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**Olayinka-Olagunju, Josephine Omowumi**

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# FROM ELECTRONIC WASTE TO SUSTAINABLE LIVELIHOOD FOR THE URBAN POOR IN NIGERIA: A STUDY OF LAGOS

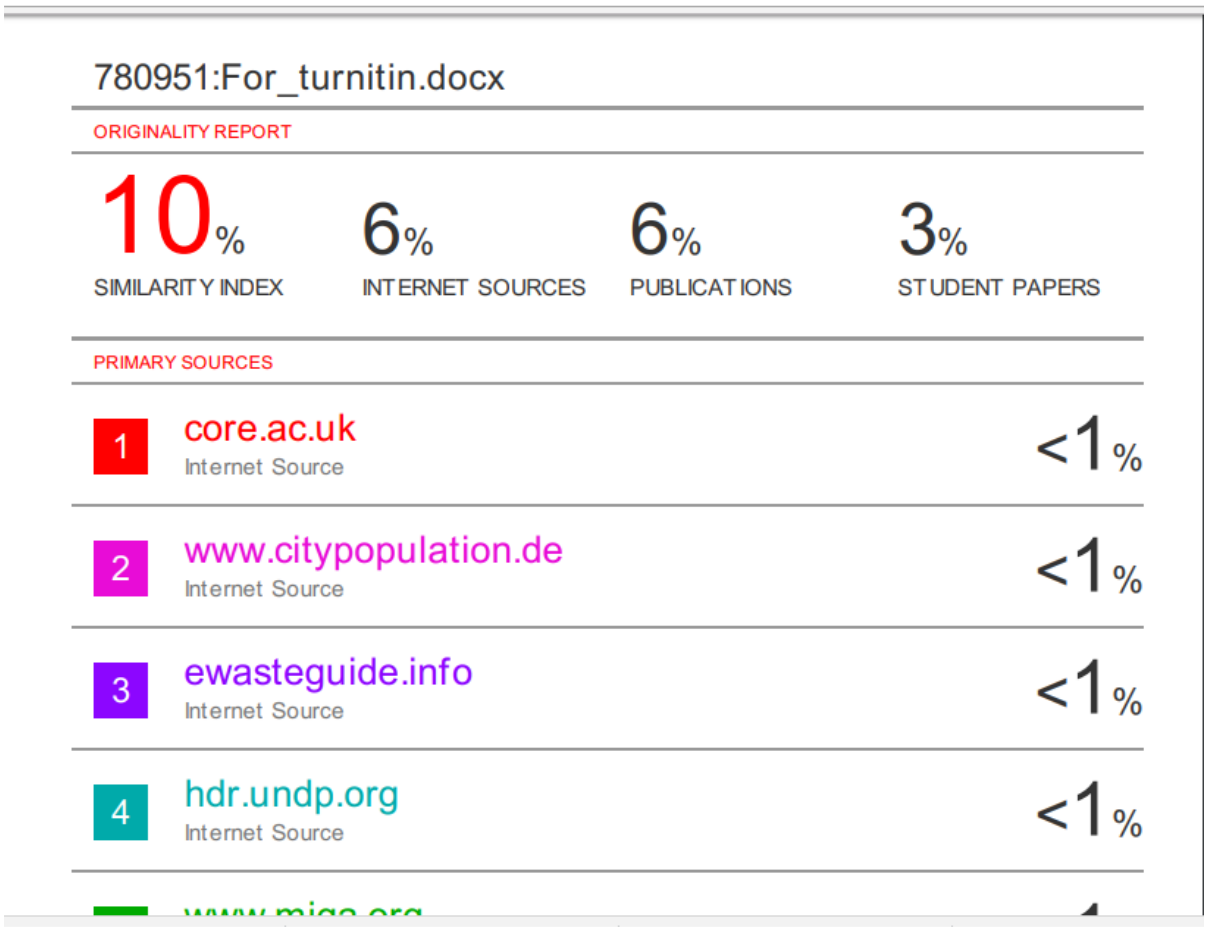
**JOSEPHINE OMOWUMI OLAYINKA-OLAGUNJU**

A thesis submitted to the Faculty of Science, University of the Witwatersrand, Johannesburg, in fulfilment of the requirements for the degree of Doctor of Philosophy Geography and Environmental Studies

**SUPERVISOR: PROF. MULALA D. SIMATELE**

**2018**

## DECLARATION 1-PLAGIARISM



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## DECLARATION 2

I, Josephine Omowumi Olayinka-Olagunju, declare that this thesis is my own, unaided work. It is being submitted for the Degree of Doctor of Philosophy at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.



_____

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## ABSTRACT

E-waste is a relatively new phenomenon that is of a growing concern in countries of the Global South. Rising population and rapid improvement in technology have resulted in increasing demand for new and old electrical and electronic appliances, speeding the generation of e-waste. This study investigates the challenges of e-waste management in the city of Lagos with the particular interest in the institutional and legislative frameworks that exist in its management and the different areas in which e-waste scavenging can contribute to sustainable livelihoods of the urban poor. Using desk study review and field-based data collected in eight study sites: Alaba international electronic market, Alakija scrap site, Ikeja computer market, Abule-Egba dumpsite, Olusosun landfill, Solous MRF, Owode-Onirin and Westminster market. The study found that Lagos State has detailed legislative and policy frameworks which can be effectively used to manage e-waste but it is hindered by poor implementation, enforcement and monitoring which is due to a weak institutional framework. Other factors such as financial, lack of space for storage and landfills, behaviour and lack of awareness, etc., also hinder the management. The highest stakeholders observed in e-waste management are from the informal sectors but recovery methods used in these sectors are crude and dangerous. It was observed that over 90% of the e-waste collectors were able to provide a sustainable living for their families while over 50% were able to as save and invest. In addition, soil samples were collected during the dry and wet seasons from four of the study sites. The physical, chemical and trace/heavy metals parameters were examined. The research found that the soil pH from two locations was lower than the stipulated standard which makes the soils acidic but all the chemical parameters were within the required limits. However, from the heavy metal parameters, Fe, Zn, Pb and Mn were found to be higher than the regulatory limits. The pollution load index of Cu and Cd were greater than 1 in two sites and the highest contamination factors of 6.09 for Pb was found at Owode-Onirin. It can, therefore, be argued that: (a) until the e-waste informal sector is integrated into the formal sector, e-waste collectors may not be socially recognised; (b) the heavy metal concentrations, pollution load index, contamination factors of soils and recycling activities will keep affecting the environment and may lead to severe health threat.

## DEDICATION

This thesis is dedicated to my late father, Pa Fredrick M. Orilogbon who ensured all his girls' children are educated. To my late sister Mrs Abiola E. Adedeji (nee Orilogbon) for helping me fulfil my academic dreams and providing financial support for my study when you were here.

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## LIST OF ACRONYMS

UNEP: United Nations Environmental Programme

UN: United Nations

CED: Centre for Environment and Development

EoL: End of Life

OEMs: Original Equipment Manufacturers

E-waste: Electronic waste

WEEE: Waste Electrical and Electronic Equipment

DEFRA: Department for Environment Food and Rural Affairs

EPA: Environmental Protection Agency

EU: European Union

EPR: Extended Producer Responsibility

LAWMA: Lagos Sate Waste Management Authority

LASEPA: Lagos State Environmental Protection Agency

NESREA: National Environmental Standards and Regulatory Enforcement Agency

MoE: Ministry of Environment

MoEF: Ministry of Environment and Forest

(LATS): Landfill Allowance Trading Scheme

ICT: Information and telecommunication technology

EEE: Electrical Electronic Equipment

PBCs: Polychlorinated Biphenyls

BFRs: Brominated Flame Retardants

RoHS: Restriction of Hazardous Substances

SSA: Sub-Saharan Africa

PSP: Private sector participation

BAN: Basel Action Network

OECD: Organisation for Economic Co-operation Development

# CHAPTER 1

# FRAMES OF REFERENCE

## 1.1 Introduction

Municipal solid waste management continues to be one of the major environmental challenges faced by cities throughout the world. Ezeigwe (1995) is of the view that municipal solid waste management has three major features which are: storage; collection and transportation; and treatment and disposal. The most recent global municipal solid waste generation is approximately estimated at 1.3 billion tonnes per year and the volume has been projected to double by 2050 to about 2.2 billion tonnes per year (World Bank, 2017; Gardner, 2012). The problems of solid waste management are further compounded by rapid urbanisation and population growth, weakness in institutional and policy frameworks which further reduces the resources of the cities because it will over stretch the resources of the cities (Okot-Okumu, 2015; Rajesh *et al*., 2014; Agamuthu*et al*., 2008). Hadland (2008) argues that the wave of urbanisation is a global phenomenon, leading to the growth of human population in urban areas. More so, it has been observed by UNEP (2013), and Cunningham and Cunningham (2010), that over 50% of the current global population lives in the cities resulting in land-use and infrastructural challenges. This proportion is projected to be more than 70% by 2030. It should however be noted that urbanisation has not only led to increase in the size of population living in the cities, but has also increased the landscape coverage, socio-economic and political growth (UN-Habitat, 2013). The UN-Habitat (2013), argues that the main reasons for rapid urbanisation in many cities rise in urban infrastructural development, improved standard of living, equity, social inclusion as well as environmental sustainability. These factors have increased the MSW management challenges caused by failed or weak institutional and policy framework and inadequate regulation and law enforcement.

In most sub-Saharan African countries, the problem of solid waste management is more pronounced due to lack of appropriate waste management strategies (Simelane and Mohee 2015). Besides, waste generation and management strategies also differ across African countries, from the variations in the level of economic development, standards of living, availability of funding, political stability, willingness and weakness in waste management regulations (CED, 2011). A significant issue in MSW management crisis in sub-Saharan Africa according to Taylor (2014) is institutional deficiencies which are due to poor infrastructures and planning which play vital roles in waste management. As a result of institutional problems, the volumes of solid waste generated in many urban areas in Africa are from illegal dumpsites or available space (Cointreau, 2006). Simatele and Etambakonga (2015) have argued that political instability in sub-Saharan Africa has increased civil conflicts and contributed significantly to the failing institutional and policy framework. This instability thus hinders the success and efficiency of the socio-economic services needed for the operation of solid waste management. On the other hand, fundamental issues such as unjust legal system, reduction in national economy, inadequate capable workforce, low economic restructuring agendas, absence of waste management organization structure, poor road construction, lack of waste resource plants and landfills have contributed to the difficulties

in the development of a proper and successful solid waste assembly and treatment scheme in sub-Saharan Africa (Kubanza and Simatele, 2015; Kassay, 2011).

The above mentioned problems are not foreign to urban Nigeria. This is because Nigeria as a nation has had problems of managing solid waste since her independence in 1960. According to the Nigerian Federal Ministry of Environment (2016), the recent annual solid waste generation volume in Nigeria is estimated at 63million/tonnes (0.45kg/capital/annum). The statistics is however overwhelming to the urban waste management agencies. The biggest problems of waste management in Nigeria are institutional weaknesses and lack of policies and legislation enforcement. However, Kofoworola (2007) argues that there are four major problems associated with municipal solid waste management in Lagos Nigeria. *Firstly*, improper collection systems, which are due to absence of facilities needed for collecting and managing waste in most local government areas of the state. These consequently culminate into defaced landscape, air pollution and road obstruction. *Secondly*, lack of adequate waste collection equipment like vehicles for gathering and moving waste which obstructs the beauty of the street as waste is illegally dumped around. *Thirdly*, indiscriminate dumping of solid waste; in Lagos, waste is dumped at any location that suit the inhabitants because there are no specific collection points. *Finally*, lack of continuous implementation of government policies on municipal solid waste management. All the above challenges need to be improved on as the population in Lagos keep increasing. Considering the poor and inadequate nature of solid waste management in Nigeria, this study will focus on the management electronic waste in Lagos, Nigeria.

### 1.2 Statement of problem

The problem of managing solid waste in urban Nigeria has further been compounded by the emergence of electronic waste (e-waste). According to Oteng-Ababio (2012 pg 2), e-waste can be defined as follows: 'electrical and electronic materials that enter the waste stream and are destined for reuse, resale, recycling, or disposal'. This includes: computer, television, mobile phones, washing machine, etc. Latifah (2009), Park and Heo (2002), and Ogawa (2000), observe that one of the rapidly expanding waste resource in Nigeria is e-waste and that it has various environmental and health impacts. The observed increase in e-waste could be attributed to increase in the demand of Information Technology equipment which has resulted to an unending development of new ones, but simultaneously, decreasing the item's lifecycle (Nnorom and Osibanjo, 2007; Odeyingbo, 2011). The rapid demand for electrical and electronic devices in Nigeria has resulted to the growing e-waste volume generation.

A survey by E-waste Africa Project, shows that the generation of e-waste in Nigeria is extremely higher than what is generated in all other West African countries (Manhart *et al.*, 2011). Previous studies have reported that Nigeria receives most of the largest e-waste shipment of 1.2 million/tonnes in Africa and thus making it by far the highest generation of e-waste in West African (Greenpeace International, 2005; Toxic Links India, 2007; Basel Action Network, 2011). In addition, more than 500,000 second-hand computers are shipped into the country yearly through the Lagos sea port. Moreover, only about 25% of the products are in good condition, whereas the 75% are scraps or irrepairable which are eventually dumped illegally and some are burnt openly in other to recover valuable materials (Basel Action Network, 2005).

Kidde *et al*., (2013) and Zhang and Forssberg (1997) are of the view that e-waste composition differs chemically and physically from other forms of municipal waste. It consists of large varieties of materials that are valuable and hazardous that must be handled with utmost caution during recycling in order to prevent environmental contaminations and health effects on human. According to Kidde *et al*., (2013), the toxic substances may be transported through landfill leachates into groundwater while combustion in an incinerator can emit noxious gases into the atmosphere. Hoffman (1992) observed that the chemical composition of e-waste is determined by on how old the item is. Furthermore, e-waste comprises mixture of metals, majorly copper (Cu), aluminium (Al) and iron (Fe) attached to various plastic and ceramics. A study by Berkhout (2004), estimates that a faulty computer with CRT monitor usually weighs 25kg with electronic components of 17.3%, metals 43.7%, plastic 23.3% and glass 15%. Notable valuable materials in e-waste are copper (Cu) and plantinium group, while the hazardous materials include lead (Pb), lithium (Li), mercury (Hg), cadmium (Cd), nickel (Ni), silver (Ag), polybrominated diphenyl ethers (PBDEs), polyvinyl chloride (PVC) and polychlorinated biphenyls (PCBs) (Robinson, 2009; Puckett and Smith, 2002). These materials are known as the highest sources of environmental pollution in Lagos whose management is unfortunately a major challenge.

In the context of Nigeria, e-waste recycling activities are carried out widely by the informal sector (Ideho, 2012; Nzeadibe, 2009). The sector activities include collecting waste through pickers and middlemen across the states. Furthermore, some waste pickers also dismantle many of the e-waste to extract materials that are of economic values and many a times dump the invaluable ones in open dumps (Ogungbuyi, 2012; Basel convention, 2011). However, Simatele and Etambakonga (2015) and Wilson et al., (2006) observed that e-waste recycling is majorly done in the cities by the less privileged and relegated in the society whose major source of livelihood is waste collection. In addition, this group is actively controlled and dominated by young males who goes around the cities with push carts gathering unwanted and purchasing stored household electronic products (Basel Convention, 2011).

In view of the fact that e-waste generation is predominantly high in Lagos State, due the presence of sea ports, the city is now being confronted with this challenge of managing e-waste. In order to transform the current nature of e-waste in urban Nigeria (Lagos) into sustainable livelihoods, what policies should be put in place in order to effectively manage e-waste? However, it is important to note that e-waste can create sustainable livelihoods for the poor by upgrading the informal recycling sector through creation of formal recycling industries which will not only provide a safe environment for the workers but will also serve as a form of income generation for the poor. In addition, a take-back system can be set up which will be more convenient and attractive to consumers to return unused/unwanted electronic materials. More so, e-waste regulations and policies can be implemented and enforced by state waste institution mandated to manage e-waste. Therefore, this study sought to investigate the various ways in which e-waste can be transformed to contribute to sustainable livelihoods of the urban poor. This study's particular interest was to investigate the role of the institutional and policy frameworks within which e-waste can be effectively managed. Furthermore, the study also examined ***institutional challenges in the management of e-waste within the city of Lagos, Nigeria.***

### 1.3 Research questions

In view of the above observations, the following questions guided the research study.

i) What institutional, legal and Policy frameworks exist within which e-waste management can be pursued in Lagos?
ii) What are the institutional challenges that exist within the management of e-waste in Lagos State?
iii) What risks can heavy metals from e-waste recycling centres and dumpsites pose to human health and the environment?
iv) In what ways can e-waste recycling be transformed into sustainable livelihood of the urban poor?
v) What are the implications of the findings of this study in a wider context, particularly in sub-Saharan Africa?

### 1.4 Research Aims and Objectives

The study aimed to investigate the factors accounting for the present institutional challenges in e-waste management in Lagos and the ways in which the absorption of informal scavengers into the formal sector can improve their livelihoods. This aim was developed in order to explore the current challenges faced by the solid waste institutions in Lagos pertaining to e-waste management and the concurrent contribution e-waste makes towards household income for the urban poor in Lagos. In view of the aims, the objectives are as follows;

i. To establish the connections between institutional framework and sustainable and effective e-waste management;
ii. To create an inventory of institutional challenges in e-waste management in Lagos;
iii. To assess the contaminations and impacts of heavy metals in the soil and how it can affect the scavengers and the environment;
iv. To create an inventory of how e-waste can be a resource for sustainable livelihood to the urban poor;
v. To assess the effectiveness of e-waste management studies in sub-Saharan Arica.

### 1.5 Hypotheses

Ho (Null Hypothesis): That the mean concentrations of parameters in soils collected from the two seasons were similar.

H1 (Alternative hypothesis): That the mean concentrations of parameters in soils collected from the two seasons were not similar.

Ho (Null Hypothesis): That the mean concentrations of heavy metals detected in soil were similar in all study locations.

$H_1$ (Alternative hypothesis): That the mean concentrations of heavy metals detected in soils were not similar in all study locations.

### 1.6 Scope of Study

One of the significant environmental challenges confronting the Lagos waste authority is solid waste management. Ogungbuyi et al., (2012) have classified the MSW management challenges in Nigeria into four broad areas, namely: financial management, equipment management (poor collection, transportation and disposal), labour or staff management and institutional planning and management. Also, lack of awareness campaign to the public is another factor. According to Ogungbuyi et al. (2012), the poor waste collection problem in Nigeria is also apparent when travelling the length and breadth of its urban and rural areas, as loads of solid waste that cause air, water and land pollutions and other issues that are injurious to human health disfigure the urban scenery. Currently in Nigeria, Ayuba (2013) observes that the most common solid waste management practice involves comingling of waste items and disposing at selected dumpsites. This practice shows that waste is not sorted at collection points (Adekunle et al., 2011). The co-disposal of solid waste in open dumpsites across the city of Lagos is common. This attitude thus makes the people vulnerable to disease as well as resulting in open burning and discharge of accidental obstinate organic noxious waste.

In addition to solid waste management the challenges in Lagos, there has been an increase in the volumes of e-waste shipped into the country which eventually gets disposed of with other forms of municipal waste. Sthiannopkao and Wong (2013) reveal that Nigeria is the central depot for e-waste import into West Africa from Europe and Asia. Ogungbuyi et al., (2012) observe that the importation of used electronics into Nigeria in the last decade is at a problematic level because un-repairable e-waste is imported into the country for recycling purposes from many developed cities in the name of reuse. E-waste is generated majorly by three sectors in Nigeria, namely: individuals and small businesses; large businesses, institutions, and governments and; original equipment manufacturers (OEMs), which accounts for over 70% of the total e-waste (Ogungbuyi, 2012). Furthermore, the bulk of the unprocessed e-waste is disposed of to the landfills, and this is dangerous because the waste is hazardous (Gaidajis et al., 2010). Many business centres, printing companies, institutes/training schools, cyber cafes and most households in Nigeria use second-hand PCs and printers. More so, computer parts are also imported through the seaports, airports, as well as through donations from charities to organisations and educational institutions. However, data on the inflow of new computers and the e-waste generation of other local electrical appliances in Nigeria are scares (Ogungbuyi et al., 2012).

In Nigeria, a large segment of the urban population obtains their livelihood opportunities in the recovery and recycling of waste, an activity known as informal recycling (Nzeadibe and Iwuoha, 2008). Informal recycling refers to the waste recycling activities of scavengers or waste pickers, and others involved in the processing/ transformation and trade of materials recovered from waste (Wilson *et al.* 2006). The main sources of collected materials are household, dump sites, refurbishing stores, streets and importers. In urban areas, millions of the poor and less privileged residents make a living from collecting, recycling and disposal of solid waste hence informal

waste management sector is a value chain that can dully sustained by the government (Dias, 2012; Gutberlet, 2010; Medina, 2007). The waste pickers sell to scrap dealers or vendors. The informal sector is an important income source for large numbers of abandon and marginalised urban groups of all genders in Nigeria (Nzeadibe and Adama, 2015). Since co-disposal of solid waste is high in Lagos, many waste collectors have been able to provide for their families through street waste picking from high-density low-income areas.

Wilson (2007) have argued that waste collection is the major economic driver of the informal recycling sector in developing cities, and Medina (2006) is of the view that this sector has shown to be active in many of urban areas (Medina, 2006). Furthermore, (Ojeda-Benitez *et al.* 2002; Birkbeck, 1978) point out that the trash collecting is the most noticeable feature of a huge industrialised sector and waste collectors are possibly the most prominent component of developing countries' recycling activities. Presently the city of Lagos lacks a formal recycling programme and due to this, a large number of persons are involved in informal waste recovery and recycling which also serves as a livelihood source (Nzeadibe and Iwuoha, 2008). It should be noted that the informal sector also provides employments and means of support to mostly rural migrants who do not possess any special skills but come to the urban area in search of the imaginary greener pastures. It is however appropriate to note that in many Nigerian cities, waste collecting activities by the informal organisation has not been considered within the framework of solid waste management (SWM) (Afon 2007; Akiyode and Sojinu 2007; Kofoworola 2007). Thus, an important and significant livelihood activity in e-waste management is the informal waste management sector (Nzeadibe, 2015). Owusu (2007) suggests an alternative framework for understanding contemporary livelihood in urban areas the "Multiple Modes of Livelihood Approach" according to the author, it has antecedent in the household survival strategy and the informal sector literature. In addition, he supports the definition of a "livelihood system" as "the mix of individual and household strategies, developed over a given period of time that seeks to mobilize available resources and opportunities."

In a bid to reduce the dangers caused by the informal e-waste recycling sector in Nigeria, new treatment methods are needed to divert End of Life (EoL) e-waste from disposal with other forms of municipal waste. In order to achieve diversion of e-waste from the landfills or dumpsites, various approach must be considered. This approach must be based on economics, sustainability, eco-efficiency, available technology, and a realistic level of social support for the programme. This approach includes reuse, recycling and material recovery of EoL electronic products. According to Kang and Schoenung (2004), the major approaches of e-waste recycling are collecting method, sorting, recovery technologies, material recycling processes and disposal methods. Effective e-waste recycling can be increased if challenges such as politics, legislation and economics as well as societal and cultural behaviours are examined. Tanskanen (2013) is of the view that inadequate awareness recycling programme and its environmental impacts are major difficulty to e-waste recycling in Nigeria.

Enforcement of the existing regulations and policies of e-waste in Lagos can be used to solve the current challenges of e-waste in the city. Sinha-Khetriwalet al., (2009) observes that some countries (both developed and less developed) have adopted the extended producer responsibility (EPR) program in the past decade and have shown that it was successful. The EPR

policy is designed in a way that the producers will bear the cost of dealing with e-waste products and also motivate to reduce the value of the products. However, in the Nigerian National Environmental (Electrical/Electronic Sector) Regulations (NESREA) of 2010 and the recent e-waste policy draft of Lagos State, the EPR program is stated there for all electronic importer, exporters, manufacturers, retailer, assembler etc., as well as their responsibilities which include the take-back of end of life (EoL) electronic items. However, the national and state e-waste institution has failed in the enforcement of the EPR programme (Tanskanen 2013). Implementation of the EPR policy will indicate that the producers only pay for costs related to their products. Some of the challenges associated with the take-back EoL products are (i) In what ways can there be a balance between the producers and resource collectors concerning finances, set-ups, technical know-how etc.? (ii) In what way is the various business types managed by stakeholders from the industries (how active are the guiding principles? while manufacturing laws or guidelines are required for some specific companies); (iii) By what means are the obligation of stakeholders met? (Bhutta et al., 2011).

Institutional challenges remain a huge problem in Nigeria as many of the policies are adopted and formulated, but there is a lack of enforcement. It is therefore essential to examine the factors that are responsible for these problems and propose long-lasting solutions that will improve the management of e-waste in the city of Lagos due to its ever-growing population. However, the multiple modes of livelihood approach in the analysis of the e-waste resource collectors' survival strategy in the informal sector will be adopted. Because of this, the study attempts to establish that the informal sector can be sustainable for resource e-waste collectors. The study will suggest some enabling strategies for proper collection and recycling of e-waste as well as methods of implementation for a viable and sustainable e-waste disposal management. It will further contribute to the current body of knowledge on solid waste management with a particular focus on e-waste management and the transformation of the poor urban livelihoods.

### 1.7 Ethical Considerations

Ethical considerations are essential in many areas of a research process and also influence the decision of the researchers as to whether a particular field of study requires a specific moral code before the researcher goes to the study sites. Ethical guiding principles involve informed consent, access and acceptance, and confidentiality to the anonymity of participants. Flicker et al., (2007) are of the view that informed consent is sought from the participants by describing the reasons for the research, dangers or benefit of taking part, privacy, use of information and that they can withdraw from the study if they are no longer interested. Furthermore, Creswell (2003) suggests that researchers ought to respect participants and study sites and highlights the need to seek informed consent from participants. This study involved human subjects and data were collected through structured and semi-structured interviews, as well as through the use of survey questionnaires self-administered by the researcher (see Appendix 2-4). The participants involved in this study were drawn from the national and state waste institutions, chairpersons, e-waste collectors and dealers from the informal e-waste sector.

In the course of this study, participants' confidentiality is ensured, consent is informed, formality was maintained, and the study did not pose any harm or threat to the society. Also, the reasons for conducting the study were explained to the participants so that they can decide to participate

or not. The consent forms designed by the research were used, and participants were informed that they could withdraw from the research if they were not convinced about the study. Robson (1993) advised: "whenever possible, the investigator should inform all participants of the objectives of the investigation and all aspects of the research or intervention that might reasonably be expected to influence willingness to participate". The implication of this is that the rights of the participants are secure during data collection, they may participate in the study of their own volition, understand the purpose of the study, may ask the researcher any question or withdraw from the study without consequences. Permission to conduct this research in various dumpsites and e-waste markets was sought and granted by LAWMA. Furthermore, at each study site, permission was sought and allowed by chairpersons before the primary study was conducted and confidentiality was guaranteed in all the study sites. Before going into the field, ethics clearance was obtained from the University of the Witwatersrand to confirm that the study would be carried out ethically and the certificate is in Appendix 1. Only the researcher and the supervisor had access to the raw data from the field. At the completion of the study, data collected will be analysed and stored securely for confidentiality purposes.

### 1.8 Structure of the thesis

**Chapter one** of this thesis presents the frames of reference hence giving a brief theoretical background of the study, the problem statement, research questions, aims and objectives. In addition, the rationale of the study, the scope of the study is explained and the ethical considerations reflected on during the research are discussed in this chapter. The purpose of the **second chapter** is to review the various existing literature on solid waste management with a specific focus on e-waste management in a global, regional and local perspective. **Chapter three** provides a brief description of the study locations and in-depth methods of data collection on the existing regulation and policy framework, institutional challenges, sustainable livelihoods of the e-waste collectors and soil samples collected from four different study sites during the dry and wet seasons. **Chapter four** shows the empirical evidence obtained from policy and regulation document reviews, questionnaire survey and interviews conducted with some officials from the waste management institution, chairpersons and informal e-waste dealers and collectors. **Chapter five** presents the empirical findings analysis and discussions. The findings from this study are compared and contrasted with the Lagos State institutional challenges and the environmental and health implications of e-waste management. In **Chapter six**, the summary of the most critical findings which revolves around this study, the conclusions, recommendations and suggestions for future studies are presented.

# CHAPTER 2

# THEORETICAL CONSIDERATIONS AND LITERATURE REVIEW

## 2.1 Introduction

This chapter is dedicated to discussing the theoretical considerations and literature review of this study. It is critical to engage with literature to understand the historical and current discussions on issues surrounding solid waste management, mainly electronic waste (e-waste), within the context of developing countries. E-waste is a new phenomenon that is of growing concern in the field of solid waste management, primarily in the urban areas of developing countries. It is therefore essential to critically explore and identify the gaps that exist within the subject of solid waste management with a specific focus on e-waste. Thus, this chapter is divided into the following sub-sections: The first sub-section examines solid waste management in a global context. Sub-section two will look at waste management issues within a developing world context with emphasis on sub-Saharan Africa. Third sub-section will review some relevant studies on e-waste management in Nigeria, and the fourth sub-section will examine the research gaps in the field of e-waste management.

## 2.2 Contextualising Solid Waste Management: A Global Perspective

Solid waste management (SWM) is one of the significant environmental challenges faced by many cities in the world, particularly in the densely populated urban areas of the developing countries. The management of solid waste has been challenging due to the daily increase in the volume of waste generation, and this is attributed to rapid population growth, urbanization, industrial growth, globalization coupled with improving lifestyles (Ravindra, et al., 2015; Mohee and Bundhoo, 2015; Sharholy et al, 2007). Recent statistics show that the world's population is rapidly growing; in 2001, the world's population reached 6 billion, and it increased to 6.5 billion in 2005. According to the United Nation (2008), this number is expected to rise to over 9 billion by 2050. However, the increase in the world's population growth has led to an unprecedented urban growth in the past decades. Rapid urbanisation growth in many countries is due to industrialisation and globalisation. Previous studies have reported that in 2001, 46% of the global population resided in urban areas and 50% in 2008 (Latifah et al., 2009; UN World Urbanization Prospects, 2007). In the developed countries, 74% of its population resides in urban areas, while 44% of the people in developing countries live in urban areas. It should be noted that urbanisation is increasing at an alarming rate, particularly in developing countries. UNWUP (2007) argues that by 2050, 70% of the world population will be living in urban areas and most urban growth will occur in developing countries. These statistics shows that by 2050, only a few people from both industrialised and developing countries will be residing in the rural areas. However, Barredo et al., (2004), reveal that with the larger population of the world living in urban areas, there will be economic, social and environmental issues which will affect the people in such cities.

As the world population increases, UNEP (2005) and Singh et al. (2014) observe that MSW generation also continues to affect urban areas around the globe. Achankeng (2003) for example, argues that globalisation, industrialisation and rapid urbanisation have also been identified as playing a negative role in MSW management in African cities. These impacts include increased in

imports of goods and services from developed to developing countries which mostly results to change in lifestyle and consumption patterns that affect the waste sector directly or indirectly. Gardner (2017), for example, observes that globally, approximately 1.3 billion volume of solid waste is generated annually. This figure, shown by the World Bank (2012), is expected to double by 2025 due to population and urban growth. Furthermore, the volume of solid waste is projected to be more than twice in developing countries in the next two decades. This assertion, as observed by the World Bank (2012), is based on the fact that solid waste management in developing countries is abysmal due to lack of formulation and enforcement of legislation. However, the challenges of MSW in the developing nations can further be attributed to weak institutional and policy frameworks, lack of infrastructure, financial resources and management, and technical know-how at the local and national level (Simelane and Mohee 2015). These challenges prevent effective and efficient management of solid waste and also result in limited resources. Narayana (2009), Latifah et al., (2009) and Sharholy et al., (2008) are of the view that limited resources in solid waste management have contributed mainly to the small collection, transportation, and disposal of solid waste in many urban areas. These factors do not only affect solid waste management in developing countries but also in some developed nations (Hazra and Goel 2009; Sharholy et al., 2008).

Previous studies have shown the importance of solid waste management including waste collection, recycling, treatment and disposal in different cities in many developed and developing countries, e.g., London (White et al., 2012; Asase et al., 2009), Florida (Storm et al., 2004; An et al., 1999), Ontario (Asase et al., 2009, Mohareb et al., 2008) Beijing (Qu et al., 2009; Li et al., 2009; Xiao et al., 2007), Lagos (Ogwueleka, 2009; Kofoworola, 2007; Afon, 2007), Kumasi (Oteng-Ababio, 2010; Asase et al., 2009; Awortwi, 2004). However, it should be noted that comparison among these cities revealed that many cities in the developed countries have been able to manage solid waste successfully better than developing countries by adopting some specific strategies. In the United Kingdom (UK), for example, large volumes of solid waste have been diverted from its landfills, falling from 80% in 2001 to 49% in 2010 (DEFRA, 2015). More so, its recycling trend had also increased from 12% in 2001 to 39% in 2010. The statistics, however, was achieved by introducing the landfill tax (DEFRA, 2010). In addition to landfill tax, other strategies are the landfill allowance trading scheme (LATS), providing additional funding for local councils, meticulous enactment of the European Union (EU) directives and by targeting waste in some specific sectors like automobile, waste electrical and electronic equipment (WEEE) and packaging industries.

Furthermore, in the United States of America, the Environmental Protection Agency (EPA) observes that the volume of MSW generated per person per day has increased from 3.66 to 4.40 pounds between 1980 and 2016, an amount that is more than the global average of 2.6 pounds (Loki, 2016). In 2013, for example, the U.S. EPA estimates that 254 million tonnes of the MSW were generated in the U.S. However, there has since been an increase in the amount of waste recycled and composted in the U.S. The recycling rate has increased from less than 10% in 1980 to 34.3% in 2015, while landfill disposal rate also decreased from 89% to less than 54%. Besides, in 2013, it was observed that 87.2 million tonnes of solid waste materials were diverted from the United States' landfill through recycling and composting, thereby preventing the release of approximately 186 metric tonnes of carbon dioxide into the air (EPA, 2013).

The above strategies on MSW diversion from landfills, landfill tax, LATS etc., have in a way helped cities in developed countries to achieve their goals in solid waste management and also ensured that all laws associated to waste are successfully managed and legally enforced. Besides the strategies mentioned above, the design of adequate waste policy and regulatory frameworks, as well as supports from waste initiatives support organisations have also enabled these countries to manage solid waste effectively. In contrast, in developing countries, Latifah et al., (2009) and Moghadam et al., (2009) observe that MSW management difficulties include lack of adequate infrastructure, public health issues (Geng et al., 2009), and lack of policies and regulations enforcement (Guerrero et al., 2013). Other factors affecting developing countries include many failed systems, inadequate funding of waste department, insufficient collection vehicles and poor disposal strategies. Furthermore, Matete and Trois (2008) and Asase et al., (2009), observe that lack of environmental control systems and evaluation, are other factors affecting solid waste management in developing countries.

Many studies in the field of solid waste management have shown that in developing countries like China, economic development is responsible for the exceptional increase in the volume of its solid waste (Xue and Chen, 2007; World Bank, 2005; Dong et al., 2001). The assertion by these authors, however, is based on the assumption that no other country in the world has had such MSW quantities increase than China due to its growing population. From this point, it can be argued that the Chinese government has not put sustainable strategies in place that can be used to overcome the challenges associated with solid waste. In a bid to reduce the volume of MSW generation in China, Chen et al., (2010) observe that strategies such as regulations and policies have now been developed, the government has also increased its waste financial resources, local authorities have increased waste collection periods, there has been an increase in recycling rate, and waste treatment and disposal. However, Yuan et al., (2012) argue that China still has a lot to do with its SWM strategies when compared to developed countries.

Similarly, in India, Sharholy et al. (2008) observe that solid waste management is going through a severe phase in many of its urban areas due to lack of appropriate facilities needed for waste treatment and disposal. The lack of facilities coupled with the indiscriminate dumping of waste has resulted in adverse impact on the environment and human health. In India, the Ministry of Environment and Forest (MoEF) released regulation on the management and handling of solid waste (including collection, transportation, and disposal) in the year 2000 (Sharholy et al., 2008). It was also included that the ministry will monitor the implementation and enforcement of MSW laws. In spite of these laws and regulations, Siddiqui et al., (2006), Kansal (2002), and MoEF (2000) observe that most municipalities in Indian have not been very efficient in providing the desired level of service due to series of challenges.

