%	3.654	38.526	1%
597	£30,718,900	80%	3.654	38.526	10%

598	£27,304,447	80%	3.654	38.526	20%
599	£23,889,994	80%	3.654	38.526	30%
600	£6,817,730	80%	3.654	38.526	80%
601	£33,728,503	80%	3.132	64.21	1%
602	£30,661,260	80%	3.132	64.21	10%
603	£27,253,211	80%	3.132	64.21	20%
604	£23,845,163	80%	3.132	64.21	30%
605	£6,804,921	80%	3.132	64.21	80%
606	£33,744,355	80%	3.132	57.789	1%
607	£30,675,671	80%	3.132	57.789	10%
608	£27,266,021	80%	3.132	57.789	20%
609	£23,856,371	80%	3.132	57.789	30%
610	£6,808,123	80%	3.132	57.789	80%
611	£33,760,207	80%	3.132	51.368	1%
612	£30,690,081	80%	3.132	51.368	10%
613	£27,278,830	80%	3.132	51.368	20%
614	£23,867,580	80%	3.132	51.368	30%
615	£6,811,325	80%	3.132	51.368	80%
616	£33,776,059	80%	3.132	44.947	1%
617	£30,704,492	80%	3.132	44.947	10%
618	£27,291,640	80%	3.132	44.947	20%
619	£23,878,788	80%	3.132	44.947	30%
620	£6,814,528	80%	3.132	44.947	80%
621	£33,791,910	80%	3.132	38.526	1%
622	£30,718,902	80%	3.132	38.526	10%
623	£27,304,449	80%	3.132	38.526	20%
624	£23,889,996	80%	3.132	38.526	30%
625	£6,817,730	80%	3.132	38.526	80%

Supplementary 6.1. Correlation analysis to understand the cause of the problem with improper waste management in the state.

Supplementary 6.1. Correlation analysis to understand the cause of the problem with improper waste management in the state in Excel.

Pearson Bivariate Correlation HIGH INCOME AREA

	Waste issues	*Corruption*	*If waste is collected efficiently, people will pay*	*People throw waste on street because they don't see govt waste collectors*	*Regular collection is the solution*	*How to solve the problem*	*waste Littering*	*Age*	*Communication Preference*	*Waste generation*
Waste issues	1									
Corruption	0.075943014	1								
If waste is collected efficiently, people will pay	0.188246363	0.15399104	1							
People throw waste on street because they don't see govt waste collectors	-0.06739119	0.30369649	0.199274294	1						
Regular collection is the solution	-0.16177417	0.27502334	0.299253877	0.347871672	1					
How to solve the problem	0.161457607	-0.1576024	0.030135251	-0.055934134	-0.16344	1				
waste Littering	0.182430042	-0.13704843	-0.11041418	-0.389343017	-0.2294	0.205276	1			
Age	0.012807704	0.00839355	-0.105518271	0.081009744	0.008553	0.013305	-0.09956	1		
Mode of communication	0.055944571	0.121343	-0.09255407	0.295835184	0.053588	0.165801	-0.10489	0.204704	1	
Waste generation	-0.00370574	-0.05029156	0.082964393	0.106317326	-0.11421	0.008427	-0.04692	-0.20562	-0.04542	1

Pearson Bivariate Correlation MIDDLE INCOME AREA

	Problem	*Corruption*	*If waste is collected efficiently, people will pay*	*People throw waste on street because they don't see govt waste collectors*	*Regular collection is the solution*	*How to solve the problem*	*waste Littering*	*Age*	*Communication Preference*	*Waste generation*
Problem	1									
Corruption	0.16443572	1								
If waste is collected efficiently, people will pay	-0.0311182	0.49959984	1							
People throw waste on street because they don't see govt waste collectors	0.09054397	0.68858285	0.820835615	1						
Regular collection is the solution	0.083627661	0.34426519	0.785553319	0.559713438	1					
How to solve the problem	-0.18002267	0.10109918	-0.014284257	-0.082468938	0.253359	1				
waste Littering	-0.05285164	0.02357023	-0.045291081	0.022541741	0.121716	-0.27334	1			
Age	-0.46340976	-0.21333333	-0.172938406	-0.114763808	-0.2582	0.309245	-0.14142	1		
Mode of communication	0.115935365	0.31022189	0.060714206	0.142848518	-0.16316	-0.36898	-0.48747	-0.09192	1	
Waste generation	-0.18883617	0.2610671	-0.218460616	0.02416214	-0.02174	0.338059	0.446619	0.378968	-0.21771	1

Pearson Bivariate Correlation LOW INCOME AREA

	Problem	Corruption	*If waste is collected efficiently, people will pay*	*People throw waste on street because they don't see govt waste collectors*	*Regular collection is the solution*	*How to solve the problem*	*waste Littering*	*Age*	*Communication Preference*	*Waste generation*
Problem	1									
Corruption	-0.09890241	1								
If waste is collected efficiently, people will pay	-0.02336652	0.3473107	1							
People throw waste on street because they don't see govt waste collectors	-0.21073295	0.42038803	0.537795956	1						
Regular collection is the solution	-0.15197889	0.20631018	0.184710434	0.295386009	1					
How to solve the problem	-0.16996338	0.18064158	0.014374511	0.117465157	0.187898	1				
waste Littering	-0.09322169	0.13518452	-0.093332956	-0.228903136	-0.05817	-0.06029	1			
Age	-0.02331011	0.10849128	0.192968208	0.114491113	-0.0223	0.033797	-0.05741	1		
Mode of communication	0.117160516	0.24545451	0.109447668	0.180662178	0.11512	0.07316	-0.21047	0.012111	1	
Waste generation	0.01510197	0.03101862	-0.073621792	0.035972013	-0.06405	0.018593	-0.03123	-0.04426	-0.1138	1

HOUSEHOLD SURVEY

Correlations

		WhatIsTheWasteProblemInTheStateHI	CorruptionReasonThereIsPoorMgtOfWasteHI	IfWasteCollectionIsEfficientPeopleWillPayHI	WasteLitteringBcosNoGovtWasteCollectionHI	RegularWasteCollectionIsSolutionHI	HowtoSolveWasteMgtProblemHI	DoYouSeeWastesOnTheRoadHI	WhatIsYourAgeHI	PreferedModeOfCommunicationHI	HowMuchWasteYouGenerateHI
WhatIsTheWasteProblemInTheStateHI	Pearson Correlation	1	.076	.188	-.067	-.162	.161	.182	.013	.056	-.004
	Sig. (2-tailed)		.487	.083	.538	.137	.138	.093	.907	.609	.973
	N	86	86	86	86	86	86	86	86	86	86
CorruptionReasonThereIsPoorMgtOfWasteHI	Pearson Correlation	.076	1	.154	.304**	.275*	-.158	-.137	.008	.121	-.050
	Sig. (2-tailed)	.487		.157	.004	.010	.147	.208	.939	.266	.646
	N	86	86	86	86	86	86	86	86	86	86
IfWasteCollectionIsEfficientPeopleWillPayHI	Pearson Correlation	.188	.154	1	.199	.299**	.030	-.110	-.106	-.093	.083
	Sig. (2-tailed)	.083	.157		.066	.005	.783	.312	.334	.397	.448
	N	86	86	86	86	86	86	86	86	86	86
WasteLitteringBcosNoGovtWasteCollectionHI	Pearson Correlation	-.067	.304**	.199	1	.348**	-.056	-.389**	.081	.296**	.106
	Sig. (2-tailed)	.538	.004	.066		.001	.609	.000	.458	.006	.330
	N	86	86	86	86	86	86	86	86	86	86
RegularWasteCollectionIsSolutionHI	Pearson Correlation	-.162	.275*	.299**	.348**	1	-.163	-.229*	.009	.054	-.114
	Sig. (2-tailed)	.137	.010	.005	.001		.133	.034	.938	.624	.295
	N	86	86	86	86	86	86	86	86	86	86
HowtoSolveWasteMgtProblemHI	Pearson Correlation	.161	-.158	.030	-.056	-.163	1	.205	.013	.166	.008
	Sig. (2-tailed)	.138	.147	.783	.609	.133		.058	.903	.127	.939
	N	86	86	86	86	86	86	86	86	86	86
DoYouSeeWastesOnTheRoadHI	Pearson Correlation	.182	-.137	-.110	-.389**	-.229*	.205	1	-.100	-.105	-.047
	Sig. (2-tailed)	.093	.208	.312	.000	.034	.058		.362	.336	.668
	N	86	86	86	86	86	86	86	86	86	86
WhatIsYourAgeHI	Pearson Correlation	.013	.008	-.106	.081	.009	.013	-.100	1	.205	-.206
	Sig. (2-tailed)	.907	.939	.334	.458	.938	.903	.362		.059	.058
	N	86	86	86	86	86	86	86	86	86	86
PreferedModeOfCommunicationHI	Pearson Correlation	.056	.121	-.093	.296**	.054	.166	-.105	.205	1	-.045
	Sig. (2-tailed)	.609	.266	.397	.006	.624	.127	.336	.059		.678
	N	86	86	86	86	86	86	86	86	86	86
HowMuchWasteYouGenerateHI	Pearson Correlation	-.004	-.050	.083	.106	-.114	.008	-.047	-.206	-.045	1
	Sig. (2-tailed)	.973	.646	.448	.330	.295	.939	.668	.058	.678	
	N	86	86	86	86	86	86	86	86	86	86