However, Ekere et al., (2009) suggest that for developing countries to effectively manage its MSW challenges, the residents should be motivated to participate in environmental management. Clapp (2002), observes that the waste management practices where the generators of such waste are not participating in its cleaning process are known as waste distancing. Soltani et al., (2015) are of the view that participants' involvement in solid waste may lead to the expansion of management options, as well as increase their financial and human resources. Bani et al., (2009) further observe that lack of effective communication between the municipalities and stakeholders

may lead to serious conflicts. According to Achillas et al., (2013) the municipality can only build an effective waste management system, with the consideration of stakeholders' dialogues. The implication of this is that the communication between the stakeholders and the municipal waste authorities is necessary to boost solid waste management goals. Gurrero et al. (2013) reveal that the burden of solid waste in any city will be reduced if the authorities involved in its management work hand in hand with the relevant stakeholders. By so doing, the authority will be able to identify the factors responsible for the systems' failure. On the other hand, if the above suggestions are not considered, there will be an increase in indiscriminate disposal of waste in the environment as the residents may think the municipal authorities only have to manage the waste.

In spite of the adopted strategies and attempts to resolve MSW management problems, the world is now being confronted with a more hazardous type of solid waste, e-waste. E-waste is also known as waste electrical electronic equipment (WEEE) and in this study, both terms will be used interchangeably. Over the last two decades, advancement in technology, industrialisation coupled with improving lifestyles of people mainly in the urban areas has led to the increasing level of consumption and demand for electrical and electronic equipment (EEE) (Mundada et al., 2004). Information and telecommunication technology (ICT) is the primary source of e-waste, and it has grown significantly from industrialised countries through to the industrialising nations. UNEP (2009) and UN (2009) are of the view that globally, more electrical, electronic appliances are produced annually. These appliances have therefore contributed to the growing volumes of e-waste generation. The reason for this claim, according to Osibanjo and Nnorom (2008), is that the life cycle of electronic products has reduced due to rapid technological changes. Although the rapid growth of ICT in many urban areas give rise to improvement of computers, printers, cell phones etc., the lifetime of these products have gradually reduced and has led to an increase in the generation of old products (Oh et al., 2003). On the other hand, inadequate disposal of obsolete e-waste can impact the environment and human health negatively (Kang and Schoenung, 2004).

According to Puckett and Smith (2002), e-waste is of various forms and can be defined from different perspectives depending on the country. E-waste comprises a growing number of electronic devices ranging from large household devices such as refrigerators, air conditioners, cell phones, personal stereos, and consumer electronics to computers etc., that has been discarded by the users. The list of e-waste is limitless. In this study, the European Union (EU) classification from the EU WEEE directive shown in Table 2.1 will be used because it is the most widely accepted classification, and comprises of 10 categories (EU Directive 2002/96/EC). Ramesh et al., (2007) observe that globally, the manufacturing industries producing EEE is one of the fastest growing activities making e-waste a global concern to MSW managers. In 2014, the global volume of e-waste generated was approximately 41.8 million tonnes (Balde, 2014; Jiang et al., 2012). However, Yla-Mella et al., (2004) observe that the e-waste management challenge is not only due to its growing volumes but also its complexity. Kumar et al., (2005) argue that e-waste is complicated because its recovery and recycling methods are complex due to the variation of product designs, size changes, compatibility problems etc.

In addition to e-waste complexity, it is also made up of both toxic and valuable substances. Pinto (2008) observes that the toxic constituents are harmful to human health and the environment if not properly handled. Chatterjee (2012) reveals that the valuable materials are very economical

and can support livelihoods if it is sorted rightly. Chatterjee (2012), Wath et al., (2011) and Finlay and Liechti (2008) are of the opinion that the valuable materials contained in e-waste are ferrous materials (38%), non-ferrous metals (28%), plastic (19%), glass (4%), others include wood, rubber, ceramic, etc. (11%) and they make up to 95% of the total e-waste constituents by weight. However, Gao et al., (2004), observe that polychlorinated biphenyls (PCBs) connectors which consist of valuable metals like gold, silver, copper, and other precious metals like palladium, tantalum etc. make up to 3-5% of the total e-waste. Table 2.2 shows the possible hazardous materials in e-waste. The unsafe e-waste components which are of growing concern are the heavy metals like lead, mercury, cadmium, chromium (VI), halogenated substances (e.g., CFCs), polychlorinated biphenyls, plastics, and circuit boards that contain brominated flame retardants (BFRs). Other materials and elements that can be found in e-waste are arsenic, asbestos, nickel, and copper. DEFRA (2004), observes that these substances may act as a catalyst to increase the formation of dioxins during e-waste incineration.

**Table 2.1**. Categories of WEEE according to the EU WEEE Directive

| WEEE category | WEEE | Examples |
|---|---|---|
| 1 | Large Household Appliances | Refrigerator, microwaves, washing machine |
| 2 | Small Household Appliances | Coffee machine, vacuum cleaner, toaster |
| 3 | IT and telecommunications equipment | Computers, telephones, printers, facsimiles, photocopying machines |
| 4 | Consumer equipment | Radio, television sets, audio amplifier |
| 5 | Lighting equipment | Luminaries, discharged lamps |
| 6 | Electrical and electronic tools* | Drills, saws |
| 7 | Toys, leisure and sports equipment | Video games, electric trains or cars |
| 8 | Medical devices** | Radiotherapy equipment, cardiology |
| 9 | Monitoring and control instruments | Smoke detectors, heating regulators |
| 10 | Automatic dispensers | For hot drinks, solid products |

**Source**: Khetriwal *et al.*, (2007) and Antrekowitsch *et al.*, (2006)

*With the exception of large-scale stationary industrial tools;

**With the exception of implanted and infected products.

**Table 2.2** Possible hazardous substances in WEEE/E-waste components

| Component | Possible hazardous content(s) |
|---|---|
| Cooling | Ozone Depleting Substances (ODS) e.g. CFS CFCs, halons, methyl chloroform (1,1,1,-trichloroethane; MCF), carbon tetrachloride (CTC), hydrochlorofluorocarbons (HCFCs), and methyl bromide |
| Plastic | Phthalate plasticize, brominated flame retardant (BFR) |
| Insulation | Insulation ODS in foam, asbestos, refractory ceramic fibre |
| Glass | Lead, Mercury (if coated) |
| CRT | Lead, Antimony, Mercury, Phosphors |
| LCD | Mercury |
| Rubber | Phthalate plasticizer, BFR |
| Wiring/Electrical | Phthalate plasticizer, Lead, BFR |
| Circuit board | Lead, Beryllium, Antimony, BFR |
| Fluorescent lamp | Mercury, Phosphorus, Flame Retardants |
| Thermostat Mercury | Mercury |
| BFR-containing plastic | BFRs |
| Batteries | Lead, Lithium, Cadmium, Mercury |
| External electric cables | BFRs, plasticizers |
| Electrolyte capacitors (over L/D 25 mm) | Glycol, other unknown substances |

**Source**: Wath et al., (2011)

Puckkett and Smith (2002) argue that the increasing volume of e-waste combined with its hazardous nature has made its management a global issue. Previous studies show that the increasing volume of e-waste in industrialised countries is because the cost of repairing damaged electronic is more expensive than the price of a new appliance (Subramanian, 2014; Nnorom and Osibanjo, 2008; Osibanjo and Nnorom, 2007; Puckkett and Smith, 2002). In addition to this, Slade (2006) observes that the EEE producers in these countries practice a strategy known as planned obsolescence. Lodziack (2000) further expounds that this strategy makes the consumer purchase electronic products that are not of personal choice but old ones, thereby increasing e-waste generation. Thus, significant amount of the e-waste created in the industrialised nations are disposed of in landfills or sometimes reduce to ashes, or are pass on to developing countries. For instance, in the U.S., e-waste ends in landfills along with other solid waste (Puckkett and Smith, 2002). This method is not different from what was observed in the European Union (EU) countries in previous years (Schenkman, 2002).

However, presently in the U.S, only one to two per cent of its e-waste is sent to the landfill along with other solid waste. Bhutta (2011), argues that the reason for this decrease in the region is because the country now exports large volumes of its e-waste to the developing nations. More so, in the EU countries, due to lack of space for the constructions of new landfill sites and the increasing hazardous nature of e-waste, many of its countries have now introduced some strategies. This include, for example, the landfill tax which encourages the diversion of e-waste from landfills (Arora, 2008), and the extended producer responsibility scheme, which allows the producer of EEE to take responsibility for its management. Examples of some legislation adopted by some developed countries and the year of enforcement are shown in Table 2.3.

On the other hand, in unindustrialized nations, the management approach is different. Many cities in developing countries like Asia and Africa are currently experiencing an increase in the volume of e-waste generation. This increase is not only due to economic growth and improved lifestyle, but also due to the illegal importation of e-waste for recycling purposes (Lui, 2006). A study by Nnorom and Osibanjo (2007) revealed some of the challenges of e-waste management in developing countries. They include the lack of infrastructure for effective waste management and lack of existing regulatory framework for end-of-life product take-back or execution of extended producer responsibility (EPR). Arora (2008), for example, is of the view that old electronic devices exported to developing countries like India, China, Pakistan and some part of Africa are due to the cost-benefit purpose which also creates ecological footprints. Hypothetically speaking, e-waste recycling in developing countries creates employment and source of livelihoods to several informal workers, collectors, segregators, intermediaries, scrap dealer and recyclers who manage e-waste in an unpolished manner. Furthermore, Sinha-Khetriwala (2004) is also of the view that e-waste serves as a source for income generation in developing countries. It is because, in developing countries, e-waste recycling is carried out majorly by the informal recycling sectors.

**Table 2.3**. WEEE legislation Adopted in various countries around the world

| Country | Legislation | Responsibility | In force since |
|---|---|---|---|
| Switzerland | Ordinance on the Return, Taking back and Disposal of Electrical and Electronic Equipment. (ORDEE) | Manufacturer/importer | July 1998 |
| Denmark | Statutory Order from the Ministry of Environment and Energy No. 1067 | Local Govt. | December 1999 |
| Netherlands | Disposal of White and Brown Goods Decree | Manufacturer/importer | January 1999 |
| Norway | Regulations regarding Scrapped Electrical and Electronic Products | Manufacturer/importer | July 1999 |
| Belgium | Environmental Policy Agreements on the take-back obligation for waste from electrical | Manufacturer/importer | March 2001 |
| Sweden | The Producer Responsibility for Electrical and Electronic Products Ordinance (SFS | Manufacturer/importer | July 2001 |
| United Kingdom | WEEE Regulation | Producer (manufacturer/importer/exporter) | January 2007 |
| Japan | Specified Home Appliances Recycling Law (SHAR) | Manufacturer/importer | April 2001 |

**Source**: Khetriwal et al., (2007).

Informal recycling method according to Simatele et al., (2017), is a survival strategy for scavengers in low-income countries. A survey by the United Nations, for example, revealed that informal waste recycling is done by the deprived, underprivileged, defenceless and/or ostracised community (for instance, nomads, migrants, incapacitated, aged, the illiterates and religious groups) who regularly depend on waste collection as a means of livelihood (UN HABITAT, 2010). Widmer (2005), for example, argues that the informal sector recovers valuable materials from e-waste in a way that is not environmentally acceptable. In 2004, Kumar and Li (2007) observe that informal recycling made up to over 50% of China's workforce. Currently, China recycles larger volumes of its imported and generated e-waste informally using crude methods like manual dismantling, stripping in an acid bath and open burning to recover valuable materials (Yu et al., 2010). Although the informal recyclers use unsafe and unprotected methods during recovery, it has served as a significant source of livelihood for the urban poor in China. As informal recycling continues to grow in developing countries, Puckett et al., (2002) supported by

Subramanian (2014), argue that lack of national or regional legislation of e-waste by developing countries can make the recovery of components and materials through informal recycling difficult. As mentioned above, many developing countries lack the right policies and regulations on e-waste when compared to developed countries (Nnorom and Osibanjo, 2008; Arora, 2008; Osibanjo and Nnorom, 2007). The absence of legislation has led to the indiscriminate burning of e-waste and disposal along with other municipal solid waste.

Based on the above observations, it can be argued that e-waste is a global problem. Although there are different opinions from various researchers on e-waste, Vasudev and Parthasarthy (2007), for instance, propose that e-waste trade should not be ban between developed and developing countries but should be inspected, since manual recycling of e-waste is labour and capital intensive. The proposition suggests that the international regulating bodies on e-waste should only allow the exportation of less hazardous e-waste from developed to the developing nations. In addition to this, they also suggested that e-waste created in developed countries may be exported to the developing country where manual labour force can be used for dismantling and segregation but that the toxic residues should be sent back to the developed countries where a sound technical facility can be used for their treatment. Kahhat (2008), and Williams et al., (2008) observe that this trade factor will enhance socio-economic benefit for developing countries. Furthermore, export.gov (2017) suggests that companies in the U.S. should seek information on WEEE and Restriction of Hazardous Substances (RoHS) before exporting them to any country. However, BAN (2005), argues that exporting of e-waste to developing countries by some developed countries is an act of "environmental injustice" as toxic waste will cause environmental burden and health risk to the informal handlers and recyclers.

### 2.3 Solid Waste Management in a Sub-Saharan Africa Region Context

Urban areas in sub-Saharan Africa (SSA) are currently experiencing environmental challenges from serious pollution issues caused by the increase in MSW generation and inadequate management practices. Igoni et al., (2007) and AfBD (2002), are of the view that the MSW management situation is deteriorating in sub-Saharan Africa due to poverty, rapid population growth, and urbanisation. In addition to these factors, Chandrappa and Das (2012), also observe that poor solid waste management practices in African countries may be due to lack of education, inappropriate infrastructure, lack of regulation enforcement, compounded with government unwillingness to implement adequate waste management strategies. Abuzeid (2009), argues that the combination of these factors has made solid waste management the most challenging environmental problem experienced by the government of many African countries. These factors have negative impacts and potentials on the cities' development and environment. Since MSW management challenges are at an alarming rate in SSA, many cities may find it difficult to manage successfully. Okot-Okumu and Nyenje (2011) observe that in most African cities, illegally dumped solid waste is progressively becoming a threat to the ecosystem and human health, especially among the urban poor and marginalised ones. The primary cause of this threat is the rare collection of solid waste in SSA urban areas.

Al-Khatib et al., (2010), identified lack of MSW collection as a crucial challenge in many cities and this may be due to local or state waste authorities' unwillingness to provide waste collection

services to residents in their areas. It should, therefore, be noted that without waste collection, waste disposal, recycling and treatment may be challenging. However, the poor waste collection may also lead to environmental and socio-economic problems. Furthermore, Parizeau et al., (2006), are of the view that up to 50% of the people living in urban areas in developing countries lack MSW collection services. It may be because MSW collection service rates vary in many sub-Saharan African cities. For instance, Medina (2011), reveals that only 25% of the waste generated in Nairobi (Kenya) was collected in 2011. Furthermore, in 2014, only 15% of solid waste was collected in Lusaka, 13% in Kinshasa (DR Congo) and 17% in Dar Es Salaam (Tanzania) (Simatele and Etambakonga, 2015; Simelane and Mohee, 2015). Previous studies show that low MSW collection in SSA is due to small budget allocation. Oteng-Ababio et al., (2013) and Binns et al., (2012), for example, reveal that between 20 and 50% of the annual budget in most SSA cities is allocated to MSW collection, yet, its management in most cities are poor. More so, Medina (2011), and Muniafu and Otiato (2010) are of the view that in some SSA urban areas, the residents' pay waste disposal fees, but the collection rates by the municipalities are still very irregular creating severe ecological impact.

In addition to this, Muniafu and Otiato (2010) argue that inadequate funding, lack of proper planning coupled with technical issues are some of the reasons for obsolete and inefficient waste collection system in SSA. Mohee and Bundhoo (2015) agree with previous studies that poor waste collection in sub-Saharan Africa is also due to poor infrastructure and lack of transfer and transport systems. In their discussion, they describe the transfer and transport system in a waste collection as a transfer, in which appropriate waste truck from the collection point transports waste to a transfer station or disposal site. Waste transportation is expensive, and it consumes the more substantial part of the MSW management budget. Regassa et al., (2011), however, observe that two problems are associated with waste collection trucks in sub-Saharan Africa: the waste truck may either be outdated, costly and ineffectual; or the outdated truck may be swapped with new compactor trucks that are not suitable for waste collection in the region, hence it gives rise to a waste of fund. These claims have also been supported by Coffey and Coad (2010). Lack of maintenance of waste collection vehicles does not only affect the transportation process but also result in low collection rates and high level of illegal dumping of waste. All these factors have jointly made waste management systems complex (Abu Qdais, 2007; Kum et al., 2005).

Studies by Mohee and Bundhoo (2015), for example, show that MSW collection system is complicated in sub-Saharan Africa because the management system is designed by experts from countries whose economic, social and environmental conditions and waste characteristics are different. Apart from the problems as mentioned earlier, solid waste management in SSA is also severely affected by political bias, legitimate, socio-cultural, ecological, monetary issues and accessible possessions. These factors also affect the urban areas of human societies as a lot of the world population now live in the municipalities. Urban population growth is very high in Africa. Jacobsen et al., (2012), observe that over 320 million representing 37% of the total population reside in urban areas in Africa. This statistic shows that very soon more people in SSA will live in its cities than its rural areas. They may, for example, be attracted by the cities development and industrialisation which result to increase in the volume of MSW generation in the cities'. Crucial examples can be seen in South Africa, Nigeria, Ghana, Egypt etc.

South Africa for instance, generates 0.35 metric tonnes of solid waste due to factors such as urbanisation, economic development, improving living standards, and industrialisation (Balde et al., 2015). Furthermore, Chimuka and Ogola (2015) observe in their research that most people residing in the rural areas of South Africa are migrating to the cities in search of jobs and better living standards. On the other hand, in Ghana, solid waste management has been viewed as a severe challenge. In 2014, over 4,000 tonnes of solid waste was generated daily in Kumasi and Accra and the solid waste management department struggles to collect these vast amounts of garbage (Monnney, 2014). He argues that the waste department is astounded by the daily increase in the volume of solid waste in most of its urban areas due to the ever-increasing population. Since population growth is now a severe factor in MSW management challenge, Barredo et al., (2004) are of the opinion that a growing population in a loosely planned urban system, in many African cities, will result in environmental and social consequences. Other conspicuous features hindering solid waste management in Ghana are collection, transportation and disposal issues which have led to contamination of most of its water bodies, air and environmental hazards (Evans, 2012).

Al-Khatib et al., (2010) and Fourie (2006) point out that the lack of proper management due to weak legislation enforcement in many developing countries has made solid waste management difficult in SSA cities. For instance, in South Africa, lack of national concern on MSW issues negatively impacted the environment and human health. In 1999, South Africa adopted a National Waste Management Strategy with the aim of reducing its waste generation, and to ensure that the environment and human health are not impacted negatively. Zaman and Lehman (2011), and Pires et al., (2011), on the other hand, observe that since the adoption of the above strategy, there is still shortfalls in careful planning and creating of public awareness in urban solid waste management practices. Dlamini and Simatele (2016) are also of the opinion that there is an urgent need for the new formulation and implementation of MSW management strategies that can increase the development of the waste management system in South Africa. These factors have made municipal solid waste management very difficult for the local municipalities in South Africa. A review of existing literature shows that the problem of solid waste management in Ghana is also due to lack of resources and weak institutional capacities.

Given the above observation, it can be argued that many cities in sub-Saharan Africa still lack the appropriate infrastructure for effective MSW management system and these problems cut across the continent. Furthermore, sub-Saharan Africa cities need to improve its waste collection and disposal systems as this is the only way to reduce indiscriminate dumping of solid waste. Simelane and Mohee (2015) observe that poor MSW management and collection have increased the informal recycling approach, and lower the social status of those who promote recycling. Anomanyo (2004) suggests that MSW collection difficulties can be reduced in urban areas by sub-dividing the cities into waste collection districts and also contracting the regions to private waste partnerships. Further recommendation by the author suggests that private partners should be allowed to invest in solid waste management as this will attract advanced and appropriate technologies needed and create a livelihood for the urban poor in many urban areas. Other studies by Salau et al., (2016), Manaf et al., (2009), Agamuthu et al., (2009) and Henry et al., (2006) have reported that collaboration between the government and private waste sectors have improved MSW management to a large extent in many SSA cities.

While some cities in sub-Saharan Africa are still struggling with the management of solid waste, e-waste is now seen disposed on many of its streets and dump sites. Grant and Oten-Ababio (2012) observe that the current dumping grounds for e-waste in urban Africa are as a result of its port cities and refurbishment centres. The United Nations reveals that the total volume of e-waste generated in Africa in 2014 is estimated at 1.9 Metric tonnes while the amount produced per inhabitant is only 1.7 kg/inh. (UN, 2015). UN-Habitat also argues that the large volume of e-waste in Africa is as a result of the giant wave of urban population growth and industrialisation in many of its cities (UN-Habitat, 2012). Amankwaa (2013) shows that urbanisation in Africa does not grow in proportion to its economic growth, job creation rates, and service provisions. What can be deduced from this is that although many people now reside in Africa's urban areas, the unemployment rate and poor service delivery to the residents are still high.

In South Africa, for example, Lombard and Widmer (2005) observe that the demand for electronic devices especially mobile phones have significantly increased in the last two decades. They further reveal that 1.5 million computers are imported into the South African market annually. This increase is as a result of globalisation and industrialisation which in turn increases the volume of e-waste generation in the country. Liechti and Finlay (2008) argue that although new pcs are sold annually in the country only a few are recycled, and about 70% are in storage held by the government. Lombard (2005), points out that e-waste storage by the government is as a result of a lack of adequate technology for its recycling, because many people do not know how to dispose of their old electrical appliances, cell phones and computers. In addition to this, a noticeable amount of e-waste is being recycled through both formal and informal recycling methods. The recycling methods have been driven by the ever-increasing high prices of precious metals especially gold, copper, and aluminium found in e-waste. According to Laffely (2007), the informal recycling sector has helped in salvaging and recovering a larger volume of e-waste in South Africa. Lombard and Widmer (2005) are of the opinion that only industrial and large-scale e-waste is recycled formally by a few large and small recycling companies, while household e-waste is dumped in landfills. There is no specific legislation on e-waste management in South Africa, but numerous laws exist on environmental management that can impact e-waste management.

In West Africa for example, Ghana and Nigeria are the highest receivers of e-waste from the developed countries. Ghana, for instance, is one of the primary recipients because of its increasing economic growth. Prakash et al., (2010) observe that the problem of e-waste is worsening in Ghana by an on-going stream of second-hand and old EEE importation from the industrialised countries. The issue of second-hand and obsolete e-waste is ongoing for a while in Ghana, posing serious environmental and health problems among scavengers working in various dumpsites due to the presence of some heavy metals (see Table 2.2) which also affects it aquatic and terrestrial environment. In 2009, Ghana alone imported 30% of new electrical and electronic devices and 70% of used appliances out of which only 20% were repairable and 15% were faulty. From the statistics, it is evident that more second-hand e-products are imported into the country than new ones, thereby increasing the volume of e-waste consumption and generation. Greenpeace argues that the two main continents that import e-waste into Ghana are Europe and the United States. According to Oten-Ababio (2012) illegal importation of e-waste or used electronics is a significant source of the problem in Ghana. Blade et al., (2015) attributed this to

the high demand of inexpensive electrical, electronic equipment and secondary materials, as well as low dumping prices compared to the treated with stricter standards in developed countries. Prakash et al. (2010), are of the view that between 10,000 to 13,000 metric tonnes of e-waste are treated informally in Ghana annually.

Ottaviani (2015) observes that e-waste is recycled mainly in Ghana through informal recycling approach and only a few are recovered formally. Through scavenging, many urban poor create a livelihood for themselves and support their families. At the informal recycling centres, unprotected workers, particularly children dismantle computers and televisions with little more than stones in search of valuable metals that can be sold (Ottaviani, 2015). This method of recycling is hazardous to the health of the recyclers, the resident around these centres, as well as affecting the environment by poisoning the air and water around the recycling areas. More so, leftover plastics, cables, and casings from e-waste are either burnt or directly disposed of in an open dump. As e-waste generation continues to grow in Ghana, Kawaye (2009) and Oten-Ababio (2010), argue that although Ghana has a long list of environmental legislation, there is no specific law on e-waste recycling. Recently, the country has drafted two bills on the control and management of e-waste and internationally ratified the Basel Convention framework on e-waste regulation, but the volume of illegal e-waste is yet to reduce (Prakash et al., 2010). However, none of these regulations addresses the issues of informal recycling methods.

In spite of this gloomy e-waste problem in some SSA cities, only a few have adopted some measures and initiatives that can curb e-waste menace in its cities. Meanwhile, Yin et al., (2014), supported by Ardi (2016) argue that some of the measures and initiatives have been hindered by continued illegal importation of ban and discarded e-waste, lack of e-waste specific legislation formulation and enforcement, lack of consumer awareness of the dangers associated with e-waste and failure of take-back initiatives. More so, Osibanjo and Nnorom (2008), and Prakash et al., (2010), are of the view that informal sector in sub-Saharan Africa, should be integrated into the formal organisation as a large number of toxic substances are released during the informal e-waste activities with no concern given to the safety of the workers and the environment. Although Simatele and Etambakonga (2015) have argued that the informal sectors play essential roles in solid waste management by bridging the gaps created by waste management institutions, official institutions in solid waste management can do more by creating an effective formal waste management system that can produce better livelihoods for the informal collectors.

### 2.4 Solid Waste Management in Nigeria: A Local Perspective

Nigeria is positioned in the Western part of Africa, with 36 States and a Federal Capital Territory and it is the most populous country in Africa with 186 million people (World Bank, 2016). With the increase in population growth, urbanisation, industrialisation, globalisation, poverty, poor governance coupled with low environmental awareness, Nigeria solid waste management has been very challenging (Kofoworola 2007; Adewuyi et al., 2009; Iriruaga, 2012). In the past few

years, the country's population has increased rapidly. According to a recent survey, Nigeria represents 2.35% of the world's total population, and this growth has had impacts on the country's urbanisation, socio-economics, infrastructures and solid waste management (World Population Review, 2017; Okuwashi et al., 2017). Furthermore, another survey by World Bank (2016), for example, also showed that approximately 48.6% of the total population of Nigeria resides in urban areas. Meanwhile, in 2006, for instance, only 39.9% of the people lived in the urban areas, and the number has since increased. Bloch et al., (2015) and Samson (2010) observe that the increase in the urban population has hindered the competence of the government to come up with appropriate waste management services. In cities like Lagos, for example, population growth has made it difficult for the state and local governments to provide the necessary amenities needed for its people. Moreover, as the urban population growth increases, MSW generation also increases leading to indiscriminate dumping of waste in open spaces which later results in health challenges and environmental ruins. In many other cities in Nigeria, particularly Abuja, Port Harcourt, Kano, Enugu etc. MSW management problems are caused by low collection methods, insufficient coverage of collection and indiscriminate disposal.

The United Nations revealed that the city of Lagos is, for example, the biggest city in Nigeria and that it will be the third leading megacity in the world by 2020, after Tokyo and Bombay (UN, 2011). The rapid urban growth in Lagos is because the city is the major contributor to Nigeria's economy, with a 30% contribution to the nation's GDP (LSG, 2016). Besides, it is the most significant business city in Nigeria and serves as regional significance for other West African nations as globally operating establishments have associates or head offices in Lagos (Terada, 2012). With the presence of two seaports (Tincan Island and Apapa), the city also plays a significant role in global exchange since goods originating in or destined for other West African countries are imported through these ports. The importation of products has a direct implication on MSW generation and management system in the state. Furthermore, rapid urban growth in Lagos has led to weak institutional frameworks, poor urban planning as well as high unemployment rates (Musiliu et al., 2010). In spite of the monetary contribution of the city to the national economy, urban growth challenges such as high poverty rate (over 20% of the Lagos population still live in poverty), food insecurity, lack of shelter compounded with socio-economic deprivation which stands at 41.1% are still very high (Oxford Poverty and Human Development Initiative, 2015). In a bid to proffer solution to the problems of poverty and economic deprivations, many individuals in the city of Lagos are now adopting various means of seeking livelihoods, for example, informal waste scavenging from dumpsites, households and marketplaces. This is one of the most common livelihood strategy adopted as a source of sustenance and revenue creation in the city. Salau et al., (2016), are of the opinion that 52% of the scavengers in Lagos depends solely on this job as a means of livelihoods.

Iriruaga (2012) expounds that MSW generation rate in Lagos State, for instance, is 9000 tonnes/per day. Meanwhile, Salau et al., (2016) are of the view that the massive tonnes of waste generated in Lagos is the reason why there are so many scavengers working in the informal waste sectors. Adegbola and Oladeji (2012) and Kofoworola (2007) reveal that 80% of the solid waste generated in Lagos is dumped in open spaces and about 2,400 metric tonnes of waste ends at the Olusosun landfill (the largest landfill in Africa). This figure shows that the volume of waste generated in the city of Lagos is still very high and could have severe health and environmental implications. According to Okwashi et al., (2017), due to inadequate equipment for waste collection, indiscriminate dumping of waste, weak regulatory and policy frameworks and lack of

enforcement the volume of solid waste in Lagos keep rising. The problem of poor collection of equipment has further led to co-mingling of different solid waste materials by households and waste authority at disposal sites. Previous studies show that due to the rare collection by the waste authority in the city, only 72.62% of the entire waste generated in Lagos is collected by the informal sectors (Salau et al., 2016; Olugbenga, 2006; Ahmed and Ali, 2004). In spite of this, the informal sector is not yet recognised officially by the Lagos State waste authority, although many of the cart pushers and scavengers are seen at the dumpsites and on the streets of Lagos. (Salau et al., 2016; Iriruaga, 2012).

Previously published studies on the overview of MSW management in Lagos State have reported that the city was tagged the dirtiest city in the world in the early 1970s because waste was dumped in almost every available space. Thus, the state was polluted environmentally as well as causing some public health issues (LAWMA, 2016; LAWMASC, 2015; Oresanya, 2015; Adedibu and Okekule, 1989). To address the problem of indiscriminate waste disposal in the country, Lagos became the first state in Nigeria and West Africa to create a waste management outfit in 1977. The name was called Lagos State Refuse Disposal Board. In 1981, the name was changed to Lagos State Disposal Board and finally to Lagos Waste Management Authority (LAWMA) in 1991 (Okuwashi et al., 2017; LAWMA, 2016; Salau et al., 2016). In 1994, the state introduced the private sector partnership (PSP) operations which manages municipal and commercial solid waste while LAWMA was saddled with the responsibility of collecting and disposing of industrial waste. According to Contreau, (2006), PSP introduction in solid waste management serves as the primary driver for sustainable development and economic growth. It is because the sector creates jobs and awareness through recycling and also provided sustainable livelihoods for the poor in the city. Besides, LAWMA manages the three major dump sites in Lagos (Abule-Egba, Olushosun and Solous) and the two newly constructed landfill sites (Epe and Ikorodu) (LAWMA, 2015).

Despite the efforts of LAWMA and PSP solid waste management, a new growing concern of solid waste, e-waste has hampered the waste institution goals. UNEP observes that Nigeria, particularly Lagos, is fast becoming a primary dumping site for hazardous and discarded e-waste generated from developed countries (UNEP, 2011). It is maybe because accumulated cargo containers of e-waste arrive at the Lagos seaports on a daily basis. Sullivan (2014) is of the view that Nigeria generates the highest volume of e-waste in West Africa due to the direct import of non-functioning and non-repairable used EEE or e-waste. He further argues that Nigeria dominates other West African countries in the importation of new electronic appliances, used and second-hand EEE and in the total amount of e-waste generation. In 2010, the import statistics of Nigeria revealed that the share of new and used electronics and electrical appliances was about 50%/50% (600,000 are new, and 600,000 are used EEE) imported into the country. In addition to this, approximately 30% of the second-hand devices were estimated to be non-functioning. However, half of the appliances were repaired locally and sold to consumers while the remaining 30% were irreparable and discarded (Ogungbuyi et al., 2011). Manhart et al., (2011) observe that this growing volume of e-waste in Nigeria can be attributed to the rapid increase in the domestic consumption of EEE.

Sullivan (2014), however, argues that the importation and recovery of recycled goods are a significant way to supply the nation's population with electrical devices at affordable prices. In 2010, the National Environmental Standard and Regulation Enforcement Agency observes that approximately 100,000 tonnes of e-waste were illegally imported into the country (NESREA, 2010). This illegal importation shows that there are loopholes in the institutional system of the nation. Sullivan (2014), argues that lack of implementation of exportation control in many industrialised countries and irregular borders and corrupt customs officials in Nigeria are the primary cause for the massive flood of illegal e-waste into the state. He further argues that the influx of e-waste may also be due to the aspiration to leave the cycle of poverty through the escalating high-tech industries. A survey by Basel Convection (2011), revealed that the United Kingdom, France, as well as Germany, are the top exporting country of e-waste or second-hand devices into Nigeria. Germany is the leading country in the export of television receivers and monitors and this volume is rising, while the United Kingdom exports in these areas are declining (Manhart et al., 2011).

Sullivan (2014), further observes that the seaports in Lagos State are the major receiving dock for the importation of e-waste in Nigeria. Export data from European countries revealed that Lagos is the primary endpoint for e-waste shipped to West Africa (Basel Convention, 2011). Furthermore, cargoes packed in vessels, comprising second-hand and out-dated e-equipment are imported along with second-hand vehicles and waggons predestined for re-use in West Africa (Arends et al., 2009). However, the statistics do not show any distinction amongst new, second-hand and out-dated appliances, but Manhart et al., (2011) observe that a large quantity of these goods is used and moderately not operational. According to the Basel Action Network (BAN), an estimate of 500 shipping containers of second-hand electronic products enter Lagos monthly (Ogungbuyi et al., 2012; Puckett et al. 2005). One truck may, for example, have on the average load up to 800 (eight hundred) computer monitors or central processing units or 350 large TV sets. Electrical devices, designed with low lifespan, arrive daily from the UK, Germany, France, the United States etc. into the four organised e-waste markets in Lagos State (Ikeja Computer Village, Alaba International, Westminster and Lawanson markets). BAN (2011) and Manhart et al., (2011), observe that thousands of vendors and consumers from within and outside Lagos crowd these bustling markets, purchasing computers, fax machines, television sets, cell phones etc. in stores and at roadside tables. Second-hand and out-dated e-products are passed on to the refurbishing/recycling section in the market (Manhart et al., 2011).

According to Namias (2013), e-waste recycling is a trending issue and was designed in to protect human and environmental health as a result of widespread environmental pollution. Kiddee et al., (2013), argue that large volumes of e-waste are being moved for recycling purposes from developed into developing countries like China, Nigeria, Ghana, India etc. where manual labours (informal recycling) are used in backyards of residential properties, leading to insignificant contamination of the environment in these countries. These practices as observed by Oteng-Ababio (2012) and Chi et al., (2011), have led to the poisoning of many workers who engaged in the recycling process and those that reside very close to the e-waste recycling sites. The informal sector can be identified as minorities using stressful methods, inexperience expertise, low wages, not organised and unregistered association (Wilson et al., 2006; Monirozzaman et al., 2011). Asim et al., (2012), argue that the socio-economic and demographic characteristics of the informal

waste collectors differ from location to location. However, in Lagos, due to the absence of acceptable amenities for eco-friendly recycling, e-waste is dumped indiscriminately in open dump sites, landfills, and nearby wetlands (Uluocha and Okeke, 2004). Schmidt (2006), observes that plastic casings are often burned to retrieve valuable metals or reduce the bulk, spewing carcinogenic dioxins and polyaromatic hydrocarbons into the environment. Orisakwe and Frazzoli (2010), are of the view that between the toxic smokes released into the atmosphere, chemicals leached into the soils and the lethal drinking water (in wells, streams, and lakes), e-waste recycling and refurbishing are almost reaching catastrophic proportions resulting in environmental degradation. However, sustainable and cost-efficient recycling could be achieved through innovative technological investigation and improvement might as well stimulate innovations, but the supervisory body has to enforce and provide funds to replace crude recycling criteria and the strategies to achieve the objectives (Sullivan 2014).