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Correlations

		WhatIsTheWasteProblemInTheStateMI	CorruptionReasonsThereIsPoorMgtOfWasteMI	IfWasteCollectionIsEfficientPeopleWillPayMI	WasteLitteringBcosNoGovtWasteCollectionMI	RegularWasteCollectionIsSolutionMI	HowtoSolveWasteMgtProblemMI	DoYouSeeWastesOnTheRoadMI	WhatIsYourAgeMI	PreferedModeOfCommunicationMI	HowMuchWasteYouGenerateMI
WhatIsTheWasteProblemInTheStateMI	Pearson Correlation	1	.164	-.031	.091	.084	-.180	-.053	-.463	.116	-.189
	Sig. (2-tailed)		.574	.916	.758	.776	.538	.858	.095	.693	.518
	N	14	14	14	14	14	14	14	14	14	14
CorruptionReasonsThereIsPoorMgtOfWasteMI	Pearson Correlation	.164	1	.500	.689**	.344	.101	.024	-.213	.310	.261
	Sig. (2-tailed)	.574		.069	.006	.228	.731	.936	.464	.280	.367
	N	14	14	14	14	14	14	14	14	14	14
IfWasteCollectionIsEfficientPeopleWillPayMI	Pearson Correlation	-.031	.500	1	.821**	.786**	-.014	-.045	-.173	.061	-.218
	Sig. (2-tailed)	.916	.069		.000	.001	.961	.878	.554	.837	.453
	N	14	14	14	14	14	14	14	14	14	14
WasteLitteringBcosNoGovtWasteCollectionMI	Pearson Correlation	.091	.689**	.821**	1	.560*	-.082	.023	-.115	.143	.024
	Sig. (2-tailed)	.758	.006	.000		.037	.779	.939	.696	.626	.935
	N	14	14	14	14	14	14	14	14	14	14
RegularWasteCollectionIsSolutionMI	Pearson Correlation	.084	.344	.786**	.560*	1	.253	.122	-.258	-.163	-.022
	Sig. (2-tailed)	.776	.228	.001	.037		.382	.679	.373	.577	.941
	N	14	14	14	14	14	14	14	14	14	14
HowtoSolveWasteMgtProblemMI	Pearson Correlation	-.180	.101	-.014	-.082	.253	1	-.273	.309	-.369	.338
	Sig. (2-tailed)	.538	.731	.961	.779	.382		.344	.282	.194	.237
	N	14	14	14	14	14	14	14	14	14	14
DoYouSeeWastesOnTheRoadMI	Pearson Correlation	-.053	.024	-.045	.023	.122	-.273	1	-.141	-.487	.447
	Sig. (2-tailed)	.858	.936	.878	.939	.679	.344		.630	.077	.109
	N	14	14	14	14	14	14	14	14	14	14
WhatIsYourAgeMI	Pearson Correlation	-.463	-.213	-.173	-.115	-.258	.309	-.141	1	-.092	.379
	Sig. (2-tailed)	.095	.464	.554	.696	.373	.282	.630		.755	.181
	N	14	14	14	14	14	14	14	14	14	14
PreferedModeOfCommunicationMI	Pearson Correlation	.116	.310	.061	.143	-.163	-.369	-.487	-.092	1	-.218
	Sig. (2-tailed)	.693	.280	.837	.626	.577	.194	.077	.755		.455
	N	14	14	14	14	14	14	14	14	14	14
HowMuchWasteYouGenerateMI	Pearson Correlation	-.189	.261	-.218	.024	-.022	.338	.447	.379	-.218	1
	Sig. (2-tailed)	.518	.367	.453	.935	.941	.237	.109	.181	.455	
	N	14	14	14	14	14	14	14	14	14	14