Although e-waste regulation is not correctly employed in Africa, Balde et al., (2015), observe that Nigeria is one of the countries that have national e-waste related legislation. In 2007, the Federal government of Nigeria created the National Environmental Standard and Regulatory Enforcement Agency (NESREA) as an agency under the Federal Ministry of Environment. The agency was created as a result of the illegal Koko toxic waste dump issue which happened in the old Bendel State of Nigeria, in 1988. It is responsible for the enforcement of all the environmental laws in Nigeria. The agency also enforces National laws and regulations on e-waste which include harmful and special waste. Besides, the agency has adopted some strategies/ policy instruments that enabled it to implement the legislation. The approaches include the extended producer responsibility (EPR, e.g. take-back), polluter pays principle, fines, and penalties. Despite the implementation of this strategies, e-waste collection is not yet structured in Nigeria due to lack of collection centres, and are seen disposed along with other solid waste (Edward-Ekpu, 2016). Similarly, many households and offices still find it challenging to dispose of their e-waste because recycling in Nigeria, particularly in Lagos is majorly carried out by the informal sector. In Lagos, accumulation, and burning of toxic materials at e-waste scrap sites and landfills by scavengers is common (Sullivan, 2014; Manhart et al., 2011; BAN, 2011).

However, formal e-waste collection has started in Lagos with the Lagos Waste Management Authority (LAWMA). Presently, LAWMA only collects e-waste generated at the e-waste refurbishing markets and other industrial and commercial centres within the state. In addition to this, an e-waste resource assemblage structure is currently employed by the Lagos State Environmental Protection Agency (LASEPA) aiming at e-waste from industries. Also, a lot of the e-waste collected by LAWMA is transported to the loading sites where they are kept along with some sorted solid waste because there is no land available for the construction of new landfill (Onayiga, 2016). While LAWMA does waste collection within the state, LASEPA implements, monitors and enforces the laws, regulations and policies on waste management in Lagos. The strategies employed by LASEPA on e-waste management are adopted from NESREA (LASEPA, 2015). Ogungbuyi et al., (2012), supported by Nnorom and Osibanjo (2008), argue that environmental degradation caused by poor e-waste management practices can be prevented by implementing environmentally sound e-waste management techniques in Nigeria. They further propose eco-friendly alternatives to informal recycling approach that can be employed for e-waste management which are minimisation, reuse, recycling and recovery

approaches. The methods can only be realised if the local and state authorities integrate the informal e-waste handlers into the formal institutions by training, educating and monitoring their activities.

### 2.5 E-waste Management Conceptual Framework

Solid waste management system involves the collection, transportation, storage, processing, recycling, disposal of waste (Mohee et al., 2010). This implies that SWM deals with waste from generation point through to the final disposal stage. On the other hand, e-waste management system according to UNEP (2010) consist of policies and regulations, institutions, financing mechanisms, technology for collection, storage, recycling and disposal and stakeholders' role. Thus, this study refers to e- waste management framework as a system that deals with the policies and regulations in charge of e-waste collection, transportation, processing, recycling or disposal, and monitoring of materials to create opportunities, and protect human health and the environment. This definition also involves the technology needed and the different stakeholder responsibility in the management of e-waste. Due to the dangerous methods used in the processing of e-waste in the city of Lagos, it is necessary to propose an effective framework needed for its management. For instance, policy, legislation as well as public knowledge or awareness are the most effective frameworks needed for e-waste management in many cities in developing countries which is also required in the city of Lagos.

Furthermore, previous studies have shown that several nations of the world have developed sustainable policy frameworks for e-waste management and there are entirely new business opportunities evolving around e-trading, source reduction, reuse, recycling, repairs and recovery of materials from WEEE (Öko-Institut and Green, 2010). This is because e-waste comprises of valuable and precious materials discussed earlier in this chapter. This conceptual framework will therefore look into legal and regulatory framework that includes measures against illegal dumping, mandatory take-back, disposal bans and material bans and restrictions. Another important aspect of this framework is economic and financial instruments which introduce specific laws/legislations that could send economic signals to manufacturers to reduce wastes from their products, such as deposit refund system (EPR), removal of subsidies on raw materials, e-waste recycling centres, tax and subsidies.

Other essential parts of the framework include information devices and public awareness such as environmental labelling, product hazard warnings, product durability warnings, and energy efficiency labelling. Lastly, the conceptual framework considers technological dimensions to address the need for building national e-waste handling capacity. This research would therefore examine the various national and local policy and regulation framework that could be used for sustainable e-waste recycling business that can grow in Lagos, Nigeria.

### 2.6 Gaps in Knowledge

From the above discussions, it can be argued that e-waste is still a growing global challenge. Many existing literature on e-waste have focused on the volume of e-waste generated from both developed and developing countries (Balde et al., 2015; Iqbal et al., 2015; Breivik et al., 2014;

Ogungbuyi et al., 2012, Manhart et al., 2011; Nnorom and Osibanjo, 2008; Widmer, 2005), its environmental and health implications (Robinson, 2009; Ni and Zeng, 2009, Fu et al., 2008; Wong et al., 2007), roles of the informal sectors in the management of solid waste in developing countries (Grant and Oteng-Ababio., 2012; Chi et al., 2011; Liu et al., 2006; Terazono et al., 2006) as well as the need and ways to manage it (Wath et al., 2011; Khetriwal ., 2009; Kollikkathara and Feng, 2009; Nnorom and Osibanjo, 2008 a & b). Furthermore, research on resource extraction and recovery of valuables materials from e-waste have been revealed by various authors (Khaliq et al., 2014; Lee and Pandey, 2012; Schmidt, 2006) and issues relating to regulations and strategies of e-waste management (Heeks et al., 2015; Atasu and Wassenhove, 2012; Plambeck and Wang, 2009; Nnorom and Osibanjo, 2008; Li et al., 2006). In spite of the above studies, both developed and developing countries still have challenges with e-waste management.

In the 1990s, many industrialised countries recognised e-waste as a severe challenge and therefore formulated national legislation that can address it. Globally, countries in the European Union were the first to draft and implement the WEEE and RoHS Directives. The law adopted by many of these countries shown in Table 2.3 is based on the extended producer responsibility (EPR) principle, proposed by Lindhqvist (Lindhqvist and Lidgren, 1990). In the opinion of the Organisation for Economic Co-operation Development (OECD), EPR is defined as "an environmental policy approach in which a producer's responsibility for a product is extended to the post-consumer stage of a product's lifecycle". In reality, it implies that producers are responsible for the collection or taking back of used or discarded goods for recycling including its separation and treatment. Recently, the industrialising countries have also seen e-waste as a new challenge, and many have adopted the EPR principle. However, most developing countries are still lacking in the adoption and implementation of the scheme, while those that have proposed the system are yet to enforce it.

Besides, the EPR approach was first adopted by the European Union so that there can be an improvement in the collection, treatment, and recycling of WEEE. However, a recent survey by Zero Waste Europe on EPR revealed that the EPR schemes manage only 31% of the solid waste and products. Alvares and Rosa (2016) are of the view that if the EPR is used judiciously, it can be one of the bases for the shift to a circular economy because it has the potential to produce economic incentives for producers to better in designing their products. A review of existing literature reveals that many developing countries have adopted the EPR approach without any prior observation and clear understanding Manomaivibool (2009). However, lack of investigation on EPR by developing countries may make the enforcement of EPR scheme difficult and may result in the environmental injustice (EJ) of the poor. This is because informal recycling is widely used in developing country and it widely carryout by the poor.

Kubanza and Simatele (2016) observe that environmental injustices (EJ) in MSW management are associated with the poor in developing countries. It refers to the fact that most developing countries are faced with poor urban governance, poor sanitary condition, lack of clean water, inadequate MSW infrastructure and crude recycling methods. Environmental justice, a concept that emerged in the early 1980s, explains the unbalanced distribution of ecological damage. Previous studies on EJ have focused on the quantitative records of designs of three-dimensional

and politically aware injustices, which includes the building of waste disposal sites close to the poor in the society and distance from policymaking practices (Bullard, 1990; Holifield, 2001; Pulido, 2000). Iles (2004) argues that environmental justice approach can reveal the impacts of technology and e-waste material flows. In addition to this, he observes that EJ definitions and methodologies can help any country account for how and why e-waste flows should occur. There is an increasing concern on international EJ because the burdens of environmental hazard have changed to the Global South (Lawhon, 2013). According to Okereke (2006), there are two notable cases of international injustices namely; the waste trade and dumping; and climate change. However, very little literature exists on EJ of e-waste management.

This study, therefore, seeks to critically review the gaps that exist in e-waste management framework in Nigeria particularly in the city of Lagos, types of legislation and strategies that can be adopted, and how e-waste recycling can provide sustainable livelihoods opportunity for scavengers from resource recovery in the informal sectors. Although e-waste management challenges in Nigeria have been studied, much less is known about the e-waste legislation, informal e-waste recycling, and the environmental and health risk associated with e-waste in Lagos (Obaje, 2013; Terada, 2012; Ogungbuyi et al., 2012; Adediran and Abdulkarim, 2012; Manhart et al., 2011; Nnorom and Osibanjo, 2008; Osibanjo and Nnorom, 2007). Furthermore, to date, only a few have studied e-waste strategies like EPR (take-back) policy, polluter pays principles etc. More so, very few researchers have studied the socio-economic impact of the informal e-waste sector in Nigeria (Nzeadibe, 2015; Barretta et al., 2012; Manhart et al., 2011). As e-waste material to continues to flow into Nigeria, Nnorom and Osibanjo (2008) and supported by Balde et al., (2015) observe that although the country has implemented its e-waste regulation since the year 2007, it has not been well established due to lack of enforcement. To date, e-waste management issues remain one of the most noticeable and severe problems of solid waste management in the urban areas of Lagos. Academic studies relating to the problems on a weak institutional framework, scavenger's livelihoods and research data on e-waste flow in Lagos are lacking. Knowledge gaps in e-waste management created by the weak institutional framework, lack of legislation and strategies enforcement and the sustainable livelihood of the urban poor in Lagos State need to be examined and discussed as these issues are not answered appropriately in the existing literature.

Because of these existing gaps, this study is particularly interested in examining the current institutional challenges and the roles policymakers and stakeholders can play in the effective management of e-waste in urban areas of Lagos. More so, problems involved in the implementation and enforcement of the extended producer responsibility (EPR) principles as related to importers, dealers and manufacturers of electrical and electronic products will be addressed. It is argued in this study that if stakeholders (i.e. waste creators or generators) are involved in the management of e-waste, if encouraged and supported through awareness, and incentives, it can lead to a valuable transformation in the management of e-waste. Also, the study set out to identify the means and extent to which scavenging of scraps form e-waste from the informal recycling sector can be used to improve and contribute to the livelihoods of the urban poor in Lagos, in a way that it will not cause harms to the scavengers and the environment. It is further argued in this study that the recovery of scraps from e-waste in the city of Lagos produces real markets for commercial activities, which will serve as a source of livelihoods for

the urban poor and the informal sector should be integrated into the official formal industry, urban development and policy planning in the state. In view of these existing gaps, this study is particularly interested in examining the current institutional challenges and the roles policymakers and stakeholders can play in the effective management of e-waste in urban areas of Lagos. More so, challenges involved in the implementation and enforcement of the extended producer responsibility (EPR) principles as related to importers, dealers and manufacturers of electrical and electronic products will be addressed. It is argued in this study that if stakeholders (i.e. waste creators or generators) are involved in the management of e-waste if encouraged and supported through awareness, and incentives, it can lead to an important transformation in the management of e-waste. In addition, the study also identifies the means and extent to which scavenging of scraps form e-waste from the informal recycling sector can be used to improve and contribute to the livelihoods of the urban poor in Lagos, in a way that it will not cause harms to the scavengers and the environment. It is further argued in this study that the recovery of scraps from e-waste in the city of Lagos produces positive markets for commercial activities, which will serve as a source of livelihoods for the urban poor and the informal sector should be integrated into the official formal sector, urban development and policy planning in the state.

## 2.7 Conclusion

From the above discussion, it can be observed that solid waste management issues have really been tackled globally, regionally and locally. However, in spite of these achievements, the world is now being confronted with the challenge of e-waste management. E-waste challenge is no doubt a global issue because of its hazardous nature. Nevertheless, it can be seen that many developed countries have been able to curb some of the problems associated with e-waste by adopting and implementing working legislation and policy frameworks. In contrary, only a few developing countries have regulatory and policy frameworks on e-waste. It can be seen from the above discussions that those who have adopted and implemented e-waste regulations and policies are still lacking in the area of enforcement. And without the enforcement of any policy, it may be difficult to curb the indiscriminate disposal of e-waste on the street of any city. It was further observed that e-waste gets to the developing countries from the developed ones in the name of gifts and charitable donation. More so, illegal importation is the most notable challenge of e-waste management in developing countries.

The most common way of handling e-waste in the developing countries is majorly through the informal sector and this sector uses crude and hazardous means. These method has caused serious environmental damages and health issues for the workers and the people residing around the recycling site. The solid waste management bodies in developing countries, particularly in sub-Saharan Africa region still needs to address the challenges of e-waste management in the region as this is fast becoming a serious issue. E-waste management unit in the city of Lagos can, therefore, tackle its challenges by developing a working institutional framework, enforcing and monitoring the e-waste regulations and policy, creating awareness to the public on the hazardous nature of e-waste and integrating the informal sector into the formal sector for better management purpose.

# CHAPTER THREE

## Methodological Issues and Considerations

### 3.1 Introduction

This chapter presents a discussion of the methods and data collection tools that were used in this study. It adopted a mixed methods approach. Generally, mixed methods research approach involves the combination of qualitative and quantitative methods of data collection, analysis and interpretation of results in a particular study (Leech and Onwuegbuzie, 2008). This approach does not only involve the collection of data through quantitative and qualitative methods, but it also indicates that the various data collected will be mixed and linked together during the research process. According to Bryman (1988), the research method is usually classified into two paradigms; quantitative (positivist) and qualitative (constructivists and interpretivists) approach. Quantitative research approach engages the use of post-positivist claims, strategies of inquiry, for example, experimental trials and assessments, and collection of data through proposed research methods. The positivist approach perceives social observation as objects, in the same way, that a physical scientist recognises physical phenomena (Brewer and Hunter, 1989; Bryman, 1984). The positivist purists opposed the fact that the observer differs from the objects used for observation. They, however, advocated that researches conducted in the scientific and social science field have to be unbiased. It implies that the study should be valid and reliable (Johnson and Onwuegbuzie, 2004).

According to Hong (2005), quantitative methods can be further sub-divided into deductive (interpretations from all philosophies), inductive (from evidence to assumptions to conclusions) and ideal building. Maryling (2007) argues that the quantitative approach is insubstantial because the participants' opinions are not openly heard. Qualitative research approach, on the other hand, relies on case studies, constructivist perspective (ethnography), and the use of narrative theory (Ezeah, 2010). The approach is not reliable because the researcher interprets the results to suit its interest, which may be due to researcher's biases or problem in finding a large group of participant for the research. The constructivist and interpretivist purists contradict the positivist approach since they accept the fact that "subjective inquiry is the only kind possible to do" (Creswell and Plano, 2007).

Therefore, in a bid to balance the deficiencies in both qualitative and quantitative research approaches, the mixed methods approach has been developed to provide more facts for studying a research problem. The mixed methods research approach informed this study. Tashakkori and Teddlie (2003) refer to it as a 'third methodological movement', Johnson and Onwuegbuize, (2004) call it the "third research paradigm" while Marrying, (2007), terms it "a new star in social science sky". While different definitions of the term mixed methods approach have been suggested, this study would use the definition suggested by Stange et al., (2006), and Creswell (2003), they define the mixed methods research approach as "the combination of both quantitative and qualitative research approaches". Creswell et al., (2011), observe that the primary benefit of the mixed methods research approach is that the researcher is not limited to some sorts of data collection methods from both quantitative and qualitative research approaches. To

advance a study, research needs to be carried out systematically by investigating claims and collecting information regarding the specific research (Creswell, 2003; Pole and Lampard, 2002). This new research paradigm has been found useful in data collection and analysis in the field of solid waste management and has been adopted in this research study.

This study was also based on the review of the literature on solid waste management, particularly e-waste, urban livelihood, stakeholder consultations and documentation on e-waste management policies and practices in Nigeria, Sub-Saharan Africa as well as globally. This review was necessary as it is vital to know the various kinds of regulations and policies which existed and have been adopted by different countries around the globe, the best practices employed, the levels of success attained and the challenges that have been encountered. Primary data was collected by the researcher in eight study sites using survey questionnaires as well as interviews with both formal and informal participants. In this study, the primary field research was conducted in two phases. In the first phase, data were gathered through field observation at the study sites; questionnaires were administered to scavengers, e-business dealers and staff from waste institutions. The second phase of the study involved the collection of soil samples at some scrap sites and landfills during the dry and wet seasons, to check for toxic pollutants such as heavy metal concentrations in the soils.

This chapter, therefore, outlines the research positionality and gives the detailed description of the study area. Furthermore, it examines the fieldwork materials used by summarising the research aim and objectives that were outlined in chapter one of this thesis. Also, it looks at the research design, which comprises the study sample and the sampling procedure, and the data collection methods used in this study. The data analysis procedure, validity and reliability of the research data, ethical consideration as well as limitations of the study are also examined.

### 3.2 Research positionality

The term positionality describes the characteristics of the researcher that may change the researcher from an independent, unbiased outsider to be a participant (Wardale et al., 2105). The positivism and realism philosophical position informed this study. Positivism as a philosophy maintains the opinion that only accurate information acquired by observation is reliable (Dudovskiy, 2016). In this field of study, the researcher's position is to collect data in the study sites and interpret it through an unbiased approach. On the other hand, the outcomes of the study are generally evident and measurable. However, Wilson (2010) suggests that using a positivist approach in a research will mean that the researcher will not interfere with the participants during the study. It means that the use of positivist philosophical position in a research is based entirely on facts and argued that the world is external and objective.

Realism philosophy, on the other hand, argues that the external world is real and exists outside the human mind (Pasaribu, 2012). It is a branch of epistemology that develops the idea through a scientific approach. It also believes that objects can be researched, evaluated, studied scientifically and philosophically. Realism is further divided into two, namely direct and critical realism. Direct realism deals with what the human senses can perceive while critical realism argues that the image seen by the sights may not always show the real world (Novikov and Novikov, 2013). This

present study, therefore, supports the two philosophical approaches, as soil samples were collected from four study sites and were subjected to observation and experimentation in the laboratory. The results from the laboratory will further by analysed statistically without any form of bias. Furthermore, interviews were conducted and questionnaires were also administered to participants in the field so that their views on e-waste management might be heard.

During a research process, it is essential for the investigator to understand power subtleties. The researcher needs to determine where to stand with the participants; however, this can change during the process of conducting the study (Greene, 2014). Mcdermid et al., (2014) are of the view that researchers may also encounter difficulties when relating with respondents with whom they have had previous contacts concerning setting boundaries, building confidence and privacy as a friend and researcher. Furthermore, in positionality, the identities of both the researchers and participants are important because these influence the research process ultimately resulting in awareness and biases feeding into, and shaping the entire process (Bourne, 2014). Chiseri-Strater (1996) is of the opinion that identifiers of positionality are recognised in cultural terms, for instance, sexual category, ethnic group, population; however, individual information and experiences are subjective and contextual. Thus, identities mark the researcher's interactive positions, and familiarity becomes essential when researchers know their jobs within the given perspectives (Maher and Tetreault, 1993). Merriam et al., (2001) are of the view that positions relate to the cultural ethics and customs of both the researcher and participants. During interview research, for example, these identities may cause the researcher to be perceived at the same time as an insider and outsider (Couture & Maticka-tyndale 2012).

The researcher was aware during the fieldwork that it takes the dual position of both insider and outsider to conduct research on e-waste management and sustainable livelihoods of the urban poor (Gwenzi et al. 2017). The insider position gave the researcher some advantages during this study. As an insider, a Nigerian, an environmentalist and an academic it was easy to gain access to the people in the study sites and the various offices. The study was made possible through the enthusiasm of the participants. Furthermore, all the necessary documentations needed for this study were accessed easily through contacts the researcher had at the State and Federal Ministries of Environment. However, in some study sites, the researcher requested the assistance of those who were familiar with the study locations. Additionally, as an insider, who also shared a similar cultural identity with some participants (subjects) in the study sites, the researcher was attended to without delay (Chiseri-Strater 1996). The researcher discussed with some of the participants that would not allow her access the study locations in Yoruba (a language spoken mainly in the South-Western part of Nigeria) because the researcher sensed that some of them were intimidated when the English Language was used as a mode of expression. In their view, the researcher was disrespectful not speaking in her 'mother tongue'.

The outsider position was quite challenging because the researcher had lived in the South Western part of Nigeria since birth and was unable to communicate in Hausa (a Chadic language spoken mainly in the northern part of Nigeria). The researcher had to find a young man, fluent in Hausa and English language as a field assistant. This was because many of the condemned (scrap buyers/scavengers) were Hausa and Muslims who did not want to relate with the researcher, being a female and a married woman. It might be due to the participants' religious identity.

Hence, throughout the research process, the researcher had to constantly shift position as the insider and outsider and was able to maintain objectivity (Murillo, 2004). The motive of the researcher is to understand the role of the government in the management of e-waste in Lagos since the city serves as the major point of entry to all imported used and new electronics. The staff in charge of e-waste management attended to the researcher on the issues raised, the institutions' vision on how to reduce, reuse and recycle e-waste and their plans to partner with electrical, electronic companies in Lagos in the recovery and disposal issues.

### 3.3. Research Design

A significant component in research methodology is the research design. It allows the researcher to plan logically, addresses the research problems and answers research questions (Salkind, 2010). However, it is imperative to choose the best research approach when conducting fieldwork. According to Creswell (2003), selecting the right research approach helps the investigator understand and achieve the aim and objectives of a study. In this study, the research strategy used in investigating the role institutions played in e-waste management, the laws and regulations adopted to reduce e-waste hazard in the environment, the detection of heavy metals in the work environment of the scavengers and their livelihoods was a descriptive research approach. The descriptive research approach states the type of enquiry, strategy, and statistical analysis method that will be useful for a specified subject matter. According to Shuttleworth (2008), descriptive research is a "scientific design which includes observing and describing the behaviour of a subject without influencing it in any way". This design can be qualitative or quantitative. This study involved collecting information from scavengers, e-waste business dealers and staff of waste institutions through the use of questionnaires and interviews. An observational approach, which included viewing and recording the participants, was also employed in interpreting the information collected from the field. Kelly et al., (2003) are of the view that descriptive research aim is to observe a study by presenting the necessary features linked to the investigation. The features include demographic, socio-economic and health characteristics, events, behaviour, attitudes, experiences and knowledge.

Murphy (2017) reveals the benefits and drawbacks of descriptive research design. The benefits include the use of specific data collection techniques and observational research approach method. While the disadvantages are: research confidentiality (participant sometimes not being truthful), and objectivity and error (e.g. researcher's bias, error from predetermined questionnaires and interviews questions). Knupfer and Mclellan (2001) suggest that the type of research questions asked by the researcher will describe the best approach needed to carry out the specific research. For example, descriptive studies are predominantly used when the researcher is answering questions on 'what is', 'to' and 'how' a study is to be examined. This study aim was 'to' explore the factors accounting for the present institutional challenges in e-waste management in Lagos and ways to incorporate the scavengers into the formal sector to improve their livelihoods. Besides, the design might also be used to examine certain parameters in a targeted population and also describe interactions (Kelly et al., 2003). The various institutional challenges in e-waste management in the city of Lagos and the improvement of scavengers' livelihood in this study was informed by data collected from the various targeted

population and findings have been evaluated in the data analysis section. Figure 3.1 below shows the flow chart for the research design adopted in this study.

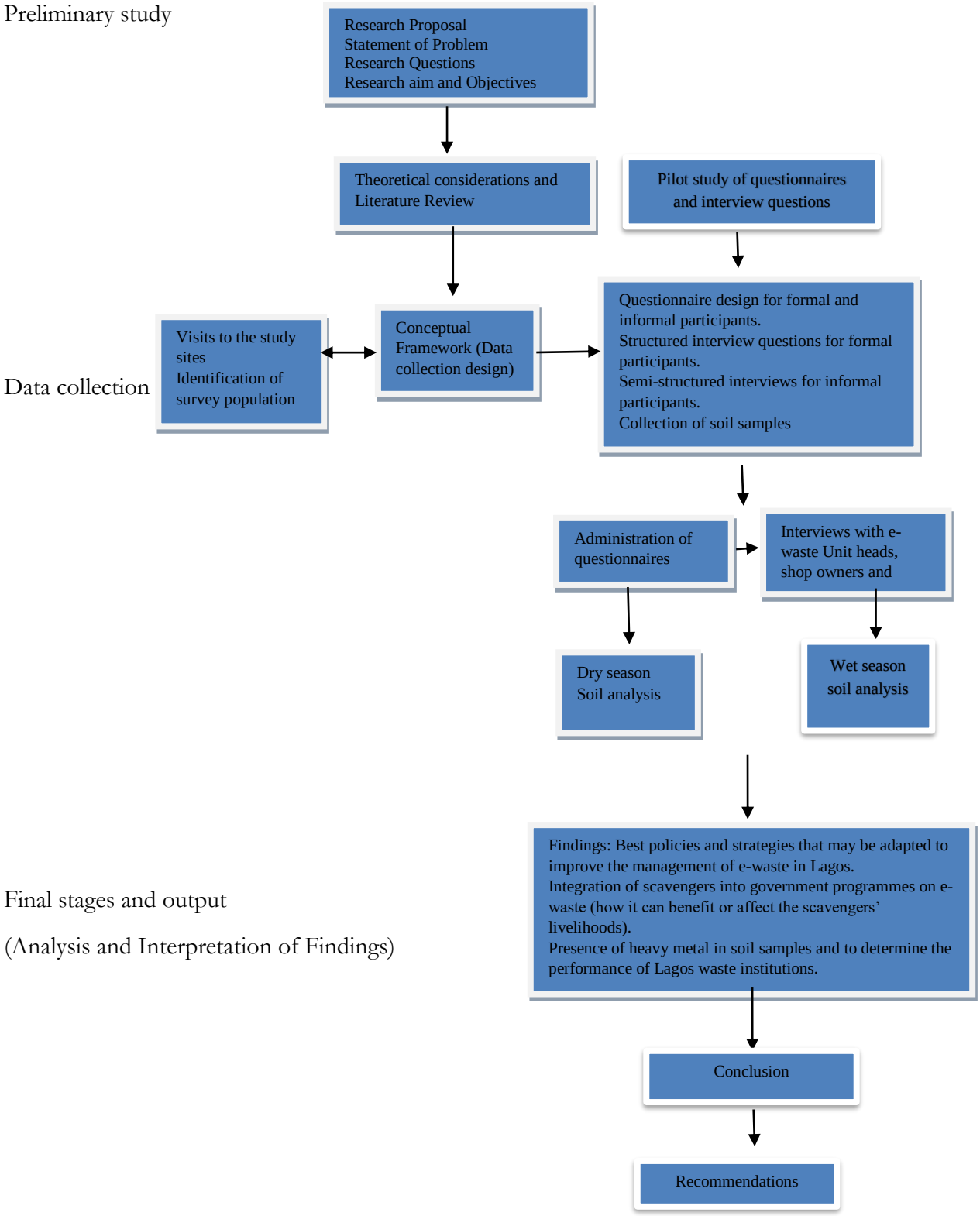



**Figure 3.1**: Flowchart showing the Research Design for this study

### 3.4 Study Area

Data used in this study were collected from eight scraps and dump sites in the city of Lagos, between October 2016 and June 2017. In this section, the brief geographical, demographic and socio-economic features of Lagos are discussed. Figure 3.2 shows the study locations within the city Lagos in Nigeria.

#### 3.4.1 A brief geographical profile of Lagos

Geographically, the city of Lagos is located in the South-Western region of Nigeria, on the Atlantic coast in the Gulf of Guinean, west of the River Niger delta. It is situated between 6 ° 27'8N and 3 °23'74E and covers a total land area of 1380.7 square kilometres. About 787.8 square kilometres of Lagos land area is made up of lagoons and creeks (LSG, 2016). Due to these features, Lagos is geographically classified into the Island and the Mainland. There are two major urban islands in Lagos. The lagoon areas are connected by bridges and are namely Lagos Island and Victoria Island. Concerning the geographical size, Lagos is the smallest state in Nigeria and has 20 local government areas (LGA).

The climate of Lagos is categorised as the tropical region with alternating dry and wet seasons. Due to its location around the Niger River delta, the city of Lagos has a long rainfall season. The rainy season is between April to September while the dry season is from October to March. The average monthly rainfall between May and July is usually over 400mm, 200mm in August and September and as low as 25mm in the dry season (Lagos State Government, 2016). Temperatures are typically high during the dry period with an average temperature of 29oC (840F) and low in the rainy season with an average temperature of 250C (770F) (NIMET, 2016).

Globally, Lagos is known to be one of the fastest growing urban areas with an average growth rate of 4.19% (World Population Review, 2018). This is because metropolitan Lagos covers over 37% of the land area which serves as a shelter to over 85% of the city's residents (Figure 3.2). The city is the principal business hub in Nigeria and West Africa due to its exceptional location. Ajibola et al., (2012) observe that over 70% of Nigeria business and commercial activities take place in Lagos. Furthermore, the presence of Apapa and Tincan Island ports adds to the city's international trade activities amongst other West African countries. Besides, it serves as Africa's largest harbour city and the most important dealer of e-waste in many countries in West Africa and the entire continent (McIntire, 2015). Due to industrial and commercial activities in the city, it is now listed as one of the dirtiest cities in the world because it lacks adequate solid waste management plans to cope with the solid waste generation. Previously, plastics and papers were the significant refuse generated in Lagos, but recently, the influx of e-waste is now taking over its streets (LAWMA, 2016).

#### 3.4.2 Demographic Features

In sub-Saharan Africa, the city of Lagos is the biggest and the second biggest city in the continent after Cairo (Ajibola et al., 2012; Lagos State Government, 2011). In 2006, the National Population Commission (NPC, 2006) estimated that 9,113,605 people were living in Lagos. Table

3.1 below shows the population development in Lagos State. However, Aluko (2010) observes that the annual growth rate in Lagos is 13.6%, about five times greater than the national growth rate of 2.8%. In 2016, the state government gave the population figure of the state as 17, 553,924. This claim was based on the parallel census carried out by the state, and it was also observed that over 88% (about 15.5 million) of the state's total population resides in the metropolitan area.

Table 3.2 below shows the population growth rate for the city of Lagos from 1886 to 2006. This figure reveals that globally, the city is one of the most rapidly developing cities (Lawal et al., 2016). In 1999, the United Nations anticipated that the Lagos metropolitan area with a total population of 290,000 in 1950 would go beyond 20 million by 2010, making it one of the tenth most populous cities in the world. In addition, the United Nation also predicted that from the way the city's population is growing, the total of people living in the city is estimated to be twice its population by 2050, thereby making it one of the biggest global towns with fewer amenities than any industrialised cities in the world (UN, 2015). Hence, in the light of the growing population, there is a need for the state government to develop methods that will address the needs of the populace. Aluko (2010) is of the view that there is an increase in the level of poverty among people living in the city of Lagos and that urbanisation overwhelms the city's facilities leading to loss of its original pride, struggles for survival and lack of adequate solid waste management plan and effective administration within the state.

**Table 3.1: Population Development in Lagos**

| Name | Status | Population Census *1991-11-26 | Population Census 2006-03-21 | Population Census **2011-03-21 |
|---|---|---|---|---|
| **Lagos** | **State** | 5,725,116 | 9,113,605 | 10,694,900 |
| Agege | LGA | 417,981 | 461, 734 | 541,860 |
| Ajeromi-ifelodun | LGA | 593,561 | 687,316 | 806,570 |
| Alimosho | LGA | 430,890 | 1,319,571 | 1,548,530 |
| Amuwo-Odofin | LGA | 225,823 | 328,975 | 386,060 |
| Apapa | LGA | 154,477 | 222,986 | 261,680 |
| Badagry | LGA | 119,267 | 237,731 | 278,980 |
| Epe | LGA | 101,464 | 181,734 | 213,270 |
| Eti-Osa | LGA | 157,387 | 283,791 | 333,030 |
| Ibeju/Lekki | LGA | 24,937 | 117,793 | 138,230 |
| Ifako-Ijaye | LGA | 233,341 | 427,737 | 501,950 |
| Ikeja | LGA | 203,383 | 317,614 | 372,720 |
| Ikorodu | LGA | 184,674 | 527,917 | 619,520 |
| Kosofe | LGA | 412,407 | 682,772 | 801,240 |
| Lagos Island | LGA | 165,996 | 212,700 | 249,610 |
| Lagos Mainland | LGA | 273,079 | 326,700 | 383,390 |
| Mushin | LGA | 539,783 | 631,857 | 741,490 |
| Ojo | LGA | 215,837 | 609,173 | 714,870 |
| Oshodi-Isolo | LGA | 449,781 | 629,061 | 738,210 |
| Shomolu | LGA | 358,787 | 403,569 | 473,590 |
| Surulere | LGA | 462,261 | 502,865 | 590,120 |

**Sources**: National Bureau of Statistics (2011)

National Population Commission (1998)

**The 2011 population projection assumes the same rate of growth for all LGAs within a state.

*The undercount of the 1991 census is estimated to be about 25 million.

**Table 3.2** Population growth rate in the city of Lagos 1886-2006

| Year | Area covered in $km^2$ | Total Population | Inter-Census Percentage Increase or Decrease | Rate of Change Per Annum For 1000 People | Average Inter-census Growth Rate Per Annum | Annual rate of Increase |
|---|---|---|---|---|---|---|
| 1866 | 3.97 | 25,083 | - | - | - | - |
| 1871 | 4.01 | 28,518 | 13.7 | - | - | - |
| 1881 | 4.01 | 37,452 | 31.3 | 13 | - | - |
| 1891 | 4.01 | 32,508 | 13.2 | - | - | - |
| 1901 | - | 41,847 | 28.7 | - | - | 2.5 |
| 1911 | 46.62 | 73,766 | 76.3 | 58 | - | 5.7 |
| 1921 | 52.24 | 99,690 | 35.1 | 31 | | 3.1 |
| 1931 | 66.28 | 126,108 | 26.5 | 24 | 2.3 | 2.3 |
| 1950 | 70.50 | 230,256 | 82.6 | 32 | 1.2 | 3.3 |
| 1963 | 70.50 | 665,246 | 188.9 | 86 | 8.5 | 8.0 |
| 1988* | 405.53 | 2,168,163 | 50.2 | - | - | - |
| 1991 | 405.53 | 4,248,963 | 96.0 | - | - | - |
| 2006 | 999.60 | 9,113,605 | 86.82 | | | 3.2 |

**Source**: (Aluko, 2010)

- Not available

* Projection

### 3.4.3 Socio-economic Feature

Human Development Index (HDI), "a combination of life expectancy, education, and gross domestic product per head", in Nigeria for 2015 is estimated at 0.527 and its gross national income (GNI) per capita is the US $ 5,443 putting Nigeria at 152 out of 188 countries (UNDP, 2016). This shows that human progress is meagre in the nation because many Nigerians are living in abject poverty surviving on less than a US dollar ($) a day (Iyoha and Oriakhi, 2008). However, UNDP (2016) observes that Nigeria's GNI per capita has increased by 98.4% between 1990 and 2015. Table 3.3 below shows some HDI figures for Nigeria from 1990 to 2015.