Correlations

		WhatIsTheWasteProblemInTheStateLI	CorruptionReasonsThereIsPoorMgtOfWasteLI	IfWasteCollectionIsEfficientPeopleWillPayLI	WasteLitteringBcosNoGovtWasteCollectionLI	RegularWasteCollectionIsSolutionLI	HowtoSolveWasteMgtProblemLI	DoYouSeeWastesOnTheRoadLI	WhatIsYourAgeLI	PreferedModeOfCommunicationLI	HowMuchWasteYouGenerateLI
WhatIsTheWasteProblemInTheStateLI	Pearson Correlation	1	-.099	-.023	-.211	-.152	-.170	-.093	-.023	.117	.015
	Sig. (2-tailed)		.368	.832	.053	.165	.120	.396	.832	.286	.891
	N	85	85	85	85	85	85	85	85	85	85
CorruptionReasonsThereIsPoorMgtOfWasteLI	Pearson Correlation	-.099	1	.347**	.420**	.206	.181	-.135	.108	.245*	.031
	Sig. (2-tailed)	.368		.001	.000	.058	.098	.217	.323	.024	.778
	N	85	85	85	85	85	85	85	85	85	85
IfWasteCollectionIsEfficientPeopleWillPayLI	Pearson Correlation	-.023	.347**	1	.538**	.185	.014	.093	.193	.109	-.074
	Sig. (2-tailed)	.832	.001		.000	.091	.896	.396	.077	.319	.503
	N	85	85	85	85	85	85	85	85	85	85
WasteLitteringBcosNoGovtWasteCollectionLI	Pearson Correlation	-.211	.420**	.538**	1	.295**	.117	-.229*	.114	.181	.036
	Sig. (2-tailed)	.053	.000	.000		.006	.284	.035	.297	.098	.744
	N	85	85	85	85	85	85	85	85	85	85
RegularWasteCollectionIsSolutionLI	Pearson Correlation	-.152	.206	.185	.295**	1	.188	-.058	-.022	.115	-.064
	Sig. (2-tailed)	.165	.058	.091	.006		.085	.597	.839	.294	.560
	N	85	85	85	85	85	85	85	85	85	85
HowtoSolveWasteMgtProblemLI	Pearson Correlation	-.170	.181	.014	.117	.188	1	-.060	.034	.073	.019
	Sig. (2-tailed)	.120	.098	.896	.284	.085		.584	.759	.506	.866
	N	85	85	85	85	85	85	85	85	85	85
DoYouSeeWastesOnTheRoadLI	Pearson Correlation	-.093	-.135	.093	-.229*	-.058	-.060	1	-.057	-.210	-.031
	Sig. (2-tailed)	.396	.217	.396	.035	.597	.584		.602	.053	.777
	N	85	85	85	85	85	85	85	85	85	85
WhatIsYourAgeLI	Pearson Correlation	-.023	.108	.193	.114	-.022	.034	-.057	1	.012	-.044
	Sig. (2-tailed)	.832	.323	.077	.297	.839	.759	.602		.912	.688
	N	85	85	85	85	85	85	85	85	85	85
PreferedModeOfCommunicationLI	Pearson Correlation	.117	.245*	.109	.181	.115	.073	-.210	.012	1	-.114
	Sig. (2-tailed)	.286	.024	.319	.098	.294	.506	.053	.912		.300
	N	85	85	85	85	85	85	85	85	85	85
HowMuchWasteYouGenerateLI	Pearson Correlation	.015	.031	-.074	.036	-.064	.019	-.031	-.044	-.114	1
	Sig. (2-tailed)	.891	.778	.503	.744	.560	.866	.777	.688	.300	
	N	85	85	85	85	85	85	85	85	85	85