**Table 3.3** Nigeria's HDI developments based on regular time series data

| Year | Life expectancy at birth | Expected years of schooling | Mean years of schooling | GNI per capita (2011 PPP$ | HDI value |
|---|---|---|---|---|---|
| 1990 | 46.1 | 6.7 | - | 2,743 | - |
| 1995 | 46.1 | 7.2 | - | 2,529 | - |
| 2000 | 46.6 | 8.0 | - | 2,378 | - |
| 2005 | 48.7 | 9.0 | 5.2 | 3,606 | 0.466 |
| 2010 | 51.3 | 9.6 | 5.2 | 4,834 | 0.500 |
| 2011 | 51.7 | 9.7 | 5.5 | 4,940 | 0.507 |
| 2012 | 52.1 | 9.8 | 5.7 | 5,035 | 0.514 |
| 2013 | 52.4 | 10.0 | 5.9 | 5,173 | 0.521 |
| 2014 | 52.8 | 10.0 | 5.9 | 5,443 | 0.525 |
| 2015 | 53.1 | 10.0 | 6.0 | 5,443 | 0.527 |

**Source:** UNDP (2016)

As a result of high urbanisation, the city of Lagos has experienced high unemployment rates. The National Bureau of Statistics (2010) observes that the unemployment rate in the city has increased from 5.3% in 2001 to 27.6% in 2010. However, when compared to other states in Nigeria, the city has the highest employment and lowest unemployment rates. It is imperative to note that as the unemployment rate increases at the national level, the impact can also be seen at the state levels. In a bid to combat the unemployment situation in Lagos, many individuals have started creating jobs for themselves and their communities making the city a major economic hub in Nigeria. Although many of the jobs created are from the informal sectors, mostly small businesses, only a few are formal. Opoko and Olwatayo (2014) observe that the incomes from the informal business sectors are very low and uncertain. The informal sector economy is a part of the urban economy in Africa particularly in Lagos, and it has created livelihood strategies for many 'Lagosians'. At the moment, the informal sector now includes professionals, administrators and highly ranked employees (Opoko and Oluwatayo, 2014). Although surviving on jobs from the informal sector may be difficult, since the city of Lagos has a rich economic growth few people have been able to provide livelihoods for their immediate families. For instance, in chapter 2 of this thesis, it has been shown that in Lagos, many people have created jobs from scavenging to invent urban livelihoods for themselves and their families.

Also, the city has the highest internally generated revenue (IGR), mainly through taxes because many commercial banks, financial institutions and primary cooperation headquarters in Nigeria are situated within the city (Nwagwu and Oni, 2015). Most of these business activities are carried out in the central business district located on Lagos Island. Kazeem (2017) is of the view that the increasing IGR rate and rising economy has contributed to the city's development, making it one of the leading cities in Africa and the world. In 2014, for example, Kazeem (2016) reveals that the gross domestic product (GDP) of Lagos was US $90 billion which made the city the 7th largest economy in Africa, bigger than Cote d'Ivoire and Kenya and also, it generates around 10% of Nigeria's GDP. Furthermore, since the city houses the major ICT centre and the largest ICT market in West Africa and the continent, Ofudje et al., (2015) observe that used electronics

refurbishing sector in Lagos generates up to 0.015% of Nigeria's GDP and that the sector also pays up to $419,000 to the state government annually as taxes.

Recently, the Lagos State Government (2016) announced that the city has also discovered crude oil and this will make the city one of the oil producing states in Nigeria. Although the oil producing activities will create more jobs for the unemployed because many petroleum producing companies have started building refineries in the city, it will also earn it more revenue; however, this activity will create environmental threats to the city since it is densely populated. Because of this, it is crucial for the state government to look into and enforce its environmental laws so as not to give room for environmental injustices against the poor in the city of Lagos.

### 3.4.4 Locating the study sites

The research sites in this study were chosen because of their size, location, international recognition level and for various economic activities. Fieldwork selection site for this study was complicated as previous studies on solid waste management have been carried out in some of the locations. As a researcher, one of the challenging issues was getting a location devoid of biases, as this could have severe implications on the research result of a study (Chambers, 1983). This is because some study locations may be readily accessible and the researcher might be familiar with the study site. In this study, the researcher was familiar with Solous MRF and Olusosun landfill because of their location and the waste sorting activities which provides a livelihood for the scavengers as well as Ikeja computer village as it is the most popular ICT market in the city of Lagos.

#### a) Alaba International market

The market is the biggest and widely patronised electrical and electronic open market in West Africa. It is situated between latitude: 6.460 and longitude: 3.1570 in Ojo LGA (see Figures 3.2) of Lagos State (Isimekhai et al., 2017). The market was established in 1978, and it occupies a land area of approximately 2 km2 in the South Western part of Lagos (Jibiri et al., 2014). The market houses more than 2500 shops doing refurbishing and selling second-hand electronic products. A lot of these goods include end-of-life electronics appliances like mobile phones, television, computers, microwave oven, etc. that are made up of a different mix of metals and nn-metals (Ogungbuyi et al., 2012). Due to congestion in the market, temporary buildings are put up in the market to house the growing population (Jibiri et al., 2014). A major dump site (about 100 m2 in size), where dangerous dismantling and recycling activities such as burning and other practices take place is also located around the market. This is done in an attempt to recover some useful materials from unused/damaged electronics, is located outside the market. Isimekhai et al., (2017) observe that informal activities such as manual dismantling of electronics to recover metals and other precious materials as well as open burning of electronic components and wire cables started in the market in 2010. More so, there are residential buildings around the scrap site. Previous studies have shown that crude recycling activities from the e-waste scrap site around the market have resulted in contaminations of soil, plant, air and water sources due to heavy metal existence in the environment (Isimekhai et al., 2017; Jibiri et al., 2014; Olafisoye et al., 2013).

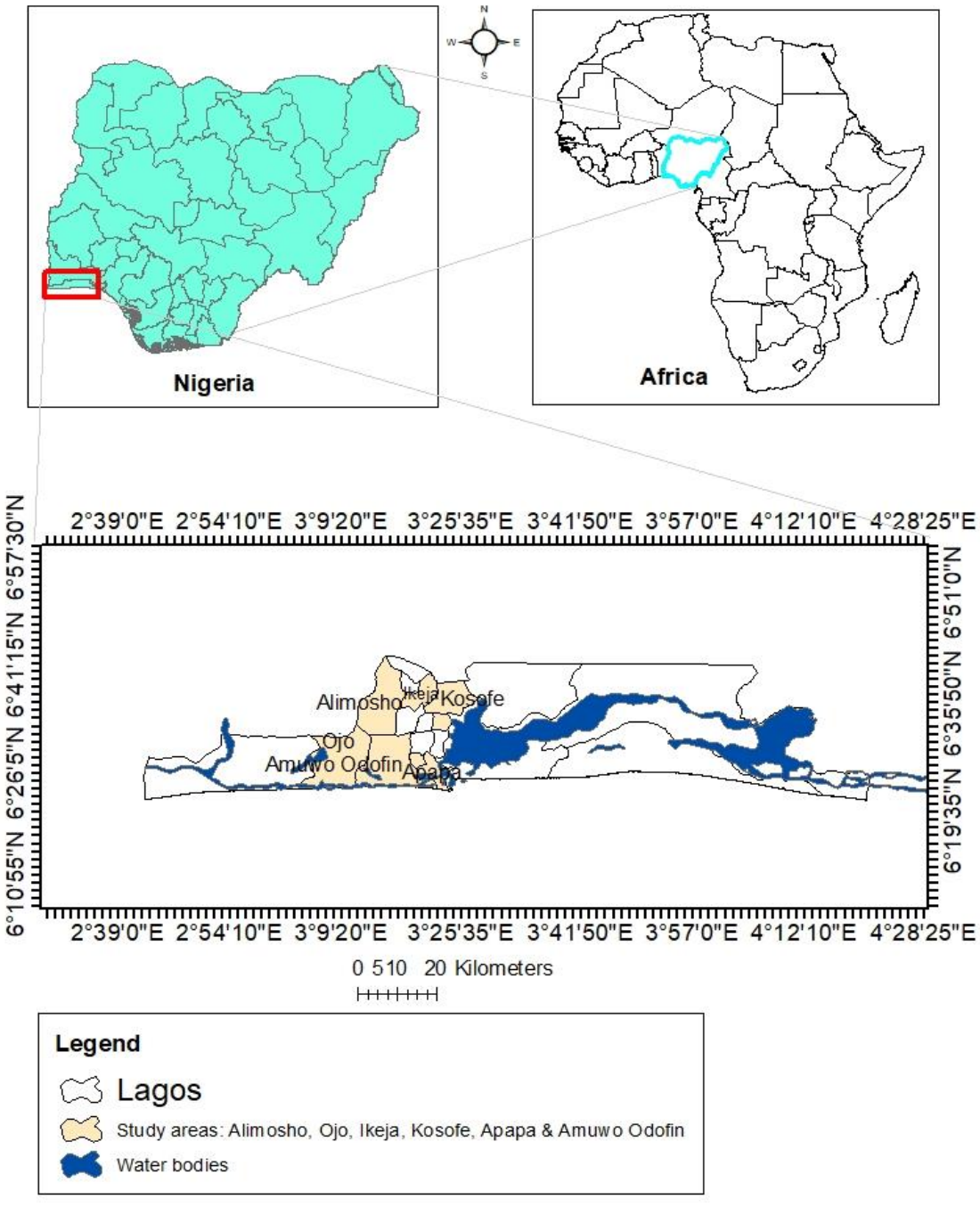



**Figure 3.2: Map of Lagos in Nigeria showing the study locations**

**Source**: School of Geography, University of the Witwatersrand

**b) Ikeja computer village**

The market is located between latitude 6.590 and longitude 3.340 in Ikeja LGA (Figure 3.2) of Lagos State. According to Ofudje et al., (2015), the market is an exceptional hub of commercial and ICT bustle in Lagos that draws numerous consumers from within and outside Nigeria. It grew from small ICT shops to a broad marketplace which now affords jobs for the unemployed youths, creating an enabling working environment for private companies and stakeholders, as well as providing ICT training for over 3,000 small-scale business owners. Goods are imported from the USA, China, Germany, Singapore, Hong Kong and Dubai, however, the amount of goods imported differs from one trader to the other (Ogungbuyi, 2012).

**c) Olusosun Landfill**

It is situated at about 10km South East of Ikeja Local Government Area, (Figure 3.2) and lies between 6°23'N; 2°42'E and 6°41'N; 3°42'E (Oyeku and Eludoyin, 2010). It began operation in 1992. The size of the landfill is 42.7 hectares, the largest in Africa and one of the largest in the world (Oyiboka, 2014; LAWMA, 2011; Sanusi, 2002). According to LAWMA (2011), over 40% of the solid waste collected from Lagos is dumped on this site. The landfill receives unprocessed waste of all sorts, from biological to non-biological and toxic to harmless waste. The waste dumped in this site includes batteries, unserviceable electronics and computers, household cleaning equipment, industrial wastes, pharmaceuticals and personal care products (PCPs), among others. Also, scraps from over 500 containers are dumped in the landfill, increasing the volume of e-waste in the site (Ogungbuyi et al., 2012). Freeman (2012) also observes that on the dump, toxic substances are used to remove valuable materials from e-waste leading to the release of toxic fumes into the environment.

**d) Solous Landfill**

The site is situated at Igando between Latitude 6.570N and Longitude 3.250E in Alimosho LGA (Nwambuonwo and Mughele, 2012). According to LAWMA (2010), operation commenced in 1996 with a proposed duration of 5 to 6 years. The site consists of both existing and closed dumpsites, and it is a registered dumpsite under LAWMA. Solous landfill is separated into three divisions, i.e. Solous I, II and III; all divisions are still functioning despite its expiration date (Oyiboka, 2014). The three divisions occupy about 10.8 hectares of land, also at least 2, 250 m3 of waste is disposed of in each section per day (LAWMA, 2017). Over the past few years, due to the growing population in Lagos, Solous area is presently being occupied by citizens, entrepreneurs and manufacturing companies. The state government have recently converted the landfill site to material recovery facilities (MRF) where sorting and recycling activities take place.

**e) Westminster Electronic Market**

The market is situated in Apapa area of Lagos State (Figure 3.2). Ofudje et al., (2015) observe that although the market is small, it is located in a strategic area very close to Tincan Island Port (a major seaport for import activities in Lagos). Doherty and Ladipo (2014) observe that the location is desirable because it is the point used for disembarking and selling of used electrical

and electronics equipment (second hand). Over 300 shops in the market sell varieties of used electrical and electronic devices (Olakitan et al., 2012; Osibanjo, 2010). However, the primary activity in this market is off-loading, selling of tested electrical devices and repairs of all damaged e-waste.

**f) Abule-Egba Dumpsite**

This site occupies about 10.2 hectares of land and lies between Latitude 6.640N and Longitude 3.300E, (Figure 3.2) in the western part of Lagos in Alimosho LGA (Nwambuonwo and Mughele, 2012). The dumpsite is positioned within residential areas along the Oshodi– Sango road and shares borderline with Oko-Oba market. This is somewhat contrary to the international environmental law, which requires that protected area be left between dumpsites and its neighbouring areas (Akinjare et al., 2011). The remaining lifespan of this site is approximately eight years. The principal activity on this site is now the sale of all manner of scrap. Unlike other dump sites in Lagos, the management of this site is relatively weak as waste especially food waste from the market is dumped openly along the road. Although LAWMA has closed the dumpsite, trash is still dumped on this site by the people in the neighbourhood. Presently, the state government has constructed road entrance to the dump site for easy accessibility for waste trucks and cart pushers.

**g) Owode Onirin Scrap Market**

The scrap market is situated near Mile 12 in Lagos and located between latitudes 6°36'14.87"N and 6°36'32.4"N and longitudes 3°24'47.05"E and 3°24'48.6"E (Figure 3.2). Varieties of scraps are bought and sold in this market. It is one of the many steel markets where different kind of metal spare parts can be found. According to Ojekunle et al., (2016) the market is divided into metal scrap dismantling and auto division. Many of the second-hand goods and scraps are imported into the market from Japan, Europe and sometimes Malaysia and China. There are about five hundred shops in this market. Also, there are steel milling companies owned by foreigners from Lebanon, China and India. Furthermore, different scraps for building, varieties of aluminium, electrical wires of all type, car spare parts, scraps of ship/plane parts, beams and rods, among others are sold in the market. Ojekunle et al., (2011) reveal that the market area is well known for the disposing and burning of hazardous waste that destroy the surroundings. Furthermore, the people residing in this neighbourhood are exposed to dangers from heavy metals because little or no attention has been given to the market.

**h) Alakija Dumpsite**

This is an illegal scrap site created by the scrap and plastic waste collectors. It is a wetland zone located in Festac Town Third Gate, Amuwo Odofin LGA, (Figure 3.2) Badagy Expressway, Lagos, Nigeria. It lies between Latitude 6.45770N and Longitude 3.27130E. According to Adeleke (2012), there are no specific regulations associated with swamplands, erosion, protected areas and the conduct of environmental impact assessment in Amuwo Odofin Local Government. This accounts for the reasons why waste dumps and scrap sites are set up anywhere within the local government. Although there are other illegal dumpsites within the local

government, this site was chosen because people have shops and businesses around the area. Also, it is a major bus stop where commuters use for public and private transport purposes.

### 3.4.5 Target Population and Sampling

Before the fieldwork of this study, research participants in Lagos waste institutions were contacted by telephone and e-mail, the institutions that agreed to participate were sent the questionnaires and predetermined interview questions via e-mail.
In all the study sites, the criteria for selection of participants were:

i) All participants knew about solid waste (e-waste) management or were people dealing in second-hand electronics (e-waste importers, scrap dealers, electrical repairers and collectors) and e-waste policy makers in government agencies.

ii) All participants were 18 and years above.

iii) The researcher ensured that all respondents resided in Lagos and owned businesses within the six local government areas selected for this study.

Using a sample size calculator designed by Creative Research Systems (2012), the population size in this study was established. For e-waste pickers, the assumed population size was 400 and a confidence level of 95% (0.05) as used by Ezeah (2010), a sample size of 291 was calculated. More so, populations of 120 were assumed for e-waste dealers and sample sizes of 108. Furthermore, 50 respondents were considered for solid waste institutions and the sample size of 48 was determined hence, the total population of respondents for the questionnaire assessment is 447. Table 3.4 presents the details of sample sizes for the three questionnaire survey.

**Table 3.4 Sample Size Calculation**

| | Confidence level (%) | Confidence interval | Population size | Sample size |
|---|---|---|---|---|
| E-waste collectors | 95 | 3 | 400 | 291 |
| E-waste Business | 95 | 3 | 120 | 108 |
| Waste institution | 95 | 3 | 50 | 48 |
| **Total** | | | | 447 |

### 3.4.6 Methods of Data Collection

Specific data collection methods are chosen to answer the research questions in this study. The research employed a mixed methods research approach. According to Creswell (1998) and Denzin and Lincolin (2000), this approach adds consistency and gives detailed knowledge on the subject matter, and provides corroborative evidence of the data obtained. In this study, a field investigation was carried out in two stages.

In the first stage, data were gathered through field observation in the study areas described in section 3.5.4; questionnaires were administered to scavengers, e-waste business dealers and staff from e-waste institutions at LASEPA, LAWMA and NESREA, interviews were also conducted with some e-waste dealers, scavenger/scrap chairpersons and waste institution staff. In the second phase, soil samples were collected at some scrap and dump sites to check for toxic

pollutants and the level of contamination by heavy metals. This was done to assess the presence of toxic heavy metals and also to check whether the waste institutions had been able to divert e-waste disposal from landfills.

### i) Designing Research Questionnaires

The use of questionnaires was the primary methods of data collection. According to Ian (2015), using surveys for data collection has many advantages that include; potential bias reduction, anonymity and improved validity of responses by the participants, provides structured data that can be readily analysed and allows participant complete at a convenient time. On the other hand, the researcher may not be able to gather useful data using questionnaire if the questions are too vague, slow responses from the respondents and failure of the researcher to have control over the participants. It has been observed "*that too often, surveys are carried out on the basis of insufficient design and planning or on the basis of no design at all. 'Facts gathering' can be an exciting and tempting activity to which a questionnaire opens a quick and seemingly easy avenue; the weaknesses in the design are frequently not recognised until the results have to be interpreted- if then!*" (Oppenheim, 1992:7). Therefore, before a researcher designs a questionnaire, it is essential to identify the information needed. Furthermore, it is crucial that the researcher conducts a pilot study on a survey before administering to the respondents. This is necessary because it will allow the researcher to make necessary corrections to the questions in the research and to know if accurate data can be generated.

In this study, comprehensive well-structured questionnaires were designed. The study employed three different types of research questionnaires (waste pickers, e-waste businesses and waste agencies) to collect data on e-waste regulations and sustainable livelihoods of the urban poor in Lagos. The questionnaires designed by the researcher are presented in Appendix 2, 3 and 4. They were designed to draw information that could be obtained through written responses from the targeted populations on e-waste management in Lagos. The rationale for survey questionnaire includes: (i) the ability to get hold of data for analysis purpose which might be suitable to achieve the objectives of the study and (ii) to gather information on e-waste management and poor urban livelihoods in these study areas. Burns and Groove (1993) are of the view that data collected from the use of a questionnaire is similar to data girthed through an interview, but questionnaire has less depth. The importance of an excellent research study and suggested best practices for questionnaire design and administration have been clearly described by De Vaus (2007) and Baker (2003). Based on these suggestions, the survey questionnaires were designed to be completed by participants and written in short-term, easy to read and comprehend entirely without preference or uncertainty.

The questionnaire for e-waste collectors is broadly divided into four sections. Section 1 included the identification number, region of origin and site location. Demographic data are presented in section 2. Section 3 consisted of questions on solid waste management, and it was subdivided into the following four parts:

(i) general solid waste management

(ii) questions on e-waste

(iii) questions relating to environmental issues and health of e-waste pickers/collectors

(iv) questions on policy and management

In the last section of the of the questionnaire, questions on informal livelihoods of the poor were asked.

Questionnaires for e-waste business owners and waste management staff from waste institutions were similar, while section 1 and 2 were identical to that of e-waste collectors. Section 3 comprised questions on electronic waste management and it was subdivided into five parts:

(a) Government Organisation

(b) E-waste Related Issues

(c) E-waste Importation

(d) The informal sector

(e) Policy and Challenges

The questionnaire consisted of open-ended and close-ended questions that provided various details on the study. Reja et al., (2003) and Foddy (1993) are of the view that while the close-ended questionnaire limit respondents, open-ended questionnaire allows the respondent to give answers without interference by the researcher. Furthermore, open-ended questions were included so that respondent could answer the questions using their own words and give their views and sufficient details on the research issues. Closed-ended questions were also included because they can quickly be answered by participants and analysed statistically. However, Polit and Hungler (1993) observe that closed-ended questions are well organised because it is easier for respondents to complete within a given period than open-ended questions.

**ii) Pilot Study**

Pilot studies are done before the primary data collection exercise. Munn and Drever (1990) observe that pilot studies can be used in determining the thoroughness and strength of methodological considerations for research. Thabane et al., (2010) are of the view that pilot studies can be used in both quantitative and qualitative analysis. The study is essential in the determination of the questionnaire or predetermined interview question; also it helps the researcher establish the research objectives of a survey (Ezeah, 2010). In addition to this, it ensures the validity of responses (Pole and Lampard, 2002). Van Teijlingen et al., (2001) and Van Teilingen and Hundley (2001, provide the summary of the explanations for using a pilot study. Samples for the pilot study in this research were drawn from amongst some Nigerian elites in Johannesburg due to the distance from the study area, financial and time restrictions. Ten copies of the questionnaires and three predetermined interview questions were self-administered to various participants for the pilot study. Of the study population, eight respondents completed and returned the questionnaires and interview questions. Data collected from the pilot study revealed valuable corrections to the sections of the questionnaire as well as predetermined interview questions that required adjustment before the actual research. Furthermore, from the feedbacks, some questions were readjusted to accommodate responses that were coming back and the average time it was taking to complete one questionnaire.

### iii) Survey Questionnaires

Questionnaires were handed to the e-waste pickers, e-waste business owners and government waste institutions by the researcher. The benefit of this approach is mainly to increase the frequency of questionnaires the researcher had administered to the participants. This is essential, since the researcher needs to collect them after completion. A study by Philip et al., (2002) reveal that the research questionnaires return rate should be 98%. However, the return rate approach is not realistic as it is difficult, time-consuming and costly. This study adopts the probability sampling method (simple random sampling). In this method, the respondents were randomly selected.

### 3.4.7 Interviews

Qualitative research interview is a discussion that involves the in-depth collection of information on a subject matter (Berg, 2009). Rubin and Rubin (1995) argue that interviews are ways of gathering data and that the conversation should be flexible and interacting. The key features of qualitative research interviews are to explore the study from the perspective of the interviewee and to know the reasons for the particular view (King, 2004). To understand the purpose of research interview, Kvale (1983) observes that "qualitative research interviews will generally have the following features: a low degree of structure imposed by the interviewer; a preponderance of open questions; and a focus on 'specific situations and action sequences in the world of the interviewee' rather than abstractions and general opinions". According to McNamara (1999), interviews are very beneficial because they help the researcher obtains in-depth details from the participant responses. Therefore, it can be argued that the interviewer may be able to get profound information on the subject matter and it may be expedient as a follow-up to some other responses from the questionnaires. McLeod (2014) observes that interviews are different from questionnaires due to the social interaction involvement. There are different categories of interviews classified by different researchers under structured, semi-structured and unstructured groups. The significant difference in these interview types is their strict similarity to the structured approach (Gill et al., 2008; Fitzgerald and Cox, 2002; Bryman 2001).

This research adopted structured and semi-structured interview approaches so that the crucial topics could be covered within the given time. Structured interviews are referred to as orally distributed questionnaire because the lists of predetermined questions are asked (Gill et al., 2008). On the other hand, semi-structured interviews contain varieties of questions that enable the researcher describes the subject area, it as well allows the interviewer or interviewee deviate from the questions to provide detail information (Britten, 1999). Semi-structured interviews were also adopted so that the interviewees can express themselves and also allow those in the formal sector to write down their opinions because of their busy schedules. The first structured interviews were administered to staff in the government institutions and the completed copies were collected at intervals during data collection.

Silverman (1993) is of the opinion that to improve the reliability of interviews, an interview guide is needed. This helps the researcher to direct the conversation towards the research area. The interview guide in this research is broadly divided into three main topics: the current management practices employed by the waste institutions in the management of e-waste, port of

entering (means by which e-waste gets to Lagos) of second-hand electronics and the adopted regulations for import as well as policy and legal framework adopted for e-waste management within Lagos State. In a bid to cover these topics, the interview guide included questions on waste institutions for the interviewees, general practices adopted for disposal of e-waste by the waste institutions, main strategies/ policies adopted on e-waste management to cite a few (see Appendix 5 for details). Research on e-waste management requires the participation and interaction of different stakeholders. In this study, the stakeholders involved in the structured and semi-structured interviews include government officials dealing in solid waste management, e-waste dealers, dismantlers and repairers. Discussed below are the categories of those who participated in the discussions.

**a) Informal Respondents**

All the informal interviewees were asked questions on sources and methods of e-waste procurement, how they disposed of their e-waste and how its management can be improved. Below is a brief description of the participants involved in the structured and semi-structured interviews and their unique features:

**Dealers** are traders that import or buy second-hand electrical and electronics devices (from industries, institutions, households etc.). They play the most significant role in the e-waste market and engage in trading, collection, disassembling and sending e-waste for recycling. They function both locally and nationally. In Nigeria for example, e-waste dealers and importers are bound by regulations and principles provided by the National Environmental Standards and Regulations Enforcement Agency (NESREA).

**Collectors** usually referred to as condemned (damaged or unused e-scrap) buyers in Lagos, Nigeria. They are the most notable among e-waste stakeholders because they can be seen going from door-to-door in some residential areas and shop-to-shop at the e-waste markets. Many of these scrap buyers work for bosses they deliver the scrap materials to on a daily basis, only a few work on their own. They sell the collected scraps to local e-waste dealers or e-waste recycling companies.

**Second-hand shops and repairers**: Lagos houses the largest second-hand market in West Africa. This market does not only provide services to those in the city of Lagos but also to clients from all the 36 States within Nigeria and other countries across West Africa. Many second-hand electronic marketers import used computers, televisions, mobile phones, refrigerators etc. from overseas countries (like the United States, United Kingdom, Germany and China), and they sell to the household, bulk users, traders and other collectors. However, it should be noted that many of the e-waste importers/ second-hand shop owners also employ the services of electrical and electronic repairers who are trained in computer hardware, television, phones etc. repairs.

**Dismantlers and Recyclers** - they specialise in e-waste sorting, disassembling and dismantling of scrap materials that have been discarded. During the manual sorting, e-waste is separated into metals and non-metals that are eventually sold through intermediaries. Some of the dismantlers

can refurbish and reassemble condemned e-waste parts and components that are sold to the second-hand users.

**b) Formal Respondents**

Formal respondents were selected majorly from the government agencies dealing in solid waste management. They are; LAWMA, LASEPA and NESREA. Initial surveys on the different departments handling e-waste had been carried out, and officials responsible were targeted. At each of the institutions, staff members with knowledge and experience on e-waste management were selected. Thematic questionnaires and predetermined interview questions were sent to the institutions beforehand, and some members provided answers before the interview dates as they knew their schedule would not allow them to participate in the set dates while others appointed other members of staff in the field of e-waste to stand in for them.

### 3.4.8 Field Observation

This was done to authenticate the information provided by NESREA and LASEPA on e-waste regulations as well as participants' responses during this study. It is crucial for a researcher to have prior knowledge on the study to be conducted and about the environment chosen as study sites, as it will enable the researcher to validate the collected data and also to understand what should be achieved at the end of the study. Bryman (2004) is of the view that field observation may be accomplished by searching for correlations or disparities between what participants in the survey say and what they practice in the real world. Observation in this study was based on participant observation, and according to Kawulich (2005), this method enables the investigators to observe the participants in the field, as well as identify detailed evidence that the interviewee may not be willing to share with the researcher during the interview. Also, some pictures were taken on the field as part of the process and notes were taken. The e-waste scavengers were observed during waste/ condemn collection from the scrap sites and some shops within the market. Some important points were noted during the field observation and were included in the study.

## 3.5 Soil Sample Collection

Soil samples were collected at the end October 2016 representing the dry season and the wet season samples were collected in June 2017. The selected study sites are Alakija, Olusosun, Solous and Owode Onirin. Surface soil samples were obtained directly from the scrap and dump sites within the depth of 0-10cm using soil auger and trowel. The trowel was used to transfer the soils from the auger into the sample plastic bags. At the end of each site collections, the soil auger and trowel were thoroughly cleaned before using on another site. Three samples were collected from each study site. A total of 12 soil samples were collected from the four study sites.

### 3.5.1 Parameters Examined

This study examined the physical, chemical and heavy metals present in the soil samples. The physical parameters investigated were: colour, temperature (0C), pH, odour, and percentage moisture contents. The chemical parameters examined include nitrates, phosphates, sulphates, % organic carbon and % organic matter. While the trace/toxic heavy metal parameter analysed

were; zinc (Zn), iron (Fe), lead (Pb), manganese (Mn), calcium (Ca), cadmium (Cd), copper (Cu), silver (Ag), potassium (K), nickel (Ni) and Sodium (Na).

### 3.6.2 Laboratory analysis

All the soil samples were taken to the Lagos State Environmental Protection Agency (LASEPA) land and soil laboratory for analysis.

The soil samples were air dried in the laboratory at ambient temperature to remove the moisture. After this, the dried samples were crushed in a pottery mortar and later sifted through a 2-mm mesh size sieve so that the soil can be even and subtle. Using a calibrated electrode pH meter (211 microprocessor meter model-50% w/v), the soil pH was determined. It was determined by adding 25ml of distilled water to 10g of soil samples in a beaker. The soils were mixed thoroughly and allowed to stand for 2 hours, and the suspension was then measured to determine the pH.

Percentage organic matter present in the soils were measured by mass loss upon ignition of oven-dried soil in a soft heating system at 550 °C, and the samples were left for at least 6 hours. Also, percentage Organic carbon was determined in the laboratory using the Walkley-Black titration.
Samples for the detection of heavy metal concentrations were weighed and digested with 70% Nitric acid (HNO3) and left in the fume cupboard overnight. The mixtures were heated continuously at 1040C for 2 hours the next day. The digested mixtures were filtered through a Whatman filter paper, and distilled water was mixed with the filtrate. There and then, the solution was poured into bottles for heavy metal analysis using Atomic Absorption Spectrophotometer.

## 3.6 Data Analysis

Data collected from the field through survey questionnaires and soil samples were analysed using the Statistical Package for the Social Sciences SPSS version 24. Other data generated from the soil samples were analysed using Microsoft Excel for Windows. Data from the questionnaires were nominal and ordinal while results from the soil sample analysis consisted of scale and nominal variables. Nominal data is made up of nominal variable - "variables that have two or more categories, but which do not have an intrinsic order" while ordinal data is made up of ordinal variables – "variables that have two or more categories just like nominal variables only that the categories can also be ordered or ranked" (Laerd statistics, 2017). Nominal and ordinal data can be analysed best using descriptive and inferential statistics (Field 2000; Tabachnick and Fidell, 2001). The data were first subjected to a normality test to determine if the data were normally distributed.

### 3.6.1 Descriptive statistical analysis

The term descriptive statistics are used to describe data measures and analysis summaries in an easily comprehended, qualitative form (Williams, 2006; Thomas and Brubaker, 2008). However, this statistical analysis does not permit researchers to make deductions outside the data that have

been analysed. Therefore, William (2006), supported by Thomas and Brubaker (2008), observe that this analysis includes the use of distribution (frequencies), measures of central tendency (mean, median and mode), dispersion (standard deviation), percentages, percentiles, measures of variability and correlation techniques to describe the various data collected during the study. This statistical method was used in this study to analyse data gathered from respondents during the fieldwork. Some of the analysed results were then represented graphically.

### 3.6.2 Inferential Statistics

Inferential statistics "involves providing an estimate of how likely a sample of people or events accurately represents a broader population of people or events" (Thomas and Brubaker, 2008). Therefore, it is necessary that the selected number of people signifies the total targeted population. The statistical approach also allows researchers to make predictions. According to William (2006), the simplest inferential test is used while comparing the average activity of two sets on a single measure to see if there is a difference. There are two methods of inferential statistics namely: (1) estimating parameters, which involves the use sample mean to describe the population mean; (2) Hypothesis test, where a researcher can answer research questions by using sample data.

#### a) Analysis of variance (ANOVA)

This is the best statistical technique that can be used to assess the differences between two or more means. Glass and Hopkins (1984) are of the view that "ANOVA is the most common of all inferential statistical techniques in education and behavioural science". It is not only used to test specific differences among mean but also used to test the general mean. Also, it can be used to simultaneously test for significant differences between the average means of three or more populations (Thomas and Brubaker, 2008). They further reveal that outcomes from ANOVA are more precise than t-test results from the analysis.

An ANOVA approach that can be used to establish statistically substantial differences between two or more subjects is called a one-way ANOVA. On the other hand, an experimental design that compares the significant effect of two items and possesses numerous remarks at each trial level is called a two-way ANOVA also the data must be balanced (Lane, 2017). Results from ANOVA are interpreted in terms of the probability (Thomas and Brubaker, 2008). If there are significant differences in a group mean, a conclusion is written from various dispersion selection of mean and the null hypothesis will imply that the means are the same is rejected.

ANOVA is mathematically written in Equation 3.1

$$SS = \sum(X - x)^2 \qquad \textbf{Equation 3.1}$$

Where SS = sums of squares, x = individual estimate and $x$ = average score

Equation 3.2 below shows the variance of n measurement

$$\sigma^2 = \frac{\sum_{i-1}^{n}(x - \bar{x})^2}{n - 1} \qquad \textbf{Equation 3.2}$$

$\sigma^2$ = Variance, $x$ = individual score, $\bar{x}$ = group mean score n= number of sample

The numerator $\sum_{i-1}^{n}(x-\bar{x})^2$ is referred to as the *sum of squares* of deviations from the average score while (n-1) is referred to as the *degrees of freedom*

Standard deviation (S) is the square root of variance ($\sigma^2$), it is can be seen in Equation 3.3

$$S=\sqrt{\sigma^2} \qquad \textbf{Equation 3.3}$$

**(a) Correlation analysis**

Correlation statistics, also known as bivariate statistics is a statistical technique that establishes the level of interaction amongst two distinct factors. Furthermore, it is a means of assessing the relationship between variables. In this technique, the two features are usually a brace of marks for an individual or article. Variation between the two features can be from strong to weak or none. A strong variation implies that knowing an individual's or article's mark on a subject will enable the prediction of their score on the second subject. A correlation is weak when an individual's mark on feature A does not help to predict the mark on feature B. A significant aspect of correlation efficient is that it ranges from -1.00 to + 1.00, if any values fall outside this range, they are invalid (Cohen et al., 2013).

### 3.6.3 Soil surface contamination

In this study, contaminations of surface soil samples from the four location sites were ascertained by determining the following; contamination factor (CF) introduced by Hakanson (1980), pollution load index (PLI) described by Tomlinson et al., (1980) and geo-accumulation index (Igeo) used by (Muller, 1969).

**a) Contamination factor**

The contamination factor formula was first used by Hakanson (1980) to determine soil contamination status. The contamination factor designed according to D. C. Thomilson et al., (1980) is written as:

$$\mathbf{CF = C_S/C_B} \qquad \textbf{Equation 3.5}$$

Where $\mathbf{C_S}$ refers to the concentrations of trace/toxic heavy metal in the soil samples

$\mathbf{C_B}$ refers to the baseline or background value.

In this study, the world shale average background concentration values used by Turekian and Wedepohl (1961), Bowen (1979) and Onyari et al., (2003) were used (see Table 3.5). These values were used as there is no background value for heavy metals in Nigeria. Many researchers have utilised the standard background concentration values to measure the contamination factors of soil samples.

To determine the extent of contamination in the soils, four categories are adopted to describe this:

To determine the extent of contamination in the soils, four categories are adopted to describe this: CF < 1 refers to low contamination factor;

1 ≤ CF < 3 indicates moderate contamination factor;

3 ≤ CF ≤ 6 shows considerable high contamination factor and;

CF = 6: very high contamination (Nasr et al., 2006).