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

B

BUSINESS SURVEY

Correlations

		WhatIsTheWasteProblemInTheStateHI	CorruptionReasonThereIsPoorMgtOfWasteHI	IfWasteCollectionIsEfficientPeopleWillPayHI	WasteLitteringBcosNoGovtWasteCollectionHI	RegularWasteCollectionIsSolutionHI	HowtoSolveWasteMgtProblemHI	DoYouSeeWastesOnTheRoadHI	WhatIsYourAgeHI	PreferedModeOfCommunicationHI	HowMuchWasteYouGenerateHI
WhatIsTheWasteProblemInTheStateHI	Pearson Correlation	1	-.150	-.089	-.068	.081	.024	.077	-.024	-.184	-.226
	Sig. (2-tailed)		.362	.589	.682	.622	.887	.640	.885	.262	.166
	N	39	39	39	39	39	38	39	39	39	39
CorruptionReasonThereIsPoorMgtOfWasteHI	Pearson Correlation	-.150	1	.166	.294*	.075	.113	.204	-.078	-.014	.129
	Sig. (2-tailed)	.362		.206	.023	.571	.499	.118	.554	.916	.326
	N	39	60	60	60	60	38	60	60	60	60
IfWasteCollectionIsEfficientPeopleWillPayHI	Pearson Correlation	-.089	.166	1	.075	-.083	.078	.021	-.195	-.001	-.066
	Sig. (2-tailed)	.589	.206		.569	.526	.642	.871	.136	.995	.614
	N	39	60	60	60	60	38	60	60	60	60
WasteLitteringBcosNoGovtWasteCollectionHI	Pearson Correlation	-.068	.294*	.075	1	.365**	-.012	.275*	.034	-.100	.086
	Sig. (2-tailed)	.682	.023	.569		.004	.941	.034	.798	.446	.514
	N	39	60	60	60	60	38	60	60	60	60
RegularWasteCollectionIsSolutionHI	Pearson Correlation	.081	.075	-.083	.365**	1	-.179	.000	.108	.083	.101
	Sig. (2-tailed)	.622	.571	.526	.004		.283	1.000	.413	.529	.443
	N	39	60	60	60	60	38	60	60	60	60
HowtoSolveWasteMgtProblemHI	Pearson Correlation	.024	.113	.078	-.012	-.179	1	-.054	.280	-.196	-.019
	Sig. (2-tailed)	.887	.499	.642	.941	.283		.747	.089	.239	.910
	N	38	38	38	38	38	38	38	38	38	38
DoYouSeeWastesOnTheRoadHI	Pearson Correlation	.077	.204	.021	.275*	.000	-.054	1	.109	-.247	.028
	Sig. (2-tailed)	.640	.118	.871	.034	1.000	.747		.406	.057	.829
	N	39	60	60	60	60	38	60	60	60	60
WhatIsYourAgeHI	Pearson Correlation	-.024	-.078	-.195	.034	.108	.280	.109	1	.073	.158
	Sig. (2-tailed)	.885	.554	.136	.798	.413	.089	.406		.577	.227
	N	39	60	60	60	60	38	60	60	60	60
PreferedModeOfCommunicationHI	Pearson Correlation	-.184	-.014	-.001	-.100	.083	-.196	-.247	.073	1	.056
	Sig. (2-tailed)	.262	.916	.995	.446	.529	.239	.057	.577		.671
	N	39	60	60	60	60	38	60	60	60	60
HowMuchWasteYouGenerateHI	Pearson Correlation	-.226	.129	-.066	.086	.101	-.019	.028	.158	.056	1
	Sig. (2-tailed)	.166	.326	.614	.514	.443	.910	.829	.227	.671	
	N	39	60	60	60	60	38	60	60	60	60