**Table 3.5**: Trace/ toxic heavy metal geochemical background world standard

| **Study Trace/Heavy metal** | **Geeochemical background shale limit (mg/kg)** |
|---|---|
| Zinc | 95* |
| Iron | 40,000** |
| Lead | 20* |
| Manganese | 900*** |
| Cadmium | 0.3* |
| Copper | 45* |
| Nickel | 68* |

*Turekian and Wedepohl (1961) **Bowen (1979) *** Onyari et al, 2003

**a) Geo-accumulation index**

The geo-accumulation index (Igeo) was first defined and used by Müller (1969) to access the metal pollution concentrations in sediment and developed global standard shale values (Ado et al., 2012; Praveena et al., 2007). This index is expressed as:

$$Igeo=\log_2(Cn/1.5Bn) \qquad \textbf{Equation 3.6}$$

Where Cn = the measured concentration of the element in the soil;
Bn = the geochemical background value and;
The constant 1.5 is introduced to analyse natural variations of the background values in the environment and to detect very small anthropogenic impact. Müller (1979), has defined seven classes of Geo-accumulation Index (see Table 3.6)

**Table 3.6**: Igeo classes

| Class | Value | Soil dust quality |
|---|---|---|
| 0 | Igeo≤0 | Uncontaminated |
| 1 | 0< Igeo <1 | Uncontaminated to moderately contaminated |
| 2 | 1< Igeo <2 | Moderately contaminated |
| 3 | 2< Igeo <3 | Moderately to heavily contaminated |
| 4 | 3< Igeo <4 | Heavily contaminated |
| 5 | 4< Igeo <5 | Heavily to extremely contaminated |
| 6 | Igeo≥5 | Extremely contaminated |

**Source:** Ado et al., 2012

**b) Pollution load index**

The Pollution Load Index (PLI) is an effective tool in heavy metal pollution evaluation. It was first was used by Tomlinson et al., (1980) to determine the magnitude of heavy metal contamination in sediment. In this study, the Pollution load index for each site was evaluated using:

$$PLI=(CF1xCF2xCF3x.....CFn)1/n \qquad \textbf{Equation 3.7}$$

Where: **n** = the number of contamination factors and sites, respectively.

According to Chakravarty and Patgiri (2009), the PLI value > 1 is polluted while PLI value < 1 indicates no pollution.

## 3.7 Data Validity and Reliability

It is very imperative to evaluate the validity and reliability of a study. Winter (2000) opines that "reliability and validity are tools of an essentially positivist epistemology." Validity shows whether the findings of the study are justified based on its design and interpretation (Botman et al., 2010). Seliger and Shohamy (1989) observe that internal and external factors could influence the validity of the research instrument. Hence, internal validity is described as "the term used to refer to the extent to which research findings are a true reflection or representation of reality rather than being the effects of extraneous variables" (Dezin, 1970). Specific factors deter internal validity, and these are sample size, the period of study, attrition and instrument sensitivity. However, external validity examines the level to which illustrations of reality are acceptably appropriate through groups (Brink, 1993). Features that disrupt external validity include types of sample size, study locations, researcher's positionality, the period of study and methods of data collection.

Reliability refers to the capacity of a methodology to continually yield similar outcomes when repeated over a testing period. Joppe (2000) uses the term reliability to refer "to the extent to which the results are consistent over time and an accurate representation of the total population under study. Also, if the results of a study can be reproduced under a similar methodology, then

the research instrument is considered to be reliable." What this implies is that a researcher using similar methods should get similar results each time the same process is used on the same subjects. Three types of reliability have been identified by Kirk and Miller (1986), these are: (i) the extent to which a measurement, given repeatedly, remains constant (ii) the stability of analysis over time; and (iii) the comparison of frequencies within a given time. Furthermore, Brink (1993) have identified four sources of errors that may affect both the validity and reliability of research findings. These sources of errors are: (i) researcher's bias and competency; (ii) the participants' irregularity; (iii) environmental situation and social context and; (iv) the methods of data collection and analysis.

Researcher's bias and competency may influence data trustworthiness if not correctly checked as the researcher's presence may affect the validity of information provided by the participants. This problem can be reduced by being aware of the possibility of bias introduction during the research process. Also, the researcher may be trained on how to use the research instrument needed during the data collection process. Participants' irregularities may be due to the characteristics or responses of the participants during data collection. The informants may which to withhold or distort information given to the researcher by not willingly sharing specific information. Furthermore, the informant may want to please the researcher by responding the way the researcher expects. Besides, the participants may fear that by giving a negative response, the researcher may not be impressed. Sources of error from participants' irregularity can be reduced by making sure the participants understand the research and data collection methods, by forming a trust-relationship with the participants; interviewing participant on several occasions, by comparing the obtained results with previous evidence and by keeping accurate and detailed field notes. Environmental situation and social context are attributed to individual behaviour under different social circumstances. For instance, the response an individual give to the researcher when alone may be different from the response he or she will present when in a group. This can be solved by the researcher's observation of such participant's behaviour. Lastly, the researcher should be mindful of sampling bias and the methods of data collection and analysis by clearly identifying and thoroughly describing all strategies used during data collection. Also, it is essential to take notes during the fieldwork so that fellow researchers may be able to use it for valid judgement.

### 3.7 Methodological Reflections

Although various literature on e-waste management in Nigeria are obtainable, only a few examined the policy and regulation, the livelihood of the scavengers and the dangers e-waste can cause in the environment in Lagos State; hence, the topic of this study was conceived. This section describes the problems encountered during the field and how they were minimised. The first issue was the potential researcher's bias. Secondly, the problem of language barrier among the scavengers on the study sites was a serious issue. This is because many of the collectors are from the northern part of Nigeria and they could neither understand nor speak the English language or Pidgin English. Another related limitation was that some of the informal interviewees were scared of been interviewed and those who accepted to be interviewed did not want to be recorded by the researcher. It was because the researcher was mistaken for a journalist working for the government or a new agency. More so, some of the informal participants were

looking up to the researcher to give them some incentives before they could participate in the study. Besides, it was tough securing appointment with some of the government officials because of their busy schedules. Lastly, time constraint was another factor; this is due to the relative distance between the study locations as well as the massive traffic congestion in the city of Lagos.

The following measures were taken by the researcher to minimise these barriers. In a bid to prevent the researcher's bias, the researcher acknowledged the research aim and objectives. Also, respondents were not allowed to write their names on the questionnaires and interview sheets, but the researcher allocated them codes. With the codes, the researcher can ensure the confidentiality of each participant. Also, the researcher employed the assistance of someone that could interpret the research interview questions and questionnaires to the participants who did not speak English Language and Pidgin English. This was helpful because the religion of some of the participants forbade them from going or talking to a married woman who was not their wives. More so, with the help of the interpreter, the respondents were able to express themselves without feeling intimidated during the study. To address the problem of participants' unwillingness to be recorded, the researcher created an environment that was conducive for the participants and explained what the research was about to them. The researcher also assured them that the recordings were only going to be used for research purposes. Although some participants still refused, they allowed the researcher to write their views on the field note.

Another major challenge was with the waste agencies. In every institution either private or government, there are existing protocols and boundaries. This was addressed by giving the copies of the predetermined interview questions and questionnaires to the government offices through their secretaries. Interview dates were set for those that were available while those that were not available were sent the predetermined questions and the answers were collected on the new appointment dates. During the appointment time, some of them had to attend some official duties while the researchers interviewed them. The issues of incentives were clarified by discussing with the informal e-waste collectors in an honest and open dialogue. Also, in the consent form, the researcher stated it clearly that there would not be any form of compensation. On time constraints, this was very challenging because the researcher devised a means to avoid traffic by leaving early for the offices. Besides, in the study sites, time was allotted to the participants taking part in the questionnaires and interviews.

### 3.8 Summary

This chapter examined the detailed methodology used in this study. The research positionality, a recap of the research aim and objectives, the research design, study location of the research data validity and reliability as well as limitation of the study were discussed. The focus of this research was to explore the institutional frameworks that exist in the management of e-waste in the city of Lagos and how e-waste scavenging can serve as a means of livelihoods it collectors. The study adopted the mixed research methodology as a means of data collection from the targeted population.

Three different questionnaires were designed for the participants, personal observation, policy and documentation on solid waste (e-waste) and interviews were used to gather data on the field.

A detailed interview was conducted with some e-waste pickers, recyclers, dealers and e-waste unit heads coordinators from solid waste agencies. The questionnaires and interviews were coded to ensure confidentiality and anonymity. In order to avoid bias and inconsistency in the study, data validity and reliability was employed. The study further examined the data analysis method that will be used. The next chapter discusses the empirical findings from the fieldwork which provide answers to the research aim and questions presented in chapter one of this thesis.

# CHAPTER FOUR[1]

## Empirical Evidence

### 4.1 Introduction

This chapter is dedicated to the presentation of the empirical data collected in the field from September 2016 to June 2017. The field data from this study were structured according to the research questions, and the crucial points were pulled out. In a bid to know the significant points that are linked to the research questions, all data collected in this study were categorised into different sections. This was achieved by carefully going through the documents obtained from the waste institutions, responses from the questionnaire surveys and interviews as well as results from the soil analysis. The data drawn from this research, on the other hand, were analysed statistically, presented in the form of tables, excerpts from interviews and documents (regulations, laws and policies) as well as in chart forms and figures. Therefore, this chapter is divided into the following subsection: The first subsection reveals the existing institutional, legal, regulatory and policy frameworks that can be used to purse the management of e-waste in Lagos, Nigeria; Subsection two, presents the institutional challenges that affect the management of e-waste in the city of Lagos; subsection three will look at the risk heavy metals pose to the informal e-waste collectors; and the transformation of scavengers' livelihood is examined in section four. The last part is the conclusion drawn from the empirical finds.

### 4.2: Institutional and policy frameworks for e-waste management in Lagos, Nigeria

One of the significant questions drawn from this study was based on the institutional and policy frameworks of e-waste management in the city of Lagos. In answering this question, the different e-waste management agencies in the city of Lagos were visited. It is imperative to understand the various institutional responses as this will provide answers to how e-waste is currently being managed and the various major stakeholders involved. However, it is essential to note that Nigeria practices the federal system of government which comprises the three tiers of government. These are the federal, state and local governments councils and each plays different roles in the management of solid waste.

In view of these, institutions in this study refer to the solid waste management agencies under the national, state and local councils in charge of both formal and informal management of e-waste in the city of Lagos. Furthermore, institutional frameworks in this study will also cover some existing national and state regulations, laws and policies that have been put in place to promote the sustainable management of solid waste particularly the ones that are suitable for the effective and efficient control of e-waste in Lagos State. It is, however, important to note that good governance is expedient in the sustainable, effective and efficient management of e-waste in urban areas of any country. Thus, Table 4.1 provides the summary of the active stakeholders' involved in e-waste management in the city of Lagos.

[1] A manuscript from the chapter has been accepted for publication in the Journal of Environmental Pollution. The paper will appear as: Olayinka-Olagunju, J.O and Simatele, D.M. (forth coming) Electronic waste management in developing countries: A study of Environmental Impacts and Issues in Lagos, Nigeria. *Journal of Environmental Pollution*.

**Table 4.1 Formal and informal active stakeholders in e-waste management**

| Active Stakeholders | Frequency | Percent | Valid percent | Cumulative percent |
|---|---|---|---|---|
| Informal e-waste collectors | 291 | 65.1 | 65.1 | 65.1 |
| Informal e-waste dealer/rebuilders | 108 | 24.2 | 24.2 | 89.3 |
| Formal e-waste collectors | 48 | 10.7 | 10.7 | 100.0 |
| **Total** | 447 | 100.0 | 100.0 | |

Source: Fieldwork data (2016)

### 4.2.1: Institutional Framework

From the field-based evidence, it was observed that e-waste is managed at the national level by NESREA while LASEPA and LAWMA with solid waste management in Lagos State. Figure 4.1 shows the different national and state institutional arrangements involve in solid waste management. However, in Lagos State, it was observed from this study that Private Sector Participation, (PSP), is also engaged in solid waste management. They work hand in hand with the state government in the collection of solid waste. Some duties of these agencies include collection, implementation and compliance monitoring of laws, regulations and policies of solid waste, creating awareness and training sessions etc. The roles of the national and state agencies according to the respondents from this study are summarized in Table 4.5. Discussed below are the various solid waste agencies and their duties as suggested by the participants.

According to the reviewed document on the various waste institutions in Nigeria, NESREA is an agency under the Federal Ministry of Environment, (FMoE) and it was established in 2007 under the NESREA Act, in agreement with section 20 of the 1999 Federal constitution of Nigeria. The agency was created to replace the Federal Environmental Protection Agency (FEPA). This assertion is supported by a research participant from NEREA who, for example, pointed out that:

> "*FEPA was scrapped because of its failure to enforce and monitor the existing environmental laws and regulations in Nigeria*" (Pers. com, 2016a).

A review of the documents shows the aim and objectives of the agency. For instance, it aims is "to protect the Nigeria environment and also to bridge the gaps that exist in the enforcement of environmental laws, standards and regulations in the country". The main objectives of the agency as stated in its acts are; *"protection of the environment, effective coordination of all environmental issues as well as creating awareness on pollution and waste management"*. Some other crucial responsibilities of the agency stated in the documents include:

> *a. "Implementation of all environmental laws, guideline, policies, standards and regulations within Nigeria.*
> *b. Enforcement and compliance to all international agreements, protocols, conventions and treaties on the environment including hazardous wastes.*

*c. More so, it implements and monitor regulations on the importation, exportation, production, distribution, storage, sale, use, handling and disposal of hazardous chemicals and waste in Nigeria.*

*d. It designs environmental education curricula strategy which can be used in the monitoring and implementation of formal and informal education system;*

*e. The agency designs and conducts environmental awareness programmes for national implementation;*

*f. Commence the development of new, and the review of existing obsolete environmental guidelines, regulations and standards.*

g. *It issues environmental permits and license to e-waste importers, manufacturing companies, environmental consultants etc.".* (FMoE, 2018).

Some participants at the agency agreed that it has been effective and efficient in the enforcement and monitoring of e-waste inflow into the country but admitted that there are still some loopholes. It shows that the agency has not lived up to his responsibilities. One of the female staff in the e-waste regulation unit argues that:

> *"the agency is doing its best to curb the importation of e-waste into the country. Our agency works hand in hand with the Nigerian Customs Service but we still have some illegal importation of e-waste"* Pers. Com, 2016b).

It was observed in the field that numerous dealers and members still smuggle e-waste illegally into the country using cars that are imported from developed countries mainly from Europe through the Lagos seaports.

Table 4.2 for example, suggests that of 108 the e-waste dealers/rebuilders, 19.4% were importers and they recognised that NESREA is in charge of issuing the license on the importation of e-waste (Figure 4.2). Figure 4.3 shows that 25.9% of the respondents were aware that NESERA creates awareness on the danger e-waste pose to their health and in the environment. These responses further support the responsibilities of the agency stated above. However, the result from this study argues that NESREA's awareness programme is low in Lagos, this might be because it is a Federal Government agency as besides, the state agencies create more awareness on e-waste as they are closer to the citizens of Lagos.

**Table 4.2 Categories of respondents involved as informal e-waste dealers/builder**

| **Occupations of informal e-waste dealers** | **Frequency** | **Percent** | **Cumulative Percent** |
|---|---|---|---|
| Repairers | 39 | 36.1 | 36.1 |
| Second-hand dealers | 23 | 21.3 | 57.4 |
| Scrap buyers | 25 | 23.1 | 80.6 |
| Importers | 21 | 19.4 | 100.0 |
| **Total** | 108 | 100.0 | |

**Source**: Fieldwork data, 2016

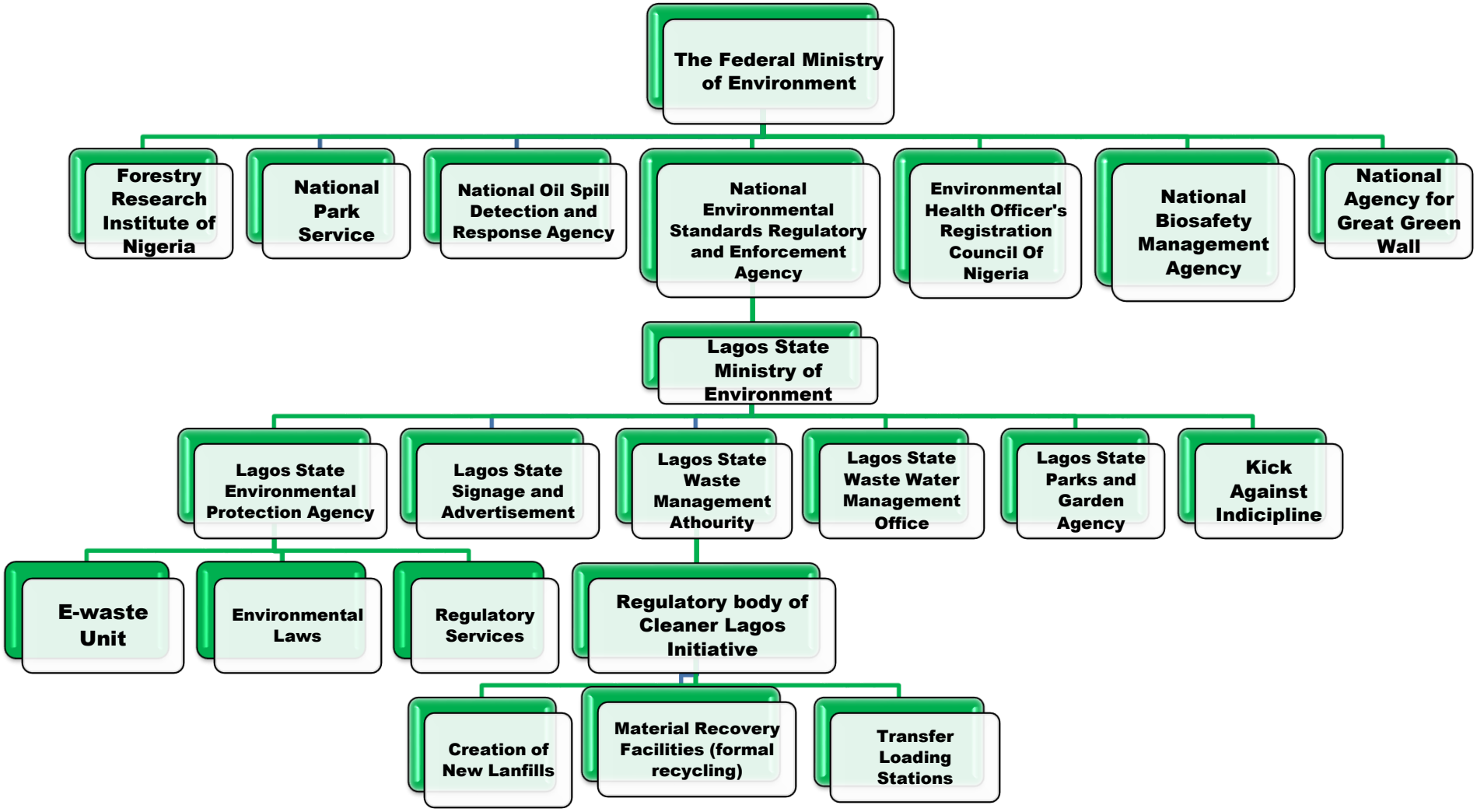



**Figure 4.1**: Instutional Framework of Solid Waste Mananagement in Lagos State, Nigeria.

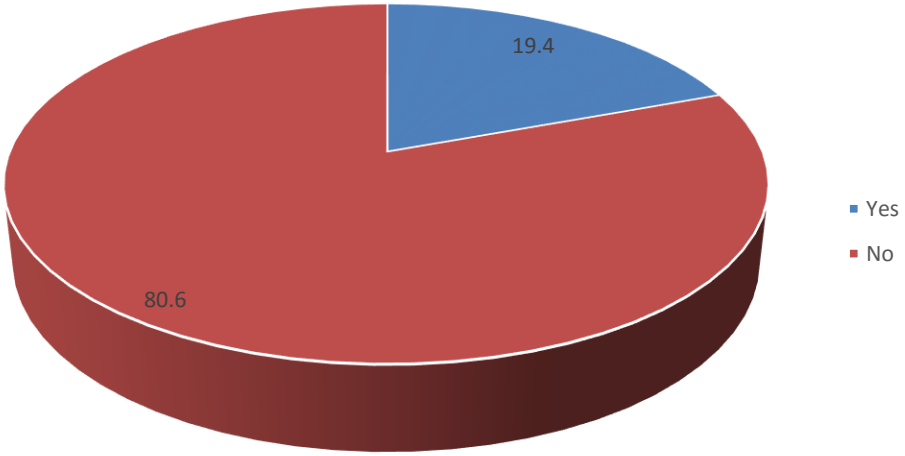



**Figure 4.2** Importers of UEEE with valid license from NESREA

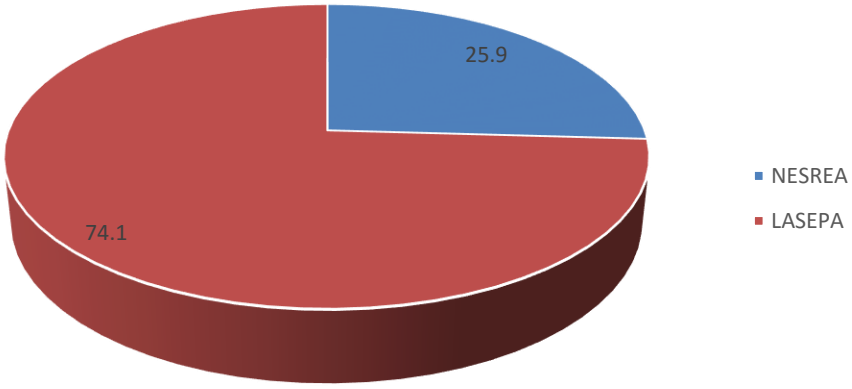



**Figure 4.3** Institutions that create awareness on e-waste in Lagos among e-waste dealers/rebuilders

A further review of the document on existing institutions on solid waste management in Lagos State shows that the Lagos State Ministry of Environment is in charge of taking care of the city's environment. The primary obligation of the ministry was to create a neat, hygienic, and sustainable environment which will be suitable for the leisure industry, trade and industry growth and welfare of its inhabitants. Other responsibilities of the institution include solid waste management, sewage management, EIA evaluation, etc. In a bid to make sure these responsibilities were accomplished, the MoE created different agencies that will be able to discharge the various duties (see Figure 4.1). It should be noted that if these responsibilities are not divided, the task would be challenging for the institution.

The document further revealed that in 1996, the Federal Government of Nigeria under Decree 59 of 1992 encouraged each states in the country to create its environmental protection agency and the

MoE created LASEPA. This claim was supported by the objective of LASEPA which is stated that as: *'to safeguard and improve the environment'; which is in accordance with section 20 (II) of the Nigeria 1999 constitution which says that "The State shall protect and improve the environment and safeguard the water, air and land, forest and wild life of Nigeria*".

On MSW management issues, the agency is responsible for siting space for landfills or dump sites, implementing, enforcing and compliance monitoring of all environmental and waste management policies and regulations within the state. In addition to these, the agency is also involved in creating awareness among the general public, the informal recycling sectors and business owners on how to deal with or handle e-waste. Other responsibilities documented by the agency on e-waste management include:

> *i) "empowerment of e-waste recyclers in the informal sector on socioeconomic impact through training and workshops.*
>
> *ii) development of a take-back scheme in various parts of Lagos which will involve giving incentives to the recyclers.*
>
> *iii) increasing awareness and educating the public on the health and environmental effects of e- waste.*
>
> *iv) to design capacity for materials flow analysis on all e-waste in companies, households and informal sectors" (LASEPA, 2014).*

From the field observations, it was found that the informal sectors are the principal actors involved in e-waste recycling. It was therefore imperative to have a more comprehensive and in-depth understanding of whether the participants in the e-waste unit at LASEPA have any knowledge of e-waste management issues in Lagos. In discussion with the unit head of e-waste at the LASEPA office, she pointed out that:

> "*LASEPA created the e-waste unit in 2011 because the agency was aware that the city of Lagos is gradually becoming the final destination of most e-waste imported into Nigeria. E-waste enters Lagos through the seaports and airports. In the same year, the agency also organised the first international e-waste summit meeting on the risk e-waste poses to its handlers and the environment. E-waste constitutes dangers to the health of the informal collectors/recyclers since they are majorly involved in its recycling for now and it also affects the drainage systems and ground water because they are disposed to the dumpsites. Presently, the informal sectors are largely involved in the management of e-waste in the city of Lagos but their approached is crude*" (Pers.com., 2016 c).

To further support the roles of the agency on the issues of e-waste and its involvements with the informal sector, another male participant from the e-waste unit stated that:

> "*LASEPA has started going to some of the electrical electronics and scrap markets to create awareness on e-waste management. We organise trainings and workshops telling the public the risks involved in handling/recycling e-waste in a dangerous manner. LASEPA has also drafted the e-waste policy in which the role of individuals is stated. The policy is to be implemented by the State Ministry of Environment and LASEPA. In addition, we have adopted the following strategies for e-waste management: Regulation of Extended Producer Responsibility (EPR), Take-back scheme and Polluter Pays Principle (PPP). In order to effectively manage e-waste through policy implementation, we also partner with some private network providers and e-waste consultants*" (Per com., 2016d).

The above comment is further supported by the response of the Head of Special Services unit in LAWMA on LASEPA's role in the management of e-waste. Besides, presently, household e-waste is disposed of along with other solid waste in the city of Lagos. According to LAWMA, LASEPA has approved and started building an e-waste dumpsite in Ogijo, along Ikorodu road, in Lagos. The response highlighted below, for example, is from another participant in the e-waste unit of LASEPA, she explains the reasons why many e-waste from households ends up in the dump sites:

> "*LASEPA has only recently created a dumpsite for e-waste in Ogijo along Ikorodu road and it is managed by MSC. MSC is a private company that has created a Private Public Partnership (PPP) programme on Waste to Wealth in Lagos State. Currently, only e-waste from commercial companies and government organisations are diverted to the site for recycling*" Pers. (Com., 2016 e).

Table 4.3, for example, suggests that 90.4% of the informal e-waste collectors recognised LASEPA as the agency that sensitises and creates awareness on e-waste management in the city of Lagos and 9.6% of the respondents are not aware of what LASEPA does. Amongst the e-waste dealers/rebuilder, 74.1 of the respondents pointed out that LASEPA creates awareness on e-waste while 25.9% recognised NESREA as the agency that creates awareness (see Figure 4.3). This may be because LASEPA represents the state government and it is responsible for any environmental challenges that happen within the city of Lagos.

**Table 4.3 Institutions that create awareness on e-waste management**

| Questions and Responses | Frequency | Percent | Cumulative Percent |
|---|---|---|---|
| **Informal E-waste dealer/rebuilders**: Name the institution that carries out e-waste awareness programme in the market | | | |
| LASEPA | 80 | 74.1 | 74.1 |
| NESREA | 28 | 25.9 | 100.0 |
| **Total** | **108** | **100.0** | |
| **Informal e-waste collectors**: Name the institution that carries out e-waste awareness programme in your association | | | |
| LASEPA | 263 | 90.4 | 90.4 |
| I am not aware | 28 | 9.6 | 100.0 |
| **Total** | **291** | **100.0** | |

**Source**: Fieldwork data, 2016

Another agency that was found in this study that deals with e-waste collection is the Lagos State Waste Management Authority (LAWMA). In the field observation and the reviewed document, LAWMA was the second agency in charge of MSW collection services in Lagos State (see Figure 4.1). The record revealed that the agency was founded in 1977 as the Lagos State Refuse Disposal Board under Edict 9 1977 and was managed by Powell Duffen Pollution Control Consultants of Canada. This creation made the agency the first solid waste management institution in Nigeria. The name was later changed to Lagos State Waste Disposal Board (LSWDB) in 1981 with additional responsibilities of collecting waste from industries and other commercial centres, drainage clearing and scrapped vehicles removal and disposal. However, in 1991, the name was changed to Lagos State Waste Management Authority (LAWMA) under Edict No. 55, which empowered the agency to collect and dispose of municipal and industrial waste, along with commercial waste which will serve both the state and local government councils. The vision of LAWMA "*is to develop and implement sustainable waste management strategies targeted at improving public health standard. Also, it is committed to achieving efficient waste management systems by employing adaptable solutions and best practices as well as encouraging regional integration and customer focused service delivery methods*" (LAMoE, 2018).

Table 4.5 reveals that all participants in the informal sector cited LAWMA as the agency in charge of collecting the general waste from the markets and that waste was collected weekly. However, another participant from LAWMA argues that the workload was indeed too much for the agency and there was a need to create an initiative that can help the city collect waste. He therefore stated that:

> *"LAWMA has created an initiative that will intercept, that is get waste materials from the point of generation rather than collecting at the dumpsites. The pros and cons is that the waste collection from the generators are much cleaner than the ones at the dumpsites and it costs less to process. In market places, trucks are stationed there for*

> *compost and other types of waste. There are certain waste companies that collect this different kind of waste."* (Pers. Com, 2016f).

In addition to the reviewed document, information on the website of LAWMA supports the above view on the creation of initiatives in Lagos State. It states that the government has put in place measures to curb the challenges of general waste collection within the city of Lagos and that the named the reform as Cleaner Lagos Initiative (CLI), founded in 2016. The initiative was introduced to address the existing solid waste management legislation gaps and to expand the LAWMA scope as a waste regulatory and revenue generation in Lagos. This further supports the above statement and also cleared the air on poor waste collection services by LAWMA. The aims of the initiative are; "to protect the environment, human health and improvement of the living conditions of Lagos residents". In September 2017, Lagos State Government empowered LAWMA to start regulating the activities of the Cleaner Lagos Initiative while the initiative was authorised to start the waste collection, recycling processing and disposal in the city of Lagos.

Other responsibilities of the initiative stated on its website include the following:

> *i) "Well-organized waste assembly process*
>
> *ii) Effective boulevard, public roads, drainage and canal cleaning process*
>
> *iii) Drafting and enforcement of new environmental laws and policies on solid waste collections process.*
>
> *iv) Building of new landfill, transfer loading station (TLS) and materials recovery facilities (MRF)*
>
> *v) Integration and creation of formal jobs for informal scavengers and improving their livelihoods.*
>
> *vi) Curbing public littering of waste and indiscriminate disposal of waste.*
>
> *vii) Motivating private sector participation in solid waste collection, processing and disposal" (CLI, 2018).*

Additionally, another male participant from the Special Services Unit in LAWMA explained the role of the agency in the management of e-waste, he pointed out that:

> "*E-waste is a new area and we have seen and heard so much that e-waste is everywhere but people that are involved in resource recovering are using crude method like bleaching with acids or burning and all sorts. E-waste is managed in LAWMA by the department of* **special services***, under special services, you have medical waste, recycling,* **e-waste** *and waste to energy units. We are proposing to change the recycling unit to resource recovery unit because waste is resource."* (Pers. Com, 2016 g).

The comment suggests that LAWMA has started collecting e-waste within the state with the creation of the e-waste unit in special services. Another male participant from the office of the Special Services Unit also commented on e-waste issues:

> "*On the issue of e-waste, …, I think LASEPA has done great but unfortunately they cannot do LAWMA's job. LASEPA has come up with e-waste policy and it took them a while. They engaged different private companies to be collecting e-waste. The company's focus is where they sell computers, used computers and electronics. So the way this people operate is that they will move a part to another part just to make the computer work and whatever is left, that is the carcass or the parts that are irreparable is what the company will come and collect. Hum..., in fact, we just try to live up to our own responsibilities as LAWMA, to start the collection but it I salways like do we want to compete with the private companies? My own concern now is that does LAWMA want to compete with the private companies?"* (Pers. Com., 2016 h).

The above reaction corroborates the response from the LASEPA e-waste unit's participant view on e-waste policy and partnering with private electronic firms on the management of e-waste in Lagos. However, it should further be noted from the response that LAWMA has only just started collecting and storing e-waste from the government and private institutions. Because of the above reaction, the researcher asked the head of the Special Services Unit a question on e-waste collection and recycling in Lagos State. He responded that:

> "*For the e-waste, we've started collecting now, that is LAWMA… I just wrote a memo to the GM that we need to start dismantling what we've collected so far i.e. take them apart. We need to start dismantling them manually, then the treatment will come later. Definitely there will be companies that will come around that will have interest in collecting some of these dismantled parts. We have only started collecting e-waste from companies. Hum… our biggest customer is Samsung.* (Pers. Com, 2016 i).

Taking into consideration what the participant said about LAWMA's biggest e-waste customer, the researcher was interested in knowing why Samsung was not taking back its products so as to reduce the volume of e-waste the agency was collecting from the public, since space for storage and recycling was a challenge. The participant pointed out that:

> "*The e-waste we collect from Samsung are the ones that have either been returned by some customers or the faulty ones that cannot be* **exported to Korea** *for example, we collect Samsung fridge, phones etc. As we collect the products, we have to separate them into components like batteries, metals, compressors, evaporator fans, plastics etc.*" (Pers. com., 2016 j).

**Table 4.4 Some interviewees responses from the active stakeholders in this study**

| Types of responses | No of respondents | Percentage (%) |
|---|---|---|
| Involved in informal e-waste collection | 16 | 46 |
| Involved in formal e-waste collection | 3 | 9 |
| Involved in e-waste legislation implementation and enforcement | 6 | 17 |
| E-waste monitoring body | 4 | 11 |
| Partnership with private electronic companies | 6 | 17 |
| Total | 35 | 100 |

**Source: Fieldwork data (2016)**

Table 4.4, for example, gives the summary of responses by the interviewees during the fieldwork in the city of Lagos. The data shows that 46% of the interviewees were involved in informal e-waste collections. These are the scavengers, cart pusher, e-waste dealers, repairers and rebuilders (refurbishers). The table suggests that these groups of participants are still the most active stakeholders and play the most critical roles in e-waste management in the city of Lagos. Their functions in e-waste include picking e-waste from dumpsites, collecting and buying old appliances from households and electronic markets, dismantling, recycling, repairing/refurbishing, selling to middlemen and recycling companies and finally disposing of the unwanted parts to the dumps or landfills. Given the observations in Table 4.4, another participant from the Special Services Unit was further asked about e-waste resource recovery and the roles of scavenger in the city of Lagos, and he pointed out that:

> *"Recycling is a new programme in LAWMA…. However, you find out that informal recycling has been going on for years and you find most of the activities in our dumpsites by scavengers or some people call them waste pickers. We (LAWMA) also want to change the name scavengers to resource collectors. At the site, we have different collectors some collect plastics, papers, cardboards, aluminium, scraps (metals) etc. so each scavenger have their own speciality….. at the moment, e-waste resource recovery is done in a crude manner by the informal sectors through the use of open burning, acid bleaching etc. which is not environmentally sound."* (Pers. com, 2016 k).

On the other hand, only 9% of the participants was involved in the formal collection of e-waste. This is because LAWMA is in charge of collecting and disposing of only e-waste from government offices and private organisations (see the discussion in Pers. Com, 2016 e). 17% of the participants was involved in the implementation and enforcement of e-waste laws and policies. These comprise both the national and state agencies. However, the role of these agencies is not yet useful compared to the volume of e-waste seen in almost every street of Lagos. Furthermore, 4% of the participants

are also involved in the monitoring of e-waste. This figure is very small, and this may be due to the lack of skilled human resources in the agency. The table further shows that 17% of the participant responded that their agencies are partners with private e-waste companies. This enables them to educate the companies on environmental laws, take-back scheme on e-waste products as well as to execute the extended producer responsibility programme. However, this figure is low, and the effectiveness of these programmes will not be felt because the city of Lagos is big.

**Table 4.5 Summaries of Institution roles in e-waste management in Lagos according to respondents**

| **Institution** | **Informal e-waste collectors** | **E-waste dealers/rebuilder** |
|---|---|---|
| LASEPA | i) Awareness/workshops on dangers associated with e-waste<br>ii) Enforcement and monitoring of e-waste laws and policy<br>iii) Awareness on environmental and health issues relating to e-waste<br>iv) Awareness on the use of protective equipment during collection and recycling<br>v) Investigation and monitoring of environmentally polluted areas<br>vi) Collection and disposal of effluent. | i) Awareness/workshops on e-waste<br>ii) Enforcement and monitoring of e-waste laws and policy<br>iii) Awareness on environmental and health issues<br>iv) Investigation and monitoring of environmentally polluted areas |
| LAWMA | Collection and disposal of solid waste | Collection and disposal of solid waste |
| NESREA | NIL | i) Awareness/workshops on e-waste<br>ii) E-waste importation licence issuing agency<br>iii) Awareness on e-waste environmental and health issues<br>iv) Enforcement and monitoring of e-waste laws and policy.<br>v) Investigation and monitoring of environmentally polluted Federal government areas. |

**Source**: Field data (2016)

### 4.2.2 National Legislative and policy Frameworks

A review of the existing national legislative, policy and regulatory frameworks relating to environmental protection in Lagos State and Nigeria as a country, along with field-based responses from the waste agencies revealed that there are specific legislation and regulations on solid waste as well as e-waste exist. It was observed from the documents that the laws and regulations are well detailed on environmental issues, some of which directly or indirectly addressed solid waste management. At the national level, there is only one regulation on e-waste, and this was established in 2007 and commenced in 2011. Also, the document showed that the nation has just two national policies which address solid waste management issues. The National and State environmental laws, regulations and policy that are linked to solid waste management particularly e-waste are discussed below and summarized in Table 4.8.

One of the legal instrument is the Environmental Impact Assessment (EIA) Decree No 86 of 1992 Laws of the Federal Republic of Nigeria. In this legislation, EIA is compulsory for both private and public organizations before the expansion of any developmental task/projects that may probably have negative impacts on the environment. As a decree, it aims to protect the Nigerian environment.

From the document, the following were the objectives of the EIA Decree:

> *"The objectives of any environmental impact assessment (hereafter in this Decree referred to as "the Assessment") shall be:*
>
> *(a) to establish before a decision taken by any person, authority corporate body or unincorporated body including the Government of the Federation, State or Local Government intending to undertake or authorise the undertaking of* **any activity** ***that may likely or to a significant extent affect the environment or have environmental effects on those activities shall first be taken into account;***
>
> *(b) to promote the* ***implementation of appropriate policy*** *in all Federal Lands (however acquired) States and Local Government Areas consistent with all laws and decision making processes through which the goal and objective in paragraph (a) of this section may be realised;*
>
> *(c) to encourage the development of procedures for information exchange, notification and consultation between organs and persons when proposed activities are likely to have significant environmental effects on boundary or trans-state or on the environment of bordering towns and villages*" (EIA Decree, Pg 1).

In view of these objectives, it can be summarised that EIA is mandatory for projects that may have any effect on the environment; it encourages the enactment of all federal, state and local government environmental policies and; no individual should withhold any information that may have adverse environmental effects on any Nigeria environment on a proposed project. It should be noted that the objectives did not mention e-waste management but it in the creation of e-waste facilities, EIA is critical. In other to know the types of projects that would require EIA studies, the

Federal Ministry of Environment has further divided the necessary activities into three categories, and this is summarised in Table 4.6. It can be seen in Table 4.6 that construction of waste treatment and disposal facilities for hazardous and municipal solid waste under which e-waste falls require the mandatory EIA study according to the Act.

**Table 4.6 Category of Mandatory EIA study activities in Nigeria**

| Category | Type of Project | Considerations |
|---|---|---|
| 1 | **Agriculture/ Agro allied Industry:** Fisheries, Forestry **Industry/Manufacturing:** Food, Beverages, Tobacco Processing **Infrastructure:** Port, Airport, Housing, Drainage and irrigation, Railway **Transportation:** resort and recreational development **Power generation**. Petroleum, mining, quarries, **waste treatment and disposal *(toxic hazardous waste, municipal solid waste, municipal sewage)*** water supply, land reclamation and Brewery. | |
| 2 | **Agriculture/ rural development** Reforestation/ afforestation project, small scale irrigation, small scale aquaculture, saw milling, logging, rubber processing, fish processing. **Industry/ Infrastructures** Chemical, Petrochemical, non-ferrous primary smelting, non-metallic, iron and steel, shipyards, pulp and paper industry power transmission, renewable energy development, telecommunication facility, rural water supply, public hospitals, road rehabilitation. Any form of quarry or mining. | **If the project is located in**: Environmental sensitive area: such as coral reefs, mangrove swamps, small inland. Tropical rainforest areas prone to erosion, Mountain slope areas prone to desertification, Natural conservation areas Wetland of Natural or international importance Areas with protected /endangered species, Areas of scientific interest Area of historic/archaeological interest Area of importance to threatened ethnic group. **Then move to category 1** |
| 3 | **Institutional developments** health, family planning, nutritional and educational programmes. | If project involves physical interventions in the environment, **then move to category 2** |

**Source:** Federal Ministry of Environment, 1995

Furthermore, another regulation that can be used for e-waste management is the National Environmental (Sanitation and Wastes Control) Regulations, 2009 S.I. No 28. From the reviewed

document, the objective of the regulation is to "protect public health and encourage thorough environmental sanitation to reduce pollution".

"The Act provides that:

> *i) No person is to engage in any activity likely to generate Hazardous waste without permit by the Agency;*
>
> *ii) A generator of waste shall ensure a secured means of storing such wastes;*
>
> *iii) Every person who generates hazardous waste shall cause such waste to be treated using acceptable methods;*
>
> *iv) No person shall export or transit hazardous waste without permit by the Agency;*
>
> *v) No person shall transit toxic waste destined for another country through the territory of Nigeria without prior informed consent of such movement by the Agency*
>
> vi) *Any person who fails to comply with the above obligations shall be guilty of an offence punishable with a fine of N5,000,000 or imprisonment for five years or both" (NER, 2009 S.I. No 28).*

It can be seen from the above provision, that the responsibilities of individual dealing with hazardous waste (like e-waste) and the penalty for offenders are also stated. If this regulation is adequately enforced, e-waste management will improve.

In addition to the above is the Hazardous Waste (Criminal Provisions) Decree No 42 of 1988. From the Section 2 paragraph a-d of this act, for example, there are prohibitions on what and where not to dump harmful waste in Nigeria. Since e-waste consist of some harmful/toxic substances, the law is suitable and can be adopted/ or use for e-waste management. Highlighted below are some features of this decree:

> "*An Act to prohibit the carrying, depositing and dumping of harmful waste on any land, territorial waters and matters relating thereto ...*
>
> *2) As from the commencement of this Act, any person who, without lawful authority:*
>
> *(a) carries, deposits, dumps or causes to be carried, deposited or dumped, or is in possession for the purpose of carrying, depositing or dumping, any harmful waste on any land or in any territorial waters or contiguous zone or Exclusive Economic Zone of Nigeria or its inland waterways; or*
>
> *(b) transports or causes to be transported or is in possession for the purpose of transporting any harmful waste; or*
>
> *(c) imports or causes to be imported or negotiates for the purpose of importing a harmful waste; or"*
>
> *"(d) sells, offers for sale, buys or otherwise deals in any harmful waste, shall be guilty of a crime under this Act*".

More so, in Section 6, paragraphs a-b highlighted below, the penalty for anyone who is found guilty of depositing or disposing of harmful waste on any aquatic or terrestrial environment of Nigeria is stated.

> "*6. Penalties, etc. Any person found guilty of a crime under sections 1 to 5 of this Act shall on conviction be sentenced to imprisonment for life, and in addition:*
>
> *(a) any carrier, including aircraft, vehicle, container and any other thing whatsoever used in the transportation or importation of the harmful waste; and*
>
> (b) *any land on which the harmful waste was deposited or dumped, shall be forfeited to and vest in the Federal Government without any further assurance other than this Act" (Harmful waste Act, 1988).*

Even though the above act states the types of waste that should not be dumped within the Nigerian environment, tonnes of e-waste are still being imported into the country and found on many streets, along the roads and on illegal dumpsites. The above implies that the regulation has not been adequately enforced nor monitored. See Figure 4.4 below for example of e-waste dumped on the street.



**Figure 4.4**: E-waste (CRT) dumped on the street by a repairer

Another regulation associated to e-waste management is the National Environmental Protection (Waste Management) Regulations, 1991, S.I 15 No 37 which focuses on the control, collection, treatment and disposal of toxic/hazardous waste from households, offices, institutions to the

manufacturing sectors. The regulation has five objectives and eleven schedules. The objectives and schedules of the regulations are stated below:

> "The objectives of solid and hazardous waste management shall be to:
>
> *(a) identify solid, toxic and extremely hazardous wastes dangerous to public health and environment;*
> *(b) provide for surveillance and monitoring of dangerous and extremely hazardous wastes and substances until they are detoxified and safely disposed of;*
> *(c) provide guidelines necessary to establish a system of proper record keeping, sampling and labelling of dangerous and extremely hazardous wastes;*
> *(d) establish suitable and provide necessary requirements to facilitate the disposal of hazardous wastes;*
> *(e) research into possible re-use and recycling of hazardous waste"* (NEPR, 1991).
>
> **Schedules**
>
> *"1. Toxicity category, toxic hazardous/dangerous waste designation and persistent hazardous/dangerous waste tables*
> *4. Discarded chemical products, dangerous waste products, infectious dangerous waste, dangerous waste mixtures, toxic dangerous waste, persistent dangerous waste and carcinogenic dangerous waste treatments.*
> *5. Regulation for discharged chemical products*
> *6. List of infectious waste*
> *7. Toxic hazardous/dangerous waste designation table*
> *8. Extraction procedure toxic list*
> *9. Generic hazardous/dangerous waste numbers table*
> *10. Maximum concentration of constituents for ground water protection*
> *11. Hazardous (dangerous) chemical products list*
> *12. Hazardous/dangerous waste sources list*
> *13. Hazardous/dangerous waste constituents list"* (NEPR, 1991).

From the list of hazardous/toxic waste presented in the above schedules, many of the toxic components from e-waste are found on the list. This regulation is, therefore, necessary for e-waste management in Nigeria.

Moreover, from the document, the National Environmental (Electrical/Electronic Sector) Regulations 2011 S.I. No 23 is the only existing regulation that is designed explicitly for e-waste management in Nigeria. It covers both new and used Electrical/Electronic Equipment (UEEE). Its primary aim is "to prevent and minimise pollution from all operations and ancillary activities of the Electrical/Electronic sector to the Nigerian Environment". It was observed from the document that the regulation is divided into nine parts. The first part reveals the general provisions of the regulations which include the aim, bases, importation permit for UEEE (second-hand electronics),

the principles that anchored the regulations, requirements for building EEE facility etc. Below are some excerpts from the part 1 of the regulations:

> *"2) The Regulations are based on life cycle approach and shall cover all aspects of the electrical/electronic sector from cradle to grave;*
>
> *3) The principles are anchored on the 5Rs which are; Reduce, Repair, Re-use, Recycle and Recover as the primary drivers of the sector and shall encompass all the categories and EEE list as specified in Schedule 1 to these Regulations".*

From the above, it can be seen that the 5R should be the driving force in the e-waste recycling sector. In section 4, the requirements and conditions needed to build warehouses for new EEE or recycling centre for UEEE are stated and these are highlighted below:

> *"4. Every EEE manufacturing, processing, operational, power of organisation (generation, transmission and distribution) WEEE/E-Waste facility shall:*
>
> *(a) carry out EIA for new projects or modification including expansion of existing ones before commencement of activity;*
>
> *(b) submit to the agency an Environmental Audit Report (EAR) of existing facility every 3 years;"*

From the above excerpts, it can be argued that EIA is a valuable tool that is needed in building a recycling or disposal facility for e-waste, this was also stated in the EIA decree discussed above.

The regulations further provided some essential economic instruments (approaches) that are of necessity for any organisation or corporate body that pollutes the environment with e-waste. An example of the instrument is the Polluter Pays Principle.

An excerpt is highlighted below:

> 7(1) "*The Polluter Pays Principle shall apply to everybody corporate or organisation that pollutes.*
> (2) *The collection, treatment, transportation and final disposal of waste shall be the responsibility of the body corporate/organisation generating the waste within the specified standards and guideline.*
> *(3) In the event of an incident resulting in an adverse impact on the environment, whether socio-economic or health wise, the facility shall be responsible for:*
> *(a) the cost of damage assessment, control and clean up (b) remediation; and (c) reclamation and/or restoration*". (NER, 2011: B735)

The regulations further revealed the roles of all the active stakeholders dealing with e-waste, this was stated in section 11 of the regulations. See the highlight below:

> *"11. (1) Every importer, exporter, manufacturer, assembler, distributor, and retailer, of various brands of EEE products shall subscribe to an Extended Producers' Responsibility (EPR) Program including the Buy Back specified in Schedule VIII to these Regulations;*
> *(2) The importers/distributors for all EEE equipment traded or donated to individuals, educational institutions, religious organizations, communities or body corporate by whatever means, shall comply with the EPR Program;*
> *(3) Manufacturers and Importers of EEE shall partner with the Agency on the Extended Producers' Responsibility Program within two years of commencement of these Regulations in order to achieve the Buy Back Program within a period of two years".*

In Part III of these regulations document, section 34-42 provides detailed information on e-waste control. The section examines e-waste handling from importers of second-hand EEE to technicians (these are people dealing in e-waste repairs, disassembling and re-assembling). Considered the excerpt below on handling e-waste:

> *"34. (1) Every importer and technician involved in repair, dismantling and re-assembling) of UEEE shall ensure that e-waste is handled by a person and or body corporate registered to do so".*

From the above excerpt, it implied that any individual that is not registered with NESREA should not be allowed to handle e-waste. This, however, was not the case in Lagos. It was observed that some unemployed or interested persons think e-waste collection can be done without any prior notice to the association or agency. Although there are various organisations amongst the scavenging network yet not all are registered. For example, all respondents from the e-waste trader or refurbishers belong to one registered association or the other. Some of the associations observed during the fieldwork are Computer and Allied Products Dealers Association of Nigeria (CAPDAN), Electrical Dealers Association of Nigeria (EDAN), Scrap Dealers Association of Nigeria, etc. Amongst the e-waste collectors, 90% belong to the Scrap Dealers Association of Nigeria while 10% do not belong to any association (see Figure 4.5). Those who do not belong to any association are illegal collectors as mentioned in the regulations.

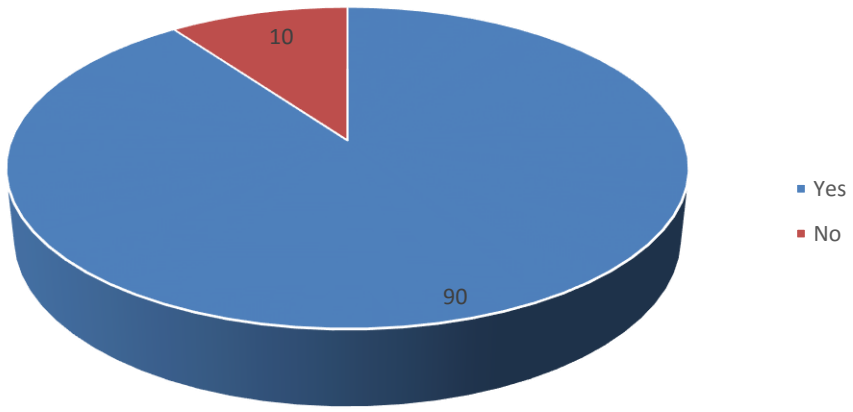



**Figure 4.5**: E-waste collectors Association

On the other hand, Subsection 3 of the regulations listed the types of e-waste that are prohibited in the country e.g. Cathode Ray Tube (see Fig. 4.4), the period of storage for e-waste in any facility, e-waste disposal methods (burning and disposal at landfill sites are prohibited) in the environment, the recycling centre or organisation responsibilities during environmental hazards, keeping of e-waste manifest and receipts by the operators, the organisation must also forward the receipt to the Agency (NESRA for the Federal Government and LASEPA for the Lagos State) within 30 days. Lastly, it was stated that organisations are required by law to separate e-waste from all other waste streams. Section 35 requires every corporate body/organisation interested in dealing in e-waste to register with the government agency (ies) in charge and also get approval before the facility can start operation. Section 36 listed the types of e-waste that are prohibited for disposal/burning in the environment and as well condemns the use of crude methods (like the use of acid bath) for the removal of valuable materials from e-waste.

More so, section 37 mandated every persons or organisation dealing in e-waste to wear personal protective equipment (PPE). The regulation on PPE is stated below:

> "*37. Everybody corporate or organisation involved in the handling of e-waste shall ensure that the technicians, repairers or scavengers wear appropriate Personal Protective Equipment (PPE)*".

However, during the field observation, the researcher observed that majority of the informal e-waste collectors and repairer were seen handling e-waste without the use of any PPE which is contrary to what is stated in the regulation. Figure 4.6 suggests that 6.5% of the informal waste collectors agreed that they use PPE during collection, recycling and disposal while 93.5% indicated that they do not use any form of PPE. However, the researcher also observed on the field that many of the scrap collectors and recyclers did not use any protective equipment, this can be seen in Figure 4.7 and 4.8

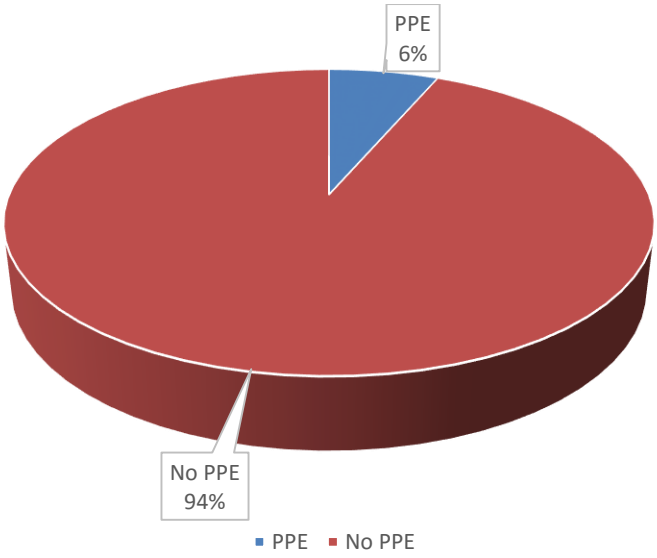



**Figure 4.6**: Respondents that use Personal protective equipment (PPE)



**Figure 4.7** Informal scrap collectors working without PPE




**Figure 4.8**: Informal e-waste dealer working without PPE

Furthermore, the documents also present the roles of stakeholders in the management of e-waste, stated in section 38. For example, it is the responsibility of stakeholders to report any illegal disposal of e-waste and ensure it is disposed of in an environmentally sound manner. Section 39 consists of the required guidelines needed at the collection and recycling centres. Furthermore, record keeping on the activities of e-waste within the organisation is stated in section 40. While section 41 requires that transit permit is collected from the agency before UEEE is exported or transported; section 42 obliges corporate body/organisation to have valid insurance policies for the staff and public in the event of risky activities.

Another policy associated with the above regulations is the National Policy on the Environment (Revised 2016). This policy is a supporting document developed by the Federal Ministry of Environment. It was first formulated in 1991, first revised in 1999 and second revision was done in 2016. The policy provides detailed guiding principles on how to effectively realise sustainable development in the conservation and management of natural resources in the Nigerian environment. It further identifies other areas of environmental concern which are; waste and environmental pollution, emerging issues (e.g. climate change, disaster), cultural issues (e.g. human settlement, environmental health), policy and strategies implementation and actions. The policy goal is to "*ensure environmental protection and the conservation of natural resources for sustainable development*". Under the Waste Management and Environmental Pollution Section of the policy, the increase in the dumping of e-waste (with a particular focus on disused IT equipment) is stated as a significant challenge confronting solid waste management in Nigeria. Highlighted below are the policy statements on waste management: "The Government will:

> *1. Enforce the implementation of the Harmful Waste Act (2004) and other waste management-related national laws and regulations.*
> *2. Setup and enforce standards for sanitary facilities for the disposal of human and solid waste in dwellings, estates, public facilities in both rural and urban areas.*
> *3. Regulate, register and license of all major land waste disposal sites and system.*
> *4. Determine the use of environmentally safe and technological sound techniques for the disposal of toxic, hazardous and radioactive wastes.*

*5. Control generation of toxic hazardous and radioactive wastes especially those that are banned.*
*6. Evolve a clean environment where waste is managed and landscaped on a sustainable basis.*
*7. Secure and enforce a legislative ban on plastic bags.*
*8. Upscale ongoing community-based waste management pilot projects.*
*9. Secure appropriate funding for Integrated Waste Management Facility projects through public-private partnership in selected urban areas*" (NPE, 2016).

It was further observed in the document that some guiding principles have been put in place and these are: environmental right, public trust doctrine, precautionary principle, pollution prevention pays principle (3P+), polluter pays principle (PPP), the user pays principle (UPP), etc. (NEP, 2016). The National Environmental Sanitation (NES) Policy 2005, for example, was developed for the safety of Nigerian and its environment. The policy also reviewed the previous pre-colonial (1900-1960) legislation on environmental sanitation and its failures. The policy observed that the previous legislation was not universal because some urban areas in the country were restricted in it. Furthermore, the post-colonial (1960-1980) legislation on environmental sanitation was also scrutinised, and it was observed that "political interference with the statutory role of sanitary inspectors led to the collapse of the house to house inspection programmes which contributed to the poor sanitary conditions in the country". More so, the present legislation and regulations that address the issues of sanitation in the country were also reviewed in the policy, and it was revealed that there is still an increase in the mortality rates among infants and children. For these reasons, it is important to improve the environmental sanitation standard in the country. The policy defines environmental sanitation as: "the principles and practice of effecting healthful and hygienic conditions in the environment, to promote public health and welfare, improve quality of life and ensure a sustainable environment."

The goal of the policy is to "ensure a clean and healthy environment by adopting efficient, sustainable and cost-effective strategies, to safeguard public health and wellbeing in line with the national development objectives". However, in Section 6.6.2 of the policy, the aim and objectives of solid waste management were stated and highlighted as thus: The aim is to "improve and safeguard public health and welfare through efficient sanitary Solid Waste Management methods that will be economical, sustainable and guarantee sound environmental quality".

While the objectives are:

*i) "To develop Policy Guidelines for efficient and sustainable Solid Waste Management in Nigeria;*
*ii) To promote a healthy environment by ensuring sanitary Solid Waste Management*
*iii) To minimize waste generation and promote sorting at source, reuse, recycling, and energy recovery*
*iv) To ensure safe and nuisance-free disposal of (urban and rural) domestic, medical, and industrial wastes in order to adequately protect public health during and after collection, transportation, treatment and final disposal*

*v) To promote effective Stakeholders participation in Solid Waste Management*

*vi) To generate employment opportunities, improve the standard of living and thus reduce poverty*

*vii) To optimize labour and equipment in waste management to enhance increased productivity;*

*viii) To facilitate cost recovery in waste management investment to ensure project replication and sustainability*

*ix) To build an institutional framework capable of ensuring an efficient waste management system*

*x) To evolve and maintain an indigenous waste management system based on the physical and socio-cultural characteristics of communities*

xi) *To maintain adequate and regular waste management services at affordable cost" (NESP, 2005).*

The following strategies were further adopted:

*i) "Promote waste minimization at household and community levels, through reduction at source, reuse and recycling and resource recovery;*

*ii) Evolve and promote appropriate technologies for recycling of waste components such as bottles, glass, metals, paper, plastic and organic matter;*

*iii) Foster the establishment of small-scale waste recycling plants at household and community levels, to source for and convert recyclable waste*

*iv) Develop technical capacity of public and private sector agencies in Solid Waste Management;*

*v) Conduct research to determine per capita waste generation and build a database on Solid Waste Management;*

*vi) vi. Establish regulations, sanctions and enforcement mechanisms for Solid Waste Management from its source of generation to the point of disposal…"* (NEP, 2005).

Given the above objectives and approaches, it can be seen that e-waste is not mentioned; however, some of its components like plastics, metals, glass etc. are listed in the policy. Therefore, this policy is also suitable for e-waste management. It can further be seen that the Federal Ministry of Environment also wants to promote a sustainable solid waste collection, recycling, sorting, transportation and disposal method within the country. Further review of the document shows that there is a plan to build capable institutional frameworks that will provide regular and affordable waste management services to Nigerians. It can be argued that since the approval of this policy, solid waste management services is yet to improve in the country.

### 4.2.3 Regulatory and Policy Frameworks in Lagos State

Given that Nigeria allows the states to draft policies, the Lagos State legislative arm has written and ratified some environmental laws in the state. These instruments are fundamental in addressing issues relating to ecological pollutions, natural resources conservation and the effect of human activities. A few of the policy documents also contain strategies adopted by the supervisory body to

achieve the aim and objectives of the legislative instrument. It was further observed that the Lagos State Ministry of Environment has a few laws and regulations that address solid waste management issues and one e-waste policy.

One of the law, for example, is the **Lagos State Environmental Sanitation Law 2000**. Its goals include improving sanitary conditions in the state by abolishing the littering of waste, inappropriate disposal of waste in open and illegal dump sites, unlawful road construction activities, etc. This law requires the citizens of Lagos to clean their environment on the last Saturday of every Month. It also provides the establishment of Environmental Sanitation Corps and proposes various penalties for persons or corporate groups that flouts the environmental sanitation principles in Lagos. In spite of this law, there are still illegal dumpsites in Lagos. This can be seen in Figure 4.10-4.12.

Furthermore, the **Lagos State Environmental Pollution Control Edict, 1989** was also passed into law in the state. The provisions in this law are similar to the ones in the National Harmful Waste (special criminal provision etc.) Decree of 1988. The Edict states that "No person or group of persons shall dump or burry or cause or allow to be buried or dumped in any water within the state any toxic or hazardous substance or harmful wastes". This law, however, was overturned by the Lagos State Environmental Protection Agency Edict No. 9, 1997

The **Environmental Protection Law of 1996,** on the other hand, have the provision that allows the registration of environmental management consultants, certification of manufacturing companies, types of waste that are prohibited for disposal within the Lagos State environment, waste treatment and permits for petroleum products manufacturing companies. Also, the agency responsibilities are stated in the law. Section 22 paragraph a-f features of the Law is highlighted below:

> 22. "Prohibition of discharge of waste, etc. into the environment
>
> *As from the commencement of this Law, no person shall:*
>
> *(a) Carry on or run any manufacturing operation or business in any premises within the State except such waste generated in the process of such manufacturing operation or business is treated or purified to the satisfactory standards approved by the Agency before discharge into the environment;*
>
> *(b) Discharge or cause to be discharged, raw untreated human waste into any public drain, water-course, gorge, storm-water or unto any land within the State;*
>
> *(c) Discharge or cause to be discharged any form of oil, grease, spent oil including trade waste, brought about in the course of any manufacturing operation or business into any public drain, water-course, water gorge and road verge;*
>
> *(d) Discharge into the air any inadequately filtered and purified gaseous waste;*

*(e) Burn, dump or bury or cause to be burnt, dumped or buried refuse of any type, bush, weeds, grass, tyres, cables or waste of any description without a written permit from the Agency: and*

*(f) Use gamalin 20 or any herbicide, pesticide, insecticide, explosive or any other chemicals to kill aquatic animals or for any other purposes in rivers, lakes and streams*"



**Figure 4.9**: Illegal Dump sites along the road



**Figure. 4.10**: Illegal e-waste site



**Figure 4.11:** Illegal dumping site for different types of waste

In the reviewed document, the only course of action that addresses e-waste management explicitly in the city of Lagos is the Lagos State E-waste Management Policy, 2015. The policy was adopted from the National Environmental (Electrical/Electronic Sector) Regulations of 2011. What it aims is to "*guide the state and other stakeholders on the implementation of the collective measures that address e-waste issues, challenges, impacts and opportunities in an environmentally sound manner while assuring sustainable socio-economic development*". It was observed from the policy document, that only environmentally sound management (ESM) approach would be acceptable in the management of e-waste within the state. The approach is necessary to conserve the natural resources and also to protect the environment and public health from the dangerous components of e-waste. The policy document further stated the types of environmental management and economic instruments that will be used to enhance the implementation of the policy, recycling methods and the responsibilities of the agency in charge. Excerpts and some specific objectives of the policy are stated thus: "*Towards this end, the following pillars of environmentally sound management such as green procurement for new or used equipment, producers take back for e-Waste, environmental management system and pollution control for facilities in recovery, recycling and disposal operations, finance mechanism for producers take back, and governance will be priority areas of action*".

The overall aims of the Policy are to:

> *i. "Establish a State governance framework to coordinate and harmonise the implementation of State-level e waste environmentally sound management activities and initiatives;*
>
> *ii. To identify all E-waste stakeholders within the State and establish the institution of a collaborative Public Private Partnership (PPP)model for E-waste environmentally sound management and decision making in Lagos State.*
>
> *iii. To assign rights and responsibilities of stakeholders under the E-waste environmentally sound management program.*
>
> *iv. To develop a legal framework for state - wide management of used electrical and electronic equipment as regards green procurement, consumption, generation, extended*

*producer responsibility on take back option, collection, distribution, recycling and disposal.*

*v. To Establish a Producer Responsibility Organization (PRO) for all local manufacturers, importers, distributors and resellers of electronic equipment where membership fees will be charged to cater for the cost of collection and recycling.*

*vi. To develop enforcement mechanism for product, take-back system that requires Producers/ Assemblers/ importers and distributors/ sellers to take back old and end of life products…"* (Lagos State e-waste policy, 2015).

Figure 4.13 suggests that 35.1% of the informal e-waste collectors were aware that Lagos state has a policy that addresses the issues of e-waste while 64.9% were not aware. Those that were aware revealed that LASEPA is the agency that enforces the policy. The result shows that the majority of the stakeholders in Lagos are not informed about the e-waste policy. It can, therefore, be argued that this is why some individuals in the informal sector still use crude methods for recycling. In section 4.2.1 above, it can also be seen that the participants from the two agencies confirmed the existence of the e-waste policy. However, a participant in the e-waste unit at LASEPA maintained that:

"*the enforcement of the e-waste policy has not really been effective, but we will start sensitizing and creating awareness among the stakeholders soon*" (Per. com, 2016l).

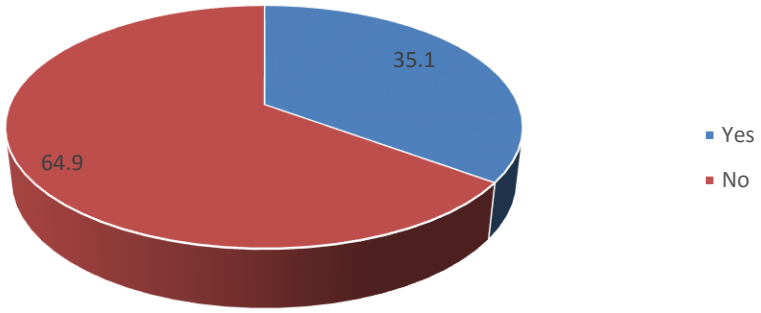



**Figure 4.12** Informal e-waste collectors on policy awareness

On the issue of the take-back policy as mentioned the document, it was observed that 95.2% of the e-waste dealers have not heard about the strategy while only 4.8% acknowledge that they know about the policy (see Figure 4.13). Since the majority of the e-waste dealers are not aware of the take-back scheme, it might be the reason why many of them give or sell out faulty electronics to condemned buyers. Moreover, all the e-waste scavengers admitted that they have not heard about the takeback scheme. At this point, the researcher had to explain the meaning of the approach to the participants.

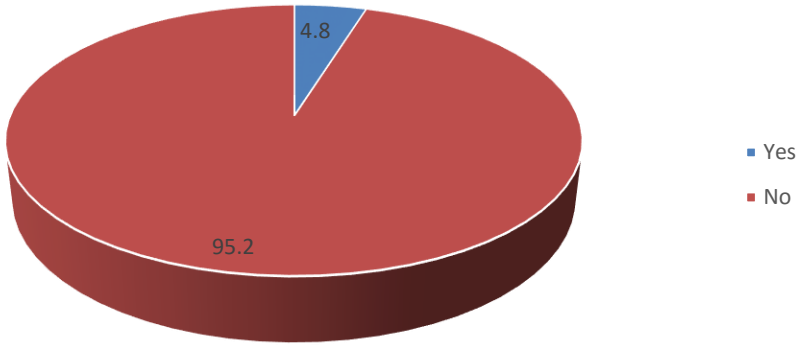



**Figure 4.13**: Take-Back scheme awareness amongst e-waste collectors

However, after the explanation, the researcher's next question was on the best way to manage e-waste. 71.8% of them suggested the take-back scheme, 26.5% indicated incineration and 1.7% recommended landfills this can be seen in Figure 4.14.

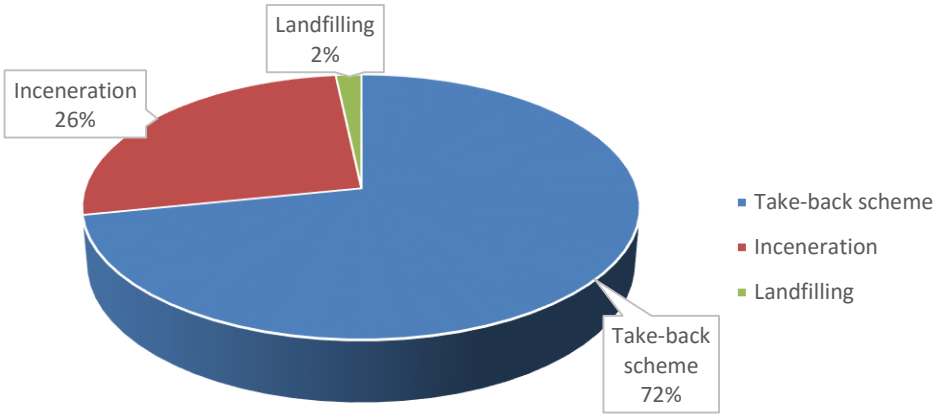



**Figure 4.14**: Best sustainable e-waste disposal method

**Table 4.7 National and Lagos State Regulations, Laws and Policies Relating to e-waste management**

| Government Level | Regulations, Laws and Policies | Key Agency |
|---|---|---|
| Federal | i) Environmental Impact Assessment Act of 1992<br>ii) National Environmental (Sanitation and Wastes Control) Regulations, 2009 S.I. No 28<br>iii) The Harmful waste (Special Criminal Provisions) Decree No 42 of 1988<br>iv) The National Environmental Protection (Management of solid and hazardous waste) 1991 S.I. 15<br>v) National Policy On Environment, 2016<br>vi) National Environmental (Electrical/Electronic Sector) Regulations 2010 S.I. No 23<br>vii) National Environmental Sanitation Policy, 2005 | |
| State | i) Environmental Pollution Control Edict of 1989,<br>ii) Environmental Protection Law, 1996,<br>iii) Environmental Sanitation Law, 2000.<br>iv) E-waste Management Policy, 2015. | Lagos State Environmental Protection Agency |

### 4.3: Institutional challenges of e-waste management in Lagos State

Observed in the study from above section were various agencies involved in the management of e-waste and their different roles. From the field based discussions it was observed that the agencies were faced with some challenges during the management of e-waste. Some of the participants' responses are shown in Table 4.8. These challenges have therefore been categorised into three namely, infrastructural challenges (e.g. lack of space, financial constraints, limited recycling programme and lack of manpower, inadequate equipment and technical know-how), behavioural and lack of information (behavioural and mentality, lack of waste education and awareness) and policy, legal and regulation challenge.

Based on these classifications, it can be argued that the major challenge in the management of e-waste is i**nfrastructural issues.** From the responses expressed by some of the participants, for example, l**ack of space for storage and landfills for disposal** seems to be a serious problem in the city of Lagos. It may be to the fact that geographically, Lagos State is the smallest state in Nigeria and also surrounded with creeks and lagoons (see the geographical profile in chapter three). Also, with the rapid growing population and urbanisation in the city, there are only limited spaces available to build landfills for waste disposal. Lack of space also contributes to the poor collection, transfer and disposal of e-waste from households. The assertion is based on the field based responses from the state waste agencies participants. Presently, in the city of Lagos, there is no

storage house/warehouse that can be refer to as e-waste recycling facility owned by the state but one of the Transfer Loading Centre located at Simpson is being used as a temporary storage facility for e-waste.
To buttress the issue of space, a staff in the special services unit at LAWMA said that:

> "*Although at the moment, Lagos does not have land or space to build landfills. Hum… in fact, we are looking into warehousing then processing plants. We've started collecting and stockpiling now but we don't have space. We have four dumpsites in Lagos, two of them are old dumpsites and already getting to their life span. Presently, we store the collected e-waste products in one of our Transfer Loading centre, the one at Simpson.*" (Pers. Com, 2016 m).