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Correlations

		WhatIsTheWasteProblemInTheStateMI	CorruptionReasonThereIsPoorMgtOfWasteMI	IfWasteCollectionIsEfficientPeopleWillPayMI	WasteLitteringBcosNoGovtWasteCollectionMI	RegularWasteCollectionIsSolutionMI	HowtoSolveWasteMgtProblemMI	DoYouSeeWastesOnTheRoadMI	WhatIsYourAgeMI	PreferedModeOfCommunicationMI	HowMuchWasteYouGenerateMI
WhatIsTheWasteProblemInTheStateMI	Pearson Correlation	1	.512	-.147	-.036	-.516	.586	-.329	-.044	.340	-.027
	Sig. (2-tailed)		.195	.729	.932	.191	.127	.426	.918	.410	.949
	N	8	8	8	8	8	8	8	8	8	8
CorruptionReasonThereIsPoorMgtOfWasteMI	Pearson Correlation	.512	1	.172	.284	.254	.431	-.396	.013	.297	-.098
	Sig. (2-tailed)	.195		.432	.189	.242	.286	.061	.953	.169	.656
	N	8	23	23	23	23	8	23	23	23	23
IfWasteCollectionIsEfficientPeopleWillPayMI	Pearson Correlation	-.147	.172	1	.492*	.611**	-.456	-.372	.091	.033	.134
	Sig. (2-tailed)	.729	.432		.017	.002	.257	.080	.679	.882	.541
	N	8	23	23	23	23	8	23	23	23	23
WasteLitteringBcosNoGovtWasteCollectionMI	Pearson Correlation	-.036	.284	.492*	1	.572**	.000	-.328	-.077	.098	.062
	Sig. (2-tailed)	.932	.189	.017		.004	1.000	.126	.728	.655	.779
	N	8	23	23	23	23	8	23	23	23	23
RegularWasteCollectionIsSolutionMI	Pearson Correlation	-.516	.254	.611**	.572**	1	-.378	-.181	-.263	.000	-.225
	Sig. (2-tailed)	.191	.242	.002	.004		.356	.408	.225	1.000	.301
	N	8	23	23	23	23	8	23	23	23	23
HowtoSolveWasteMgtProblemMI	Pearson Correlation	.586	.431	-.456	.000	-.378	1	.346	.072	.216	.405
	Sig. (2-tailed)	.127	.286	.257	1.000	.356		.401	.866	.608	.320
	N	8	8	8	8	8	8	8	8	8	8
DoYouSeeWastesOnTheRoadMI	Pearson Correlation	-.329	-.396	-.372	-.328	-.181	.346	1	-.056	-.093	-.031
	Sig. (2-tailed)	.426	.061	.080	.126	.408	.401		.801	.673	.888
	N	8	23	23	23	23	8	23	23	23	23
WhatIsYourAgeMI	Pearson Correlation	-.044	.013	.091	-.077	-.263	.072	-.056	1	.308	.585**
	Sig. (2-tailed)	.918	.953	.679	.728	.225	.866	.801		.152	.003
	N	8	23	23	23	23	8	23	23	23	23
PreferedModeOfCommunicationMI	Pearson Correlation	.340	.297	.033	.098	.000	.216	-.093	.308	1	.147
	Sig. (2-tailed)	.410	.169	.882	.655	1.000	.608	.673	.152		.502
	N	8	23	23	23	23	8	23	23	23	23
HowMuchWasteYouGenerateMI	Pearson Correlation	-.027	-.098	.134	.062	-.225	.405	-.031	.585**	.147	1
	Sig. (2-tailed)	.949	.656	.541	.779	.301	.320	.888	.003	.502	
	N	8	23	23	23	23	8	23	23	23	23