However, from LASEPA e-waste unit, it was observed that Lagos State, now has only one e-waste disposal site and it is situated in Ogijo along Ikorodu road. This can be seen in the discussion (Pers com., 2016 e) above. Given the population living in the city of Lagos, it is therefore imperative that the state government build more recycling and disposal facilities for e-waste as one landfill site cannot serve the entire state. More so, necessary because the state is fast becoming a major destination for many e-products sent into Nigeria. These facilities should be controlled, monitored and protected such that they will not pose any environmental and health threat to the stakeholders and the public at large.

Furthermore, financial constraints, is, for example, another serious challenge. Table 4.8 suggests that 14% of the participants who were staff from the three institutions complained about lack of funds from both the federal and state government. This may be because the national and state budget on solid waste management is limited and therefore affects e-waste collection. Also, due to lack of funding, waste institutions cannot purchase vehicles, equipment, employ more staff and build adequate infrastructures needed for e-waste management.

However, misappropriation of funds/corruption cannot be ruled out. Some informal e-waste dealers suggest that corruption by some officials in the waste institutions is one of the constraints affecting e-waste management in Lagos. In a bid to curb this, the federal and state government have recently informed the public not to pay cash to any staff in the agency rather all payment should be made into a single treasury account owned by the government. This is for proper administration and accountability purposes, which will enable the government to monitor the funds that are allocated to the institutions and how it's been spent.

Besides, limited use of **recycling program** is another challenge hindering e-waste management in the state. Respondents from the waste institutions as well as the informal participants also mentioned this. It may be because of lack of e-waste recycling/take-back centres by the state and private organizations within the city of Lagos. It also explains the reason why many households store or discard broken electronics along with other solid waste. LAWMA have only recently started educating and creating awareness amongst the banking sectors on paper recycling. Head of the special services unit in LAWMA pointed out that:

> *"Hum as I said earlier that recycling is a new programme … We have also been going around to companies especially banks and we have been telling them more about the recycling programmes. One of such bank is Sterling Bank where we have given them hum, hum where we have given them bins to separate their waste. And we are also getting the recycling companies involved. So that the recycling companies will go and collect all the recyclables from the banks, however, LAWMA cannot guarantee the companies incentives for recycling. I know that in other countries they do it. In fact, there was even a proposal that paper recycling companies should give printing papers to banks since they use a lot of paper*" (Pers. Com., 2016 n).

Also, on the issue of e-waste recycling, it was observed from LAWMA that there is a private company involved in the collection, but it only collects waste from the government and private/commercial institutions. For the city of Lagos, this study observes that one recycling agency is not sufficient, seeing that Lagos is a business hub. A male participant from LAWMA commented that:

> "*Hum …, there is a company in one of our closed dumpsite West African renewable energy, is a material recovery company. Some trucks are diverted to the closed site, from there they do the sorting but whatever is left or that cannot be sorted or recycled and taken to the dump sites. For now, we have just one formal recycling centre but the plan of the government is to build more. Definitely when that comes up it will increase the recycling rates. So rather than taken resource to the dumpsite, it will first be sorted and separated there"* (Pers. Com., 2016 o).

**Table 4.8**: Interviewees responses on institutional challenges of e-waste management

| **Challenges** | **No of Respondents** | **Percentage** |
|---|---|---|
| Lack of Fund | 5 | 14 |
| People's mind set and behaviour | 9 | 26 |
| Lack of manpower | 7 | 20 |
| Poor awareness on e-waste, workshops and training | 3 | 9 |
| Complaints by the communities around recycling/dump sites | 7 | 14 |
| Weak policy enforcement and monitoring | 6 | 17 |
| Total | 35 | 100 |

**Source**: Fieldwork data (2016)

**Inadequate human resources and poor service delivery** was also another challenge complained about by the participants. This is shown in Table 4.8. It was observed that the staff strength is meagre and this affects waste management service within the state. At LASEPA, staff from the e-waste unit argued that the department has not been able to do enough workshops and training in

the area of e-waste because of lack of workforce and this is slowing down the activities of the agency. It could also explain the reason why the agency has not been able to collect e-waste from households.

**Low workforce** also affects public sensitisation and e-waste collection. Low staff strength also accounts for the inadequate collection of e-waste from households and marketplaces as well as indiscriminate dumping/littering of the streets with waste. If more skilled hands are not employed, the public will have to pay more to the cart pushers or condemned buyers, and this will reduce the amount of revenue that should be remitted to the government regarding solid waste management. It will further make the recycling habits of the citizens and programmes difficult to accomplish. Furthermore, the study observed that the lack of recycling centres in specific areas might also hinder e-waste recycling and may only favour some selected groups of people. If recycling centres are not readily accessible, the public may find it challenging to take their e-products for recycling or take back.

**Inadequate equipment and technology** is another factor that affects the management of e-waste in the city of Lagos. Presently, waste collection institutions do not have processing plants that can be used for e-waste disposal in Lagos. This is supported by the comment of the respondent from LAWMA in (Pers. com., 2016n) above. More so, this could be another reason why e-waste is dumped on the streets, illegal and legal dumpsites. Also, some of the collection trucks are insufficient and outdated. However, recently the state government has bought more vehicles, but these trucks are only designed to collect household waste and not e-waste. Previously in Lagos, there was processing plant used for solid waste management, but these plants have become faulty, and no other plant has been installed. This might due to poor management and lack of skilled technical personnel that could handle the equipment. Thus, it is advisable that the new processing e-waste plants be designed with appropriate technology meant for Nigeria such that it will not easily develop electrical and mechanical faults and the right and skilled technical personnel be put in place.

**Behavioural and educational challenges** are other serious problems affecting e-waste management in Lagos. These challenges were subdivided into two, and these include the mentality and behavioural issues, lack of awareness and training and social or societal challenges. Mentality and behavioural issues, for example, are challenges that affect e-waste recycling and disposal in Lagos. This is because individuals have different perceptions towards waste. For instance, what someone regards as waste may be seen as a resource that can generate livelihood for another. During the interview at LAWMA, the head of special services unit made mention of people's mind-set toward waste management. He complained about how the coloured disposal bin distributed to many government and private organisations for recycling has not been used for the right reasons. He, therefore, pointed out that:

> "*The mind set/behaviour of people toward recycling is wrong, people dispose of waste into wrong bins. There were bins we gave out to some organisations for recycling and during our visit we saw that different types of waste were disposed in the bins. For example, in the hospitals we gave out plastic disposal containers for sharps such as needles, razor, etc. only for us to see that some of the plastics were used for storing personal belongs of some staff and not for the purpose it was designed*" (Pers. Com., 2016 p).

Because of this comment, it can be seen that even though staff from some organisations have been told or educated about recycling they still dispose of waste wrongly in the bins. It may be because of lack of participation during the recycling campaign, the distance of the recycling/disposal bins from the location of the offices, lack of awareness and education on waste disposal.

Besides, 26% of the respondents suggested that poor mind set is a reason why littering of waste is common among people from developing countries. The claim could be based on people's belief that if the environment is not littered with thrash, there are no reasons to employ street cleaners and waste collectors. Hence, since they have been hired and paid, they should discharge their duty by cleaning the environment. Some e-waste collectors are aware that e-waste is dangerous to the environment, but they still dump the leftover after recycling in open dump while others burn them openly, a practice that is against the environment in the e-waste policy. Moreover, 14% of the interviewees indicated that people residing around some scrap and dumpsites in Lagos have complained about the different kinds of pollution in Lagos.

Waste littering attitude and behaviour may also be due to individual culture and lifestyle. In some culture, maid/cleaners are in charge of making sure the house and environments are kept clean while in other places you will have to take responsibility for littering the environment. Furthermore, some individuals live in areas where everything needed for effective waste management is available, and this makes e-waste recycling very convenient.

Another challenge is the low awareness and information on e-waste management. This is a significant problem in many developing countries. Presently, in Lagos, there is little awareness of the management of e-waste among the general public because only those in the government and commercial sectors are aware. It accounts for why many households dispose of e-waste along with other general solid waste. Lack of awareness, for example, could also lead to a lack of interest in environmental or waste activities and may obstruct recycling activities as the public may not be willing to participate in such programmes. Also, inadequate information on e-waste could be the reason for lack of participation and unwillingness to recycle by individuals. For instance, some members of the public store many of their old and faulty electronics at home because they do not have information on how it can be disposed of. While those that are willing to dispose of dump them on illegal dump sites or drop them along with other types of waste.

Table 4.8, for instance, suggests that 9% of the staff from the institutions have complained that lack of awareness, training and workshops are some of the significant barriers obstructing e-waste management. Although LASEPA and NESREA are trying in sensitising e-waste stakeholders on its management, some other factors like inadequate funding and human resources are hindering their effort. It is, therefore, necessary to address these issues so that environmental awareness and e-waste management through education might impact positive attitude in the general public.

Another challenge observed in this study was centred on policy and regulatory issues. This explains some problems encountered by solid waste institutions concerning legislative, regulatory and policy framework in Lagos State. One of the problems associated with policy and regulation frameworks in the city of Lagos is weak or lack of enforcement and culpability. From section 4.3, it was observed that Nigeria is one of the countries in sub-Saharan Africa that has many legislation and regulations

on solid waste management. However, it is not the number of rules and laws documented that are important but the implementation and enforcement. Lack of enforcement by the waste and environmental agencies in the city of Lagos has contributed to the poor management of e-waste. For example, Lagos State also has a series of regulations, laws as well as e-waste policy but they cannot still enforce them.

Lack of implementation has further led to the indiscriminate disposal of e-waste and the creation of illegal dump sites in the city of Lagos (see Figure 4.9-4.11). In spite of the environmental sanitation laws, many streets in Lagos are still witnessing the creation of illegal dumpsites. It may be because the institution in charge of policy implementation are slacking in their duties, or the respective stakeholders are not aware of their responsibilities as stated in the regulations. For instance, during the fieldwork, the researcher observed that as many as 97% of the e-waste collectors and dealers were not wearing any protective equipment. This shows that they only know there is a regulation on e-waste recycling, but they are not aware that their responsibilities are stated in it. It might also be due to lack of interactions and information flow between the government waste institutions, private sectors participation, informal recycling sectors and the general public.

Another staff at LAWMA revealed to the researcher that there is a good relationship between LAWMA and representatives from Scrap Association of Nigeria, CAPDAN, etc. He made the following comment:

> *"We have been inviting the scavengers to meetings and they have been represented. Like three months ago we held a meeting and we told them we recognised their effort in sorting and recycling, but waste in Lagos dumpsites are LAWMA's properties because LAWMA collects them from households and you guys have been trading here without paying anything back to the government. So the government wants to start regulating your activities".* (Per Com., 2016 q).

It can be deduced from this discussion that the waste institution has a formal relationship with the informal sector on the management of e-waste because they have been able to form their association.

Inadequate monitoring and nonconformity by the supervisory bodies of e-waste in the city Lagos is another challenge mentioned by the participants. Table 4.8 shows that 17% of the respondents acknowledged poor enforcement and monitoring as the reason for the creation of illegal importation e-waste, dump sites as well as indiscriminate disposal. This could be due to the lack of workforce, insufficient or inadequate funding, inadequate training and awareness etc. If the monitoring teams are in place, there will be checks and balances in the siting of the illegal dump sites, littering of the environment with waste and the offenders might be prosecuted for defying law and orders. More so, if monitoring is not adequately carried out, the institutions may not know the reasons for non-compliance by the stakeholders. If the non-compliance parameters are known the chairpersons for each association or scrap markets should be notified, and failure to comply should attract a penalty.

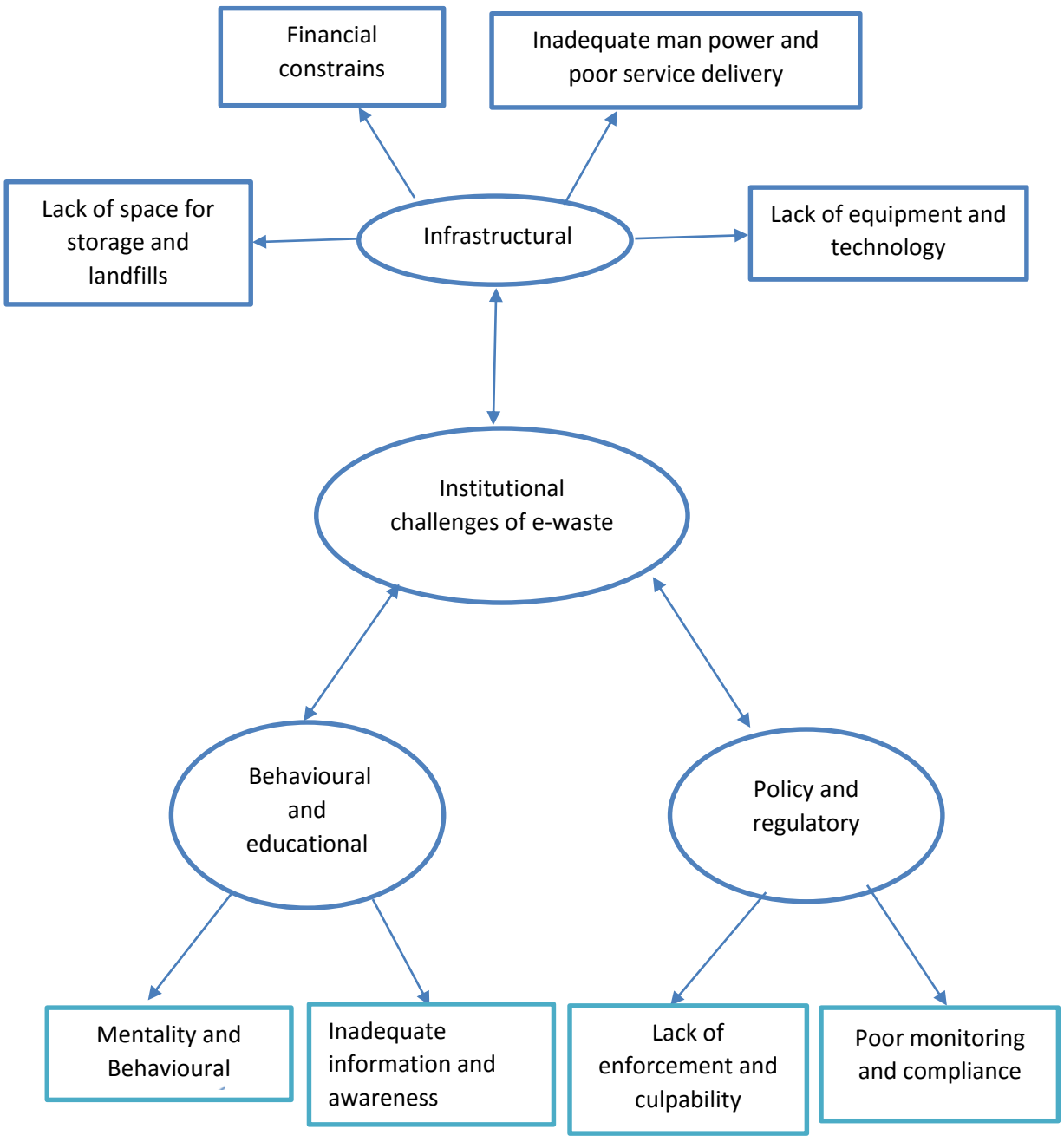



**Figure 4.15**: Inventory of e-waste challenges in the city of Lagos

### 4.4: The risk of heavy metals on human health and the environment

From the activities of the informal e-waste collectors which are common in the city of Lagos, some soil samples were collected from two dumpsites (Olusosun and Solous MRF) and two scrap sites (Alakija and Owode-Onirin scrap sites) during the wet and dry seasons and analysed. The results obtained were grouped into three subsections and are presented thus; physical, chemical as well as the heavy metal parameters for both wet and dry seasons.

#### 4.4.1 Physical parameters from the soil sample analysis

The physical properties of the soil samples collected from the four study sites during the dry and wet seasons are shown in Table 4.9. From the results, it can be seen that almost all the physical parameters were within World Health Organisation (WHO) and LASEPA standards except for the soil odour from Owode Onirin during the wet season and pH from Olusosun and Alakija during the dry season.

**(a) Analysis of soil samples from Olusosun landfill**

Table 4.9 presents the findings from the physical analysis of soil samples collected during the dry and wet seasons from Olusosun Landfill. From the table, the main parameters examined are soil colour, odour, temperature, pH and percentage moisture contents. In the dry season, it can be seen that the soil colour was dark grey, the soil was odourless, temperature 25.90C, pH 5.56 and the percentage moisture content 0.55. However, there are noticeable differences in the wet season analysis results shown in the table. For example, the soil colour for the wet season was black, and temperature increased to 27.40C. Other changes include pH (7.52), percentage moisture content (2.19) and the soil was odourless. From the table below, the dry season pH is below the WHO and LASEPA regulatory standard. These findings, therefore, show that the soils from this location are acidic and may be injurious to the health of the general public.

**Table 4.9**: Physical dry and wet seasons parameters in the study sites

| Parameters | Study sites | | | | WHO/LASEPA Limits |
|---|---|---|---|---|---|
| | Olusosun | Owode-Onirin | Soluos | Alakija | |
| **Dry season** | | | | | |
| Colour | Dark Grey | Dark brown | Reddish yellow | Dark greyish brown | NS |
| Odour | Odourless | Odourless | Odourless | Odourless | Odourless |
| Temperature | 25.90±0.20 | 25.80±0.98 | 26.9±0.30 | 26.00±040 | 35-40 |
| pH | 5.56±0.04 | 6.22±0.23 | 6.33±0.27 | 5.31+0.23 | 6-9 |
| % Moisture content | 0.55±0.01 | 1.71±0.02 | 1.19±0.14 | 0.28±0.03 | 25% |
| **Wet season** | | | | | |
| Colour | Black | Black | Weak red | Dark greenish grey | NS |
| Odour | Odourless | Unpleasant | Odourless | Odourless | Odourless |
| Temperature | 27.40±0.17 | 27.30±0.20 | 27.30±0.00 | 27.7±0.00 | 35-40 |
| pH | 7.52±0.03 | 7.40±0.10 | 7.78±0.11 | 8.11±0.04 | 6-9 |
| % Moisture content | 2.19±0.07 | 12.97±0.06 | 1.47±0.00 | 1.22±0.11 | 25% |

*NS = Not Specified

**Source**: Field data (2016 and 2017)

**(b) Analysis of soil samples from Owode Onirin scrap market**

From Owode Onirin scrap market, Table 4.9 suggests that the dry season soil sample results are: colour (dark brown), odour (odourless), temperature (25.80C), pH (6.22) and % moisture content (1.71). Meanwhile, during the wet season, the result shows slight differences; soil colour (black), odour (unpleasant), temperature (27.30C), pH (7.4) and % moisture content (12.97). From the data, it can be seen that all the parameters except for the wet season soil odour are within the WHO and LASEPA standards.

### (c) Analysis of soil samples from Solous MRF

Table 4.9 shows that during the dry season, the soil colour at the study site was reddish yellow, the soil was odourless, the temperature was 26.90C, pH was 5.31 and % moisture content was 0.28. There are differences in the results obtained in the wet season analysis when compared with dry season analysis. The soil colour, for instance, was weak red while the soil remains odourless. Others include temperature 27.30C, pH 7.78 and %moisture content 1.47. However, when the results from both seasons were compared to WHO and LASEPA, the results are within limits. This implies that the physical parameters of the soils are intact.

### (d) Analysis of soil samples from Alakija scrap site

The results presented in Table 4.9 shows that during the dry season, the soil colour was dark greyish brown, the soil was odourless, the temperature was 26.00C, pH was 5.31 and the %moisture content was 0.28. The soil pH was lower than WHO and LASEPA standard which makes the soil from Alakija slightly acidic. The wet season result shows that there were differences in all except for the soil odour. The soil colour was dark greenish grey, temperature 27.70, pH 8.11 and the % moisture content was 1.22. All the results are within WHO and LASEPA limits tact.

### (e) The overall mean of soil samples in Dry and Wet Seasons

Tables 4.10 shows the overall means of all physical parameters analysed during the dry and wet seasons. From this table, the mean results for the dry season parameters are as follows: temperature 26.150C, pH 5.85 and %moisture content 0.93. It can be seen that the pH is low which indicates slightly acidic quality when compared to WHO and LASEPA limits, the temperature and moisture contents are within limits. However, during the wet season, the results suggest that the mean physical parameters for the wet season are: temperature 27.370C, pH 7.70 and the %moisture contents 4.46. It can be deduced from the table, that all the parameters were within the WHO and LASEPA standards except for the pH.

**Table 4.10** Mean of physical parameters of soil samples within the study areas in dry and wet seasons

| Parameters | Study sites Olusosun | Owode Onirin | Solous | Alakija | Overall Mean | WHO/LASEPA standard |
|---|---|---|---|---|---|---|
| Colour | Dark grey | Dark brown | Reddish yellow | Dark greyish brown | | NS |
| **Dry season** | | | | | | |
| Odour | Odourless | Odourless | Odourless | Odourless | | Odourless |
| Temperature | 25.90±0.20 | 25.80±0.98 | 26.9±0.30 | 26.00±040 | 26.15±0.55 | 35-40°C |
| pH | 5.56±0.04 | 6.22±0.23 | 6.33±0.27 | 5.31+0.23 | 5.85±0.48 | 6-9 |
| % Moisture content | 0.55±0.01 | 1.71±0.02 | 1.19±0.14 | 0.28±0.03 | 0.93±0.58 | 25% max |
| **Wet season** | | | | | | |
| Colour | Black | Black | Weak red | Dark greenish grey | | NS |
| Odour | Odourless | Unpleasant | Odourless | Odourless | | Odourless |
| Temperature | 27.40±0.17 | 27.30±0.20 | 27.30±0.00 | 27.7±0.00 | 27.37±0.14 | 35-40°C |
| pH | 7.52±0.03 | 7.40±0.10 | 7.78±0.11 | 8.11±0.04 | 7.70±0.29 | 6-9 |
| % Moisture content | 2.19±0.07 | 12.97±0.06 | 1.47±0.00 | 1.22±0.11 | 4.46±5.14 | 25% max |

*NS = Not Specified

**Source**: Fieldwork data (2016 and 2017)

### (f) Seasonal Comparison of physical parameters

The comparison of the overall physical parameters obtained during the dry and wet seasons can also be seen in Table 4.10. It should be noted that in Table 4.9 above, the soil colours vary from site to site and differs from season to season. For example, the soil colours during the dry season at Olusosun was dark grey, Owode Onirin dark brown, Solous reddish yellow and dark greyish brown at Alakija scrap site. Meanwhile, in the wet season, Olusosun and Owode-Onirin samples were black, Solous weak red and Alakija was dark greenish grey. Furthermore, the table indicates that the soil odours for all study sites during the dry season were odourless. However, there was a slight difference in the wet season result, as Owode Onirin soil odour was unpleasant. During the dry season, the soil samples temperature values were lower, ranging from 25.80 – 26.900C. It can be seen that in the dry season, Solous had the highest mean temperature of 26.9±0.300C, while the lowest 25.80±0.980C was obtained at Owode-Onirin Scrap Market. The mean temperature for the wet season samples was higher; it ranged from 27.30 to 27.70C. The lowest temperature 27.30C was

obtained at Owode Onirin and Solous, while the highest, 27.7±0.000C was at Alakija scrap site. The mean temperature shown in Table 4.9 for the two seasons reveals that the highest temperature 27.37±0.140C was obtained during the wet season, while the dry season had the lowest. The soil samples pH ranged from moderately acidic, 5.31±0.23 to slightly acidic 6.33±0.27 during the dry season. Also, the overall pH for both seasons in Table 4.10 shows that the pH values were low, 5.85± 0.48 which implies that the soil was slightly acidic during the dry season and slightly alkaline, 7.70±0.29, during the wet season. Results from the overall mean pH in Table 4.10 shows that the dry season pH was lower than the maximum limits stipulated by the WHO and LASEPA (see Tables 4.9). The mean values of the soil moisture contents ranged from 0.28±0.03-1.71±0.02% during the dry season and 1.22±0.11-12.97±0.06% during the wet season. When the means of the two seasons were compared, it was observed that the moisture contents were higher in the wet season. However, the mean results did not exceed the maximum value of 25% specified by WHO and LASEPA.

**Table 4.11: Comparison of dry and wet seasons physical parameters**

| Physical Parameters | Dry Season | Wet Season |
|---|---|---|
| Temperature | 26.15±0.55 | 27.37±0.14 |
| pH | 5.85±0.48 | 7.70±0.29 |
| % moisture content | 0.93±0.58 | 4.46±5.14 |

Source: Field data, 2016 and 2017

### 4.4.2 Chemical parameter analysis from the collected soil samples

This section presents the chemical parameter results of all soils obtained from the four study sites during the wet and dry seasons. The parameters analysed are sulphate, nitrate, phosphate, the percentage of organic carbon and the percentage of organic matter. The results are discussed below.

#### (a) Analysis of soil samples from Olusosun landfill

Table 4.11 shows the results obtained from the mean chemical analysis of soil samples collected during the dry and wet seasons from Olusosun landfill. From this table, the results for the dry season are as follows: nitrates 0mg/kg, phosphate 1.10mg/kg, sulphate 0mg/kg, organic carbon 23.20% and organic matter 40.10%. It can be seen that nitrates and sulphates are deficient in the soils collected in the dry season. On the other hand, the wet season analysis results reveal that the soil nitrate concentration is 2.80mg/kg, phosphate was reduced to 0.44mg/kg, sulphate 29mg/kg, organic carbon and organic matter increased to 31.92% and 55.9% respectively. The data shows that the obtained results are within WHO and LASEPA limits. A one-way will be used to establish any significant differences between the seasons.

#### (b) Analysis of soil samples from Owode-Onirin scrap market

The mean concentrations and standard deviation values of the chemical parameters for the two seasons obtained from Owode Onirin scrap market soils is shown in Table 4.11. From the table it is apparent that the results from both seasons differ slightly. In the dry season for instance, the results

are: nitrate 2.0mg/kg, phosphate 3.7mg/kg, sulphate 35.0mg/kg, organic carbon 23.53% and organic matter 40.68%. Meanwhile, the wet season results show: nitrate 2.8mg/kg, phosphate 1.08, sulphate 35.0mg/kg, % organic carbon and % organic matter 29.53 and 51.05 respectively. It can be seen from the data that there was an increase in the concentrations of nitrate, percentage organic carbon and organic matter in the wet season. There was, however, a decrease in the concentration of phosphate but the value of the sulphates was unchanged for both seasons. What is striking about the results from both seasons is that although there was an increase in the chemical parameters during the wet season, the result did not exceed WHO and LASEPA limits.

**Table 4.12**: Dry and wet seasons Chemical Parameters

| Parameter | STUDY SITES | | | | WHO and LASEPA limits |
|---|---|---|---|---|---|
| | Olusosun | Owode Onirin | Soluos | Alakija | |
| **Dry season** | | | | | |
| Nitrates | 0.00±0.00 | 2.00±0.20 | 1.60±0.20 | 4.50±0.40 | 250mg/kg |
| Phosphate | 1.10±0.10 | 3.7±0.30 | 0.46±0.06 | 4.50±0.20 | 150mg/kg |
| Sulphate | 0.00±0.00 | 35.00±2.31 | 41.00±2.00 | 0.00±0.00 | 300mg/kg |
| % Organic Carbon | 23.20±0.20 | 23.53±0.88 | 18.44±0.40 | 23.49±0.02 | NS |
| % Organic matter | 40.10±1.58 | 40.68±0.93 | 31.89±1.01 | 40.62±0.58 | >6 |
| **Wet season** | | | | | |
| Nitrates | 2.80±0.32 | 2.80±0.26 | 73.20±0.30 | 3.10±0.52 | 250mg/kg |
| Phosphate | 0.44±0.00 | 1.08±0.04 | 5.30±036 | 1.19±0.25 | 150mg/kg |
| Sulphate | 29.00±0.21 | 35.00±0.00 | 18.00±0.20 | 30.00±0.00 | 300mg/kg |
| % Organic Carbon | 31.92±0.14 | 29.53±0.08 | 19.05±0.00 | 23.14±0.25 | NS |
| % Organic matter | 55.19±0.09 | 51.05±0.05 | 32.94±0.05 | 40.01±0.12 | >6 |

**Source**: Fieldwork data (2016 and 2017)

**(c) Analysis of soil samples from Solous recovery facility**

The findings from the chemical parameters analysis of soils from Solous MRF in the two seasons is shown in Table 4.11. The results are as follows: nitrates 1.60mg/kg, phosphate 0.46m/kg, sulphate 41.0mg/kg, % organic carbon 18.44 and % organic matter 31.89. Also, the wet season parameters show the following; nitrate 73.2mg/kg, phosphate 5.3mg/kg, sulphate 18.0mg/kg, % organic carbon and matter as 19.05% and 32.94% respectively. All the chemical parameters in the wet season except for the sulphate were higher in the dry season. However, the results were within the recommended limits from LASEPA and WHO.

**(d) Analysis of soil samples from soil samples at Alakija scrap site**

The mean concentrations and standard deviation values of soil samples collected during the dry and wet seasons from Alakija scrap site are presented in Table 4.11. In the dry season, the results reveal the following: nitrates 4.5mg, phosphate 4.5mg/kg, sulphate 0mg/kg, % organic carbon and organic matter are 23.49% and 40.62% respectively. The wet season results are as follows: nitrates 3.1mg, phosphate 1.9mg/kg, sulphate 23.mg/kg, % organic carbon and organic matter are 23.49 and 40.62. Results from the dry season differ from the wet season as it can be seen in the table. However, the values did not exceed WHO and LASEPA maximum limits when compared.

**(e) Overall mean of soil samples chemical parameters in Dry and Wet Seasons**

Table 4.12 shows the overall mean concentrations of the chemical parameters analysed in the dry and wet seasons. From this table, the mean results for the dry season are as follows: nitrate 2.02±1.70 mg/kg, phosphates 2.44±1.78 mg/kg, sulphates 19.00±20.06 mg.kg organic carbon 22.16±2.29% and organic matter 38.32±23.99%. It can be observed from this table that in the wet season, nitrates 20.47±31.80, phosphate 2.00±2.02, sulphate 25.91±5.33, organic carbon 25.91±5.33% and organic matter 44.70±9.20%. When the overall mean result was compared to the WHO and LASEPA values, the results did not exceed the limits.

**Table 4.13**: Mean concentrations of chemical parameters for soils in the dry and wet seasons

| Parameters | Study sites | | | | **Overall Mean** | WHO/ LASEPA standard |
|---|---|---|---|---|---|---|
| | Olusosun | Owode Onirin | Solous | Alakija | | |
| **Dry season** | | | | | | |
| Nitrates mg/kg | 0.00±0.00 | 2.00±0.20 | 1.60±0.20 | 4.50±0.40 | 2.02±1.70 | 250mg/kg |
| Phosphate mg/kg | 1.10±0.10 | 3.7±0.30 | 0.46±0.06 | 4.50±0.20 | 2.44±1.78 | 150mg/kg |
| Sulphates mg/kg | 0.00±0.00 | 35.00±2.31 | 41.00±2.00 | 0.00±0.00 | 19.00±20.06 | 300mg/kg |
| % Organic carbon | 23.20±0.20 | 23.53±0.88 | 18.44±0.40 | 23.49±0.02 | 22.16±2.29 | NS |
| % Organic matter | 40.10±1.58 | 40.68±0.93 | 31.89±1.01 | 40.62±0.58 | 38.32±3.99 | >6 |
| **Wet season** | | | | | | |
| Nitrates mg/kg | 2.80±0.32 | 2.80±0.26 | 73.20±0.30 | 3.10±0.52 | 20.47±31.80 | 250mg/kg |
| Phosphate mg/kg | 0.44±0.00 | 1.08±0.04 | 5.30±036 | 1.19±0.25 | 2.00±2.02 | 150mg/kg |
| Sulphates mg/kg | 29.00±0.21 | 35.00±0.00 | 18.00±0.20 | 30.00±0.00 | 28.00±6.48 | 300mg/kg |
| % Organic carbon | 31.92±0.14 | 29.53±0.08 | 19.05±0.00 | 23.14±0.25 | 25.91±5.33 | NS |
| % Organic matter | 55.19±0.09 | 51.05±0.05 | 32.94±0.05 | 40.01±0.12 | 44.70±9.20 | >6 |

*NS- Not specified

**Source**: Fieldwork data (2016 and 2017)

**(f) Seasonal Comparison of chemical parameters**

Also, Table 4.12 shows the comparison of the overall chemical parameters obtained from soils collected at the four study locations in the two seasons. In the dry season, nitrate, for instance, ranged from 0.00±0.00-4.50±0.40mg/kg. The highest concentration was obtained from Alakija dumpsite, while Olusosun landfill had the lowest value. During the wet season, the levels of nitrates obtained were higher than what was obtained in the dry season, ranging from 2.80±0.26-73.20±0.30mg/kg. Comparison of nitrate values for the overall seasons shows that the results obtained from the study location were higher (20.47±31.80) during the wet season than in the dry season. The result may be due to the runoff from the rainfall in the season. Phosphate ranged from 0.46±0.06-4.50±0.20mg/kg and 0.44±0.00-5.30±036mg/kg in the dry and wet seasons respectively. It can further be seen from the table that the overall mean concentration of phosphate was slightly high in the dry season (2.44±1.78) than in the wet season (2.00±2.02). Mean levels of sulphate in all the study sites ranged from 0.00±0.00-41.00±2.00mg/kg in the dry season and 18.00±0.20-

35.00±0.00 mg/kg in the wet season. When the overall mean concentrations for the two seasons were compared, the wet season means were higher. The average values of organic carbon from the study sites shown in Table 4.12 ranged from 18.44±0.40 to 23.53±0.88% during the dry season and 19.05±0.00 to 31.92±0.14% in the wet season. Comparison between the two seasons revealed that there was a minor increase in the percentage organic carbon during the wet season. The mean soil organic matter ranged from 31.89±1.01 to 40.68±0.93% in the dry season and 32.94±0.05 to 55.19±0.09% during the wet season. It can be seen in Table 4.13 that the mean concentration of organic matter during the wet season was higher (44.70±9.20) than what was obtained in the dry season (38.32±3.99). When all the overall mean concentrations were compared to the regulatory limits, it can be argued from the table that all the parameters were within the stipulated limits.

**Table 4.14:** Comparison of dry and wet seasons chemical parameters

| Chemical Parameters | Dry Season mean | Wet Season mean |
|---|---|---|
| Nitrates mg/kg | 2.02±1.70 | 20.47±31.80 |
| Phosphate mg/kg | 2.44±1.78 | 2.00±2.02 |
| Sulphates mg/kg | 19.00±20.06 | 28.00±6.48 |
| % Organic carbon | 22.16±2.29 | 25.91±5.33 |
| % Organic matter | 38.32±3.99 | 44.70±9.20 |

Source: Field data, 2016 and 2017

### 4.4.3 Trace/Toxic heavy metals concentrations

The average values and standard deviations of trace/toxic heavy metal concentrations of soils obtained from the four study sites during the dry and wet seasons compared with WHO and LASEPA standards are presented below.

#### (i) Trace/toxic heavy metals in soils from Olusosun landfill

Eleven trace/toxic heavy metals were analysed they are; zinc (Zn), iron (Fe), lead (Pb), calcium (Ca), manganese (Mn), cadmium (Cd), copper (Cu), silver (Ag), potassium (K), Nickel (Ni) and sodium (Na). The trace/toxic heavy metal concentrations obtained from the soil samples in the dry season is shown in Table 4.13. The concentrations are: Zn 4.21±0.53mg/kg, Fe 188.76±0.13mg, Pb 29.39±0.24mg/kg, Ca 0.41±0.02mg/kg, Mn 6.56±0.22mg/kg, Cd 0.41±0.02mg/kg, Cu 14.48±0.16mg/kg, Ag 0.03±0.00mg/kg, K 24.87±0.37mg/kg, Ni 0.14±0.02mg/kg and Na 31.64±0.24mg/kg. When the results were compared with WHO and LASEPA limits, it shows that Zn, Fe, Pb and Mn exceed the limits, while Ca, Cu, Na, K, Ag, Ni, and Cd are within limits. More so, the order of average concentration of the heavy metals in the surface soil samples during the dry season are: Fe > Ca > Na > Pb > K > Cu > Mn > Zn > Cd > Ni > Ag.
Table 4.14 shows the average values and standard deviations of heavy metals in soils collected in the wet season from the same site. The wet season concentrations are: Zn 63.17±0.30mg/kg, Fe 435.29±0.07mg/kg, Pb 75.57±0.16mg/kg, Ca 343.56±0.28mg/kg, Mn 27.93±0.26mg/kg, Cd 0.22±0.03mg/kg, Cu 158.32±0.56mg/kg, Ag 0.12±0.00mg/kg, K 24.74±0.08mg/kg, Ni 1.47±0.06mg/kg and Na 48.61±0.03mg/kg. It can be seen from the table that Zn, Fe, Pb and Mn are higher than the required concentrations and exceed WHO and LASEPA standards. However, Ca, Cu, Na, K, Ag, Ni, and Cd were within limits. Furthermore, the order of average heavy metal

concentrations in the season are as follows: Fe > Ca > Cu> Pb > Zn > Na > Mn > K > Ni > Cd > Ag.