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Correlations

		WhatIsTheWasteProblemInTheStateLI	CorruptionReasonThereIsPoorMgtOfWasteLI	IfWasteCollectionIsEfficientPeopleWillPayLI	WasteLitteringBcosNoGovtWasteCollectionLI	RegularWasteCollectionIsSolutionLI	HowtoSolveWasteMgtProblemLI	DoYouSeeWastesOnTheRoadLI	WhatIsYourAgeLI	PreferedModeOfCommunicationLI	HowMuchWasteYouGenerateLI
hatIsTheWasteProblem nTheStateLI	Pearson Correlation	1	-.312	-.313	.118	-.277	-.178	.[a]	.454	-.181	-.330
	Sig. (2-tailed)		.239	.238	.665	.300	.510	.000	.077	.501	.211
	N	16	16	16	16	16	16	16	16	16	16
orruptionReasonThereI PoorMgtOfWasteLI	Pearson Correlation	-.312	1	.053	.177	.170	.386	.109	-.422**	.135	-.186
	Sig. (2-tailed)	.239		.753	.288	.307	.140	.513	.008	.418	.262
	N	16	38	38	38	38	16	38	38	38	38
WasteCollectionIsEfficie tPeopleWillPayLI	Pearson Correlation	-.313	.053	1	.389*	.379*	.117	.028	-.028	-.181	.160
	Sig. (2-tailed)	.238	.753		.016	.019	.667	.866	.866	.277	.339
	N	16	38	38	38	38	16	38	38	38	38
asteLitteringBcosNoGo WasteCollectionLI	Pearson Correlation	.118	.177	.389*	1	.362*	.085	.023	-.139	.143	-.271
	Sig. (2-tailed)	.665	.288	.016		.025	.754	.892	.406	.393	.100
	N	16	38	38	38	38	16	38	38	38	38
egularWasteCollectionI SolutionLI	Pearson Correlation	-.277	.170	.379*	.362*	1	.330	-.062	-.170	.223	.177
	Sig. (2-tailed)	.300	.307	.019	.025		.212	.710	.308	.178	.287
	N	16	38	38	38	38	16	38	38	38	38
lowtoSolveWasteMgtPro lemLI	Pearson Correlation	-.178	.386	.117	.085	.330	1	.[a]	-.018	.232	.063
	Sig. (2-tailed)	.510	.140	.667	.754	.212		.000	.946	.386	.818
	N	16	16	16	16	16	16	16	16	16	16
oYouSeeWastesOnThe oadLI	Pearson Correlation	.[a]	.109	.028	.023	-.062	.[a]	1	.121	.083	.109
	Sig. (2-tailed)	.000	.513	.866	.892	.710	.000		.469	.620	.514
	N	16	38	38	38	38	16	38	38	38	38
hatIsYourAgeLI	Pearson Correlation	.454	-.422**	-.028	-.139	-.170	-.018	.121	1	-.345*	.190
	Sig. (2-tailed)	.077	.008	.866	.406	.308	.946	.469		.034	.253
	N	16	38	38	38	38	16	38	38	38	38
referedModeOfCommun ationLI	Pearson Correlation	-.181	.135	-.181	.143	.223	.232	.083	-.345*	1	-.086
	Sig. (2-tailed)	.501	.418	.277	.393	.178	.386	.620	.034		.606
	N	16	38	38	38	38	16	38	38	38	38
lowMuchWasteYouGene ateLI	Pearson Correlation	-.330	-.186	.160	-.271	.177	.063	.109	.190	-.086	1
	Sig. (2-tailed)	.211	.262	.339	.100	.287	.818	.514	.253	.606	
	N	16	38	38	38	38	16	38	38	38	38

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

a. Cannot be computed because at least one of the variables is constant.