### (ii) Trace/toxic heavy metals of soil samples from Owode Onirin Scrap markets

The heavy metal concentrations and standard deviations values are: Zn 18.78±0.10mg/kg, Fe 167.36±0.47mg/kg, Pb 27.83±0.28mg/kg, Ca 30.73±0.26mg/kg, Mn 36.18±0.20mg/kg, Cd 0.08±0.01mg/kg, Cu 157.05±0.50mg/kg, Ag 0.11±0.02mg/kg, K 35.57±0.29mg/kg, Ni 0.11±0.03mg/kg and Na 22.39±0.20mg/kg. The data shows that Zn, Fe, Pb and Mn are above the maximum limits of WHO and LASEPA, however, Ca, Cu, Na, K, Ag, Ni, and Cd were within the limits. Moreover, the order of heavy metal concentrations in the surface soils from the site during the dry season are: Fe > Cu > Mn > K > Ca > Pb > Na > Zn > Ag > Ni > Cd.

The mean heavy metal concentrations and standard deviations of soil samples collected during the wet season from Owode Onirin Scrap Market is presented in Table 4.14. The values are: Zn 99.71±0.12mg/kg, Fe 667.99±0.15mg/kg, Pb 121.7±0.04mg/kg, Ca 488.09±0.16mg/kg, Mn 46.84±0.00mg/kg, Cd 0.29±0.03mg/kg, Cu 103.47±0.03mg/kg, Ag 0.25±0.00mg/kg, K 33.61±0.57mg/kg, Ni 1.12±0.00mg/kg and Na 60.05±0.16mg/kg. As shown in Table 4.14, the concentrations of Zn, Fe, Pb and Mn exceed WHO and LASEPA standards, while Ca, Cu, Na, K, Ag, Ni, and Cd are within the standards. The heavy metal average concentrations order in the surface soil samples from the site during the wet season are: Fe > Ca > Pb > Cu > Zn > Na > Mn > K > Ni > Cd > Ag.

**Table 4.15:** Trace/toxic heavy metal concentration (mg/kg) in soil during dry season (*mean±SD*)

| Parameter | STUDY SITES | | | | WHO/ LASEPA limits |
|---|---|---|---|---|---|
| | **Olusosun** | **Owode Onirin** | **Soluos** | **Alakija** | |
| Zinc | 4.21±0.53 | 18.78±0.10 | 0.00±0.00 | 8.43±0.30 | <1 |
| Iron | 188.76±0.13 | 167.36±0.47 | 133.92±0.20 | 148.12±0.31 | 5.0mg/kg |
| Lead | 29.39±0.24 | 27.83±0.28 | 0.00±0.00 | 4.45±0.25 | 5.0mg/kg |
| Calcium | 59.02±0.10 | 30.73±0.26 | 0.00±0.00 | 97.16±0.17 | 2500mg/kg |
| Manganese | 6.56±0.22 | 36.18±0.20 | 1.32±0.03 | 3.21±0.21 | 0.2mg/kg |
| Cadmium | 0.41±0.02 | 0.08±0.01 | 0.00±0.00 | 0.00±0.00 | |
| Copper | 14.48±0.16 | 157.05±0.50 | 0.42±0.02 | 32.20±0.22 | |
| Silver | 0.03±0.00 | 0.11±0.02 | 0.07±0.00 | 0.09±0.01 | NS |
| Potassium | 24.87±0.37 | 35.57±0.29 | 5.98±0.33 | 15.15±0.26 | 725mg/kg |
| Nickel | 0.14±0.02 | 0.11±0.03 | 0.05±0.02 | 0.17±0.02 | |
| Sodium | 31.64±0.24 | 22.39±0.20 | 17.59±0.09 | 19.90±0.40 | |

* NS- Not specified

Source: Fieldwork data (2016 and 2017)

**Table 4.16**: Trace/toxic heavy metal concentration (mg/kg) in soil during the wet season (***mean***±*SD*)**

| Parameter | STUDY SITES | | | | STANDARDS WHO and LASEPA |
|---|---|---|---|---|---|
| | **Olusosun** | **Owode Onirin** | **Soluos** | **Alakija** | |
| Zinc | 63.17±0.30 | 99.71±0.12 | 6.03±0.14 | 4.80±0.95 | <1 |
| Iron | 435.29±0.07 | 667.99±0.15 | 360.31±0.27 | 391.00±0.11 | 5.0mg/kg |
| Lead | 75.57±0.16 | 121.7±0.04 | 2.82±0.18 | 2.82±0.56 | 5.0mg/kg |
| Calcium | 343.56±0.28 | 488.09±0.16 | 40.08±0.09 | 29.35±0.00 | 2500mg/kg |
| Manganese | 27.93±0.26 | 46.84±0.00 | 2.87±0.00 | 2.50±0.15 | 0.2mg/kg |
| Cadmium | 0.22±0.03 | 0.29±0.03 | 0.07±0.02 | 0.00±0.00 | |
| Copper | 158.32±0.56 | 103.47±0.03 | 0.37±0.03 | 0.63±0.06 | |
| Silver | 0.12±0.00 | 0.25±0.00 | 0.12±0.00 | 0.31±0.02 | NS |
| Potassium | 24.74±0.08 | 33.61±0.57 | 7.62±0.07 | 40.20±0.20 | 725mg/kg |
| Nickel | 1.47±0.06 | 1.12±0.00 | 0.00±0.00 | 0.33±0.00 | |
| Sodium | 48.61±0.03 | 60.05±0.16 | 2.66±0.02 | 0.00±0.00 | |

*NS- Not specified

Source: Field data, 2016 and 2017.

**(iii) Trace/toxic heavy metals of soil samples from Solous MRF**

The dry season results from Solous MRF is presented in Table 4.13 and are: Zn 0.00±0.00mg/kg, Fe 133.92±0.20mg/kg, Pb 0.00±0.00mg/kg, Ca 0.00±0.00mg/kg, Mn 1.32±0.03mg/kg, Cd 0.00±0.00mg/kg, Cu 0.42±0.02mg/kg, Ag 0.07±0.00mg/kg, K 5.98±0.33mg/kg, Ni 0.05±0.02mg/kg and Na 17.59±0.09mg/kg. From the data, it can be seen that Zn, Pb, Ca and Cd were absent in the soil, Fe and Mn exceed WHO and LASEPA limits and Cu, Ag, K, Ni, and Na were within the limits. The mean concentrations order of the heavy metals in the season are: Fe > Na > K > Mn > Cu > Ag > Ni > Zn > Pb > Ca > Cd.

Table 4.14 reveals the mean concentrations and standard deviations of heavy metals obtained in the wet season from the same site. The concentrations and standard deviation values are: Zn 6.03±0.14mg/kg, Fe 360.31±0.27mg/kg, Pb 2.82±0.18mg/kg, Ca 40.08±0.09mg/kg, Mn 2.87±0.00mg/kg, Cd 0.07±0.02mg/kg, Cu 0.37±0.03mg/kg, Ag 0.12±0.00mg/kg, K 7.62±0.07mg/kg, Ni 0.00±0.00, and Na 2.66±0.02mg/kg. The table suggests that Fe, Zn, Pb and Mn were above WHO and LASEPA limits when compared. Ni is absent in the soil, while Ca, Cu, K, Cd, Ag and Na are present in little quantities. From the data in Table 4.14, the average concentrations order of heavy metals are: Fe > Ca > K > Zn > Mn > Pb > Na > Cu > Ag > Cd > Ni.

**(iii) Trace/Toxic Heavy Metals of Soil Samples in Alakija Scrap Site**

The concentrations for trace/toxic heavy metals from soils collected at Alakija scrap site are as follows: Zn 8.43±0.30mg/kg, Fe 148.12±0.31mg/kg, Pb 4.45±0.25mg/kg, Ca 97.16±0.17mg/kg Mn 3.21±0.21mg/kg, Cd 0.00±0.00mg/kg, Cu 32.20±0.22mg/kg, Ag 0.09±0.01mg/kg, K

15.15±0.26mg/kg, Ni 0.17±0.02 and Na 19.90±0.40mg/kg. The data presented in Table 4.13 shows that Cd is not found in the soil samples, while Fe, Zn, Pb and Mn concentrations exceed WHO and LASEPA limits. Also, other heavy metals like Ni, Na, Ca, Cu, K and Ag were within the standards. The mean concentrations order for the dry season soil samples are: Fe > Ca > Cu > Na > K > Zn > Pb > Mn > Ni > Ag > Cd.

The results of heavy metal concentrations and standard deviations of soil samples found from Alakija scrap site during the wet season is shown in 4.14. The concentrations are: Zn 4.80±0.95mg/kg, Fe 391.00±0.11mg/kg, Pb 2.82±0.56mg/kg, Ca 29.35±0.00mg/kg Mn 2.50±0.15mg/kg, Cd 0.00±0.00mg/kg, Cu 0.63±0.06mg/kg, Ag 0.31±0.02mg/kg, K 40.20±0.20mg/kg, Ni 0.33±0.00mg/kg and Na 0.00±0.00mg/kg. From the table, it is obvious that Na and Cd were absent in the soil samples, while Fe, Zn, Mn and Pb exceeded the maximum WHO and LASEPA limits. Meanwhile, Ca, Cu, K, Ag and Ni were within limits. The mean concentrations order for the wet season is as follows: Fe > K > Ca > Zn > Pb > Mn > Cu > Ni > Ag > Cd > Na.

(v) **Overall Mean of Soil Samples Trace/Toxic Heavy Metals in Dry and Wet Seasons**

Table 4.15 below presents the overall average concentrations and standard deviations of all trace/toxic heavy metals obtained from all study sites during the dry season. The mean concentrations are: Zn 7.86±7.29mg/kg, Fe 159.54±21.54mg/kg, Pb 15.24±13.89mg/kg, Ca 46.73±37.42mg/kg, Mn 11.84±14.82mg/kg, Cd 0.12±0.18mg/kg, Cu 51.04±65.00mg/kg, Ag 0.07±0.03mg/kg, K 20.39±11.51mg/kg, Ni 0.12±0.05mg/kg and Na 22.88±5.58mg/kg. When the overall mean concentrations were compared to WHO and LASEPA limits, it can be seen that Zn, Fe, Pb and Mn were above the limits. The overall mean concentrations order for the dry season are: Fe > Cu > Ca > Na > K > Pb > Mn > Zn > Cd > Ni >Ag.

The overall mean concentrations and standard deviations of the heavy metals found in all soil samples during the wet season are shown in Table 4.15. The concentrations are: Zn 43.43±41.94mg/kg, Fe 463.75±126.26mg/kg, Pb 50.73±52.88mg/kg, Ca 225.36±206.15mg/kg, Mn 20.03±19.42mg/kg, Cd 0.14±0.12mg/kg, Cu 65.70±71.04mg/kg, Ag 0.19±0.08mg/kg, K 26.54±12.77mg/kg and Na 27.83±28.02mg/kg. From the data in Table 4.15 below, it can be seen that the concentrations of Zn, Fe, Pb and Mn were higher than the limits set by WHO and LASEPA for soils in Lagos State. The average concentrations order of heavy metals for the wet season are: Fe > Ca > Cu > Pb > Zn > Na > K > Mn > Ni > Ag > Cd.

**Table 4.17:** Mean concentrations of all trace/toxic heavy metals for dry season soil samples

| Parameter | Study Sites | | | | | WHO and LASEPA limit |
|---|---|---|---|---|---|---|
| | **Olusosun** | **Owode Onirin** | **Soluos** | **Alakija** | **Overall mean** | |
| Zinc | 4.21±0.53 | 18.78±0.10 | 0.00±0.00 | 8.43±0.30 | 7.86±7.29 | <1 |
| Iron | 188.76±0.13 | 167.36±0.47 | 133.92±0.20 | 148.12±0.31 | 159.54±21.54 | 5.0mg/kg |
| Lead | 29.39±0.24 | 27.83±0.28 | 0.00±0.00 | 4.45±0.25 | 15.24±13.89 | 5.0mg/kg |
| Calcium | 59.02±0.10 | 30.73±0.26 | 0.00±0.00 | 97.16±0.17 | 46.73±37.42 | 2500mg/kg |
| Manganese | 6.56±0.22 | 36.18±0.20 | 1.32±0.03 | 3.21±0.21 | 11.84±14.82 | 0.2mg/kg |
| Cadmium | 0.41±0.02 | 0.08±0.01 | 0.00±0.00 | 0.00±0.00 | 0.12±0.18 | |
| Copper | 14.48±0.16 | 157.05±0.50 | 0.42±0.02 | 32.20±0.22 | 51.04±65.00 | |
| Silver | 0.03±0.00 | 0.11±0.02 | 0.07±0.00 | 0.09±0.01 | 0.07±0.03 | NS |
| Potassium | 24.87±0.37 | 35.57±0.29 | 5.98±0.33 | 15.15±0.26 | 20.39±11.51 | 725mg/kg |
| Nickel | 0.14±0.02 | 0.11±0.03 | 0.05±0.02 | 0.17±0.02 | 0.12±0.05 | |
| Sodium | 31.64±0.24 | 22.39±0.20 | 17.59±0.09 | 19.90±0.40 | 22.88±5.58 | |

*NS- Not specified

**Source**: Field data, 2016 and 2017

**Table 4.18:** Mean concentrations of trace/toxic heavy metals for wet season soil samples

| Parameter | Study sites | | | | Overall mean | WHO and LASEPA limits |
|---|---|---|---|---|---|---|
| | **Olusosun** | **Owode Onirin** | **Soluos** | **Alakija** | | |
| Zinc | 63.17±0.30 | 99.71±0.12 | 6.03±0.14 | 4.80±0.95 | 43.43±41.94 | <1 |
| Iron | 435.29±0.07 | 667.99±0.15 | 360.31±0.27 | 391.00±0.11 | 463.75±126.26 | 5.0mg/kg |
| Lead | 75.57±0.16 | 121.7±0.04 | 2.82±0.18 | 2.82±0.56 | 50.73±52.88 | 5.0mg/kg |
| Calcium | 343.56±0.28 | 488.09±0.16 | 40.08±0.09 | 29.35±0.00 | 225.36±206.15 | 2500mg/kg |
| Manganese | 27.93±0.26 | 46.84±0.00 | 2.87±0.00 | 2.50±0.15 | 20.03±19.42 | 0.2mg/kg |
| Cadmium | 0.22±0.03 | 0.29±0.03 | 0.07±0.02 | 0.00±0.00 | 0.14±0.12 | |
| Copper | 158.32±0.56 | 103.47±0.03 | 0.37±0.03 | 0.63±0.06 | 65.70±71.04 | |
| Silver | 0.12±0.00 | 0.25±0.00 | 0.12±0.00 | 0.31±0.02 | 0.19±0.08 | NS |
| Potassium | 24.74±0.08 | 33.61±0.57 | 7.62±0.07 | 40.20±0.20 | 26.54±12.77 | 725mg/kg |
| Nickel | 1.47±0.06 | 1.12±0.00 | 0.00±0.00 | 0.33±0.00 | 0.87±0.75 | |
| Sodium | 48.61±0.03 | 60.05±0.16 | 2.66±0.02 | 0.00±0.00 | 27.83±28.02 | |

*****NS- Not specified

**Source:** Field data (201 and 2017)

**(vi) Seasonal Comparison of trace/toxic heavy metals**

Table 4.15 above also presents the summary of the mean concentrations of all heavy metals from all the study sites for both dry and wet seasons. When the mean levels of the two seasons were compared, the concentration of Zn was lower in the soil sample during the dry season. The result suggests that the mean Fe concentration for the wet season is higher than the mean in the dry season. More so, from the data, the overall mean concentration of Pb in the wet season is higher than what was obtained in the dry season. It can also be seen that the dry season concentrations of Ca are lower in the dry season than the wet season concentration. The mean Manganese concentrations in the dry season ranged from 1.32±0.03-36.18±0.20mg/kg and 2.50±0.15-46.84±0.00mg/kg during the wet season. As shown in the table above, the overall mean level in the wet season was higher than the total mean concentration in the dry season. Cadmium's mean concentrations ranged from 0.00±0.00-0.41±0.02mg/kg and 0.00±0.00-0.29±0.03mg/kg in the dry and wet seasons respectively. The data suggests that the overall mean concentration of cadmium in the wet season is slightly higher than the total mean levels in the dry season. As shown in the table, the mean concentration of Copper in the wet season is also higher than the dry season concentration. Table 4.15 shows that there was a minor increase in the level of silver during the wet season than in the dry season. The overall mean density of potassium in the wet season was higher than the dry season. The mean concentrations of Nickel ranged from 0.05±0.02-0.17±0.02mg/kg during the dry season and 0.00±0.00-1.47±0.06mg/kg in the wet season. When the dry season mean level was compared to the wet season, the wet season means concentration was higher. The mean

concentrations of Sodium ranged from 17.59±0.09-31.64±0.24mg/kg during the dry season and 0.00±0.00-60.05±0.16mg/kg in the wet season. When the overall mean level in the dry season was compared to the wet season concentration, it can be seen that the wet season concentration was higher.

**Table 4.19:** Comparison of dry and wet seasons chemical parameters

| Heavy metals | Mean Dry season | Wet season |
|---|---|---|
| Zinc | 7.86±7.29 | 43.43±41.94 |
| Iron | 159.54±21.54 | 463.75±126.26 |
| Lead | 15.24±13.89 | 50.73±52.88 |
| Calcium | 46.73±37.42 | 225.36±206.15 |
| Manganese | 11.84±14.82 | 20.03±19.42 |
| Cadmium | 0.12±0.18 | 0.14±0.12 |
| Copper | 51.04±65.00 | 65.70±71.04 |
| Silver | 0.07±0.03 | 0.19±0.08 |
| Potassium | 20.39±11.51 | 26.54±12.77 |
| Nickel | 0.12±0.05 | 0.87±0.75 |
| Sodium | 22.88±5.58 | 27.83±28.02 |

**Source:** Fieldwork data (2016 and 2017)

### 4.4.4 Statistical Test of Variance in Soil samples

**a) ANOVA Results for soil samples in the dry and wet seasons**

To determine the interactions between the two seasons, a one-way ANOVA was used. This approach was imperative as it allows the researcher compare the means of two subjects.

**Analysis of Variance (ANOVA)**

Analysis of variance on the seasonal relationship of soil sample was based on the following hypothesis:

Ho (Null Hypothesis): That the mean concentrations of parameters in soils collected from the two seasons were similar.

H1 (Alternative hypothesis): That the mean concentrations of parameters in soils collected from the two seasons were not similar.

Table 4.20 below shows the physicochemical ANOVA test results obtained for the two seasons. It can be seen from the table that temperature, pH, % moisture content, % organic carbon and organic matter are significantly different in the dry season as compared to the wet season. Furthermore, Table 4.21 shows the ANOVA test results for the trace/toxic heavy metals. It can be seen from this table that six out of the eleven heavy metals (Zn, Fe, Pb, Ca, Ag and Ni) differed or varied significantly. Thus, since the parameters differ, the Ho is therefore not accepted and the H1 is accepted or retained. The (F) statistic in the table refers to the variation between the mean parameters of the two seasons. The value of (P) statistic in the table shows if the variation between

the mean group is statistically significant. It is important to note that P ≤0.05, implies there is a significant variation or statistically significant.
Table 4.20 showed that the effect of season on physicochemical parameters was statistical significant:
Temperature F (1, 22) = 54.833, P = 0.001. This shows that the temperature was higher in the dry season than the wet season.
pH F (1, 22) = 127.616, P = 0.001}. It reveals that the pH was higher in the in the wet season and lower in the dry season.
% moisture content F (1, 22) = 5.578, P = 0.027. It shows that the moisture content in the wet season is higher than that of the dry season.
% organic carbon F (1, 22) = 5.007, P = 0.036. It denotes that the organic carbon is higher in the wet season than the dry season.
% organic carbon F (1, 22) = 4.997, P = 0.036. It means that the organic matters in the dry season was lower and higher in the wet season.

Additionally, from Table 4.21 the effect of season on heavy metal concentrations was statistical significant:
Zinc F (1, 22) = 8.380, P = 0.008. It denotes that Zinc concentrations were higher in the soil in the wet season than the dry season.
Iron F (1, 22) = 67.692, P = 0.001. It means that Iron concentration was more in the soil in the wet season than the dry season.
Lead F (1, 22) = 5.008, P = 0.036. It shows that the concentration of Lead was more in the soil in the wet season than the wet season.
Calcium F (1, 22) = 8.722, P = 0.007. It implies that the concentration of Calcium was more in the soil in the wet season than in the dry season.
Silver {F (1, 22) = 21.262: P = 0.001}. It means that the concentration of Silver was more in the soil in the wet season than the wet season.
Nickel {F (1, 22) = 12.016: P = 0.002}. It shows that the concentration of Nickel was more in the soil during the wet season than the dry season

In this statistical analysis, the significance values (P), is the likelihood that the result is consistent as well as not planned or manipulated. In all the statistical analysis, 95% confidence level at 0.05 is presumed. Where P < 0.05, implies that a 95% confidence the result is reliable. Phosphates and sulphates are not statistically significant hence, p>0.05.

**Table 4.20:** ANOVA results for the effect of seasons on physicochemical parameters

| | | Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Temperature | Between Groups | 9.004 | 1 | 9.004 | 54.833 | .000 |
| | Within Groups | 3.613 | 22 | .164 | | |
| | Total | 12.616 | 23 | | | |
| pH | Between Groups | 20.480 | 1 | 20.480 | 127.616 | .000 |
| | Within Groups | 3.531 | 22 | .160 | | |
| | Total | 24.010 | 23 | | | |
| % Moisture content | Between Groups | 74.765 | 1 | 74.765 | 5.578 | .027 |
| | Within Groups | 294.863 | 22 | 13.403 | | |
| | Total | 369.628 | 23 | | | |
| Nitrate | Between Groups | 2042.415 | 1 | 2042.415 | 4.029 | .057 |
| | Within Groups | 11152.670 | 22 | 506.940 | | |
| | Total | 13195.085 | 23 | | | |
| Phosphate | Between Groups | 1.148 | 1 | 1.148 | .317 | .579 |
| | Within Groups | 79.799 | 22 | 3.627 | | |
| | Total | 80.947 | 23 | | | |
| Sulphate | Between Groups | 485.910 | 1 | 485.910 | 2.187 | .153 |
| | Within Groups | 4887.789 | 22 | 222.172 | | |
| | Total | 5373.699 | 23 | | | |
| Organic Carbon | Between Groups | 84.150 | 1 | 84.150 | 5.007 | .036 |
| | Within Groups | 369.710 | 22 | 16.805 | | |
| | Total | 453.860 | 23 | | | |
| Organic matter | Between Groups | 251.554 | 1 | 251.554 | 4.997 | .036 |
| | Within Groups | 1107.466 | 22 | 50.339 | | |
| | Total | 1359.019 | 23 | | | |

**Table 4.21** ANOVA results for the effect of seasons on trace/toxic heavy metal concentrations

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Zinc | Between Groups | 7592.061 | 1 | 7592.061 | 8.380 | .008 |
| | Within Groups | 19931.150 | 22 | 905.961 | | |
| | Total | 27523.211 | 23 | | | |
| Iron | Between Groups | 555280.597 | 1 | 555280.597 | 67.692 | .000 |
| | Within Groups | 180468.157 | 22 | 8203.098 | | |
| | Total | 735748.754 | 23 | | | |
| Lead | Between Groups | 7483.955 | 1 | 7483.955 | 5.008 | .036 |
| | Within Groups | 32876.423 | 22 | 1494.383 | | |
| | Total | 40360.378 | 23 | | | |
| Calcium | Between Groups | 191448.489 | 1 | 191448.489 | 8.722 | .007 |
| | Within Groups | 482895.376 | 22 | 21949.790 | | |
| | Total | 674343.865 | 23 | | | |
| Manganese | Between Groups | 405.164 | 1 | 405.164 | 1.358 | .256 |
| | Within Groups | 6565.679 | 22 | 298.440 | | |
| | Total | 6970.843 | 23 | | | |
| Cadmium | Between Groups | .003 | 1 | .003 | .131 | .720 |
| | Within Groups | .508 | 22 | .023 | | |
| | Total | .511 | 23 | | | |
| Copper | Between Groups | 1289.494 | 1 | 1289.494 | .278 | .603 |
| | Within Groups | 101998.996 | 22 | 4636.318 | | |
| | Total | 103288.490 | 23 | | | |
| Silver | Between Groups | .086 | 1 | .086 | 21.262 | .000 |
| | Within Groups | .089 | 22 | .004 | | |
| | Total | .176 | 23 | | | |
| Potassium | Between Groups | 227.120 | 1 | 227.120 | 1.537 | .228 |
| | Within Groups | 3250.598 | 22 | 147.754 | | |
| | Total | 3477.718 | 23 | | | |
| Nickel | Between Groups | 3.375 | 1 | 3.375 | 12.016 | .002 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Within Groups | 6.179 | 22 | .281 | | |
| | Total | 9.554 | 23 | | | |
| Sodium | Between Groups | 147.015 | 1 | 147.015 | .360 | .554 |
| | Within Groups | 8976.044 | 22 | 408.002 | | |
| | Total | 9123.059 | 23 | | | |

**Test for Homogeneity**

Homogeneity test results for all the examined parameters are presented in Table 4.18 below. The objective of Levene statistic in this study is to check whether the differences amongst the seasons are similar. Significant values in Levene statistic ($p < 0.05$) implies that the seasonal variations are significantly different. Furthermore, to find out where the exact variation occurs in the season, a post-hoc test has to be performed. As it can be seen in Table 4.22, there is a significant difference at temperature, $P < 0.002$; pH, $P < 0.025$; % moisture content, $P \leq 0.001$; Nitrates, $P \leq 0.001$; Sulphate, $P \leq 0.001$; % organic carbon, $P \leq 0.001$; % organic matter, $P \leq 0.001$; Zinc, $P \leq 0.001$; Iron, $P \leq 0.001$; lead, $P \leq 0.001$; Calcium, $P \leq 0.001$; silver, $P \leq 0.001$; Nickel, $P \leq 0.001$; and Sodium, $P \leq 0.001$.

**Table 4.22:** Homogeneity test results for seasonal difference in soil sample

| | Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|---|
| Temperature | 12.392 | 1 | 22 | .002 |
| pH | 5.781 | 1 | 22 | .025 |
| % moisture content | 24.728 | 1 | 22 | .000 |
| Nitrate | 29.758 | 1 | 22 | .000 |
| Phosphate | .001 | 1 | 22 | .973 |
| Sulphate | 100.984 | 1 | 22 | .000 |
| Organic Carbon | 23.072 | 1 | 22 | .000 |
| Organic matter | 22.618 | 1 | 22 | .000 |
| Zinc | 62.594 | 1 | 22 | .000 |
| Iron | 18.012 | 1 | 22 | .000 |
| Lead | 49.255 | 1 | 22 | .000 |
| Calcium | 95.775 | 1 | 22 | .000 |
| Manganese | 3.007 | 1 | 22 | .097 |
| Cadmium | 1.306 | 1 | 22 | .265 |
| Copper | 1.136 | 1 | 22 | .298 |
| Silver | 22.917 | 1 | 22 | .000 |
| Potassium | .047 | 1 | 22 | .831 |
| Nickel | 243.783 | 1 | 22 | .000 |
| Sodium | 202.574 | 1 | 22 | .000 |

### a) ANOVA Results for the effect of study sites on soil samples

In this section, the effect of the study locations on the soil sample was checked using one-way ANOVA.

***Analysis of Variance***

The consequence of changes in study sites on soil samples existed on the following hypothesis

Ho (Null Hypothesis): That the mean concentrations of heavy metals detected in soil were similar in all study locations.

$H_1$ (Alternative hypothesis): That the mean concentrations of heavy metals detected in soils were not similar in all study locations.

Table 4.19 below shows the ANOVA test results obtained for the relationship between the study locations and the mean concentrations of the physicochemical parameters in the dry and wet seasons. From the table below, we can see that four physicochemical parameters; % moisture contents, nitrates, % organic carbon and % organic matter differed significantly across all study sites. Therefore, Ho is rejected, and H1 accepted.

Table 4.20 further reveals the result obtained for the relationships between the study locations and the mean concentrations of the heavy metals examined in the two seasons. It can be seen that ten out of the eleven heavy metals analysed varied significantly. Thus, since the parameters differ, the Ho is therefore rejected, and the H1 is accepted or retained. The features on the tables are, the ratio of mean square deviation between and within examined parameters, which is also referred to as the (F) statistic, it, therefore, implies that the (F) statistic in the table below represents the variation between the mean parameters of the two seasons. The value of (P) statistic in the table denotes whether the difference between the mean parameters is statistically significant. It is important to note that $P \leq 0.05$ implies that there is a significant variation.

As a result of what is shown in Tables 4.19 and 4.20, the effect of location sites on the physicochemical and heavy metal concentrations was statistical significant:

% moisture content {$F(3, 20) = 5.921, P < 0.005$}.
Nitrates {$F(3, 20) = 4.747, P < 0.012$}.
% organic carbon {$F(3, 20) = 11.034, P \leq 0.001$}.
% organic matters {$F(3, 20) = 10.940, P \leq 0.001$}.
Zinc {$F(3, 20) = 5.42, P < 0.007$}.
Lead {$F(3, 20) = 9.696, P \leq 0.001$}.
Calcium {$F(3, 20) = 10.940, P < 0.036$}.
Manganese {$F(3, 20) = 47.354, P \leq 0.001$}.
Cadmium {$F(3, 20) = 19.033, P \leq 0.001$}.
Copper {$F(3, 20) = 12.026, P \leq 0.001$}.
Silver {$F(3, 20) = 10.940, P < 0.026$}.
Potassium {$F(3, 20) = 17.670, P \leq 0.001$}.
Nickel {$F(3, 20) = 3.354, P \leq 0.039$}.

Sodium {F (3, 20) = 10.769, P ≤ 0.001}.
Temperature, pH, phosphates and iron did not show any significant statistical variation between the study sites and the examined parameters.

**Table 4.23**: ANOVA test results for the variation between study sites and physicochemical parameters

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| All temperature | Between Groups | 1.031 | 3 | .344 | .593 | .627 |
| | Within Groups | 11.585 | 20 | .579 | | |
| | Total | 12.616 | 23 | | | |
| All pH | Between Groups | .834 | 3 | .278 | .240 | .867 |
| | Within Groups | 23.176 | 20 | 1.159 | | |
| | Total | 24.010 | 23 | | | |
| % moisture content | Between Groups | 173.867 | 3 | 57.956 | 5.921 | .005 |
| | Within Groups | 195.761 | 20 | 9.788 | | |
| | Total | 369.628 | 23 | | | |
| All Nitrate | Between Groups | 5488.020 | 3 | 1829.340 | 4.747 | .012 |
| | Within Groups | 7707.065 | 20 | 385.353 | | |
| | Total | 13195.085 | 23 | | | |
| All phosphate | Between Groups | 17.746 | 3 | 5.915 | 1.872 | .167 |
| | Within Groups | 63.202 | 20 | 3.160 | | |
| | Total | 80.947 | 23 | | | |
| All sulphate | Between Groups | 1928.820 | 3 | 642.940 | 3.733 | .028 |
| | Within Groups | 3444.879 | 20 | 172.244 | | |
| | Total | 5373.699 | 23 | | | |
| Organic Carbon | Between Groups | 282.919 | 3 | 94.306 | 11.034 | .000 |
| | Within Groups | 170.942 | 20 | 8.547 | | |
| | Total | 453.860 | 23 | | | |
| Organic matter | Between Groups | 844.448 | 3 | 281.483 | 10.940 | .000 |
| | Within Groups | 514.572 | 20 | 25.729 | | |
| | Total | 1359.019 | 23 | | | |

**Table 4.24**: ANOVA test results for the variation between study sites and trace/toxic heavy metals

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| All zinc | Between Groups | 12407.186 | 3 | 4135.729 | 5.472 | .007 |
| | Within Groups | 15116.025 | 20 | 755.801 | | |
| | Total | 27523.211 | 23 | | | |
| All iron | Between Groups | 102958.339 | 3 | 34319.446 | 1.085 | .378 |
| | Within Groups | 632790.415 | 20 | 31639.521 | | |
| | Total | 735748.754 | 23 | | | |
| All lead | Between Groups | 23915.884 | 3 | 7971.961 | 9.696 | .000 |
| | Within Groups | 16444.494 | 20 | 822.225 | | |
| | Total | 40360.378 | 23 | | | |
| Calcium | Between Groups | 229526.323 | 3 | 76508.774 | 3.440 | .036 |
| | Within Groups | 444817.542 | 20 | 22240.877 | | |
| | Total | 674343.865 | 23 | | | |
| manganese | Between Groups | 6110.571 | 3 | 2036.857 | 47.354 | .000 |
| | Within Groups | 860.272 | 20 | 43.014 | | |
| | Total | 6970.843 | 23 | | | |
| Cadmium | Between Groups | .379 | 3 | .126 | 19.033 | .000 |
| | Within Groups | .133 | 20 | .007 | | |
| | Total | .511 | 23 | | | |
| Copper | Between Groups | 66451.054 | 3 | 22150.351 | 12.026 | .000 |
| | Within Groups | 36837.436 | 20 | 1841.872 | | |
| | Total | 103288.490 | 23 | | | |
| Silver | Between Groups | .064 | 3 | .021 | 3.807 | .026 |
| | Within Groups | .112 | 20 | .006 | | |
| | Total | .176 | 23 | | | |
| Potassium | Between Groups | 2525.045 | 3 | 841.682 | 17.670 | .000 |
| | Within Groups | 952.673 | 20 | 47.634 | | |
| | Total | 3477.718 | 23 | | | |
| Nickel | Between Groups | 3.198 | 3 | 1.066 | 3.354 | .039 |
| | Within Groups | 6.356 | 20 | .318 | | |
| | Total | 9.554 | 23 | | | |
| Sodium | Between Groups | 5634.708 | 23 | 1878.236 | 10.769 | .000 |
| | Within Groups | 3488.350 | 23 | 174.418 | | |
| | Total | 9123.059 | 23 | | | |

**Table 4.25**: Test of Homogeneity of Variances

| | Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|---|
| All temperature | 7.066 | 3 | 20 | .002 |
| All pH | 37.049 | 3 | 20 | .000 |
| % moisture content | 8853.636 | 3 | 20 | .000 |
| All Nitrate | 23454.179 | 3 | 20 | .000 |
| All phosphate | 132.849 | 3 | 20 | .000 |
| All sulphate | 164.377 | 3 | 20 | .000 |
| Organic Carbon | 259.512 | 3 | 20 | .000 |
| Organic matter | 186.956 | 3 | 20 | .000 |
| All zinc | 15685.911 | 3 | 20 | .000 |
| All iron | 529215.087 | 3 | 20 | .000 |
| All lead | 50192.404 | 3 | 20 | .000 |
| Calcium | 2638849.021 | 3 | 20 | .000 |
| manganese | 6298.333 | 3 | 20 | .000 |
| Cadmium | 59.750 | 3 | 20 | .000 |
| Copper | 88611.208 | 3 | 20 | .000 |
| Silver | 87.778 | 3 | 20 | .000 |
| Potassium | 3015.642 | 3 | 20 | .000 |
| Nickel | 1792.255 | 3 | 20 | .000 |
| Sodium | 5468.619 | 3 | 20 | .000 |

**Test for Homogeneity**

Homogeneity test results for all the examined parameters are presented in Table 4.21 above. The objective of Levene statistic in this study is to check whether the differences amongst the study locations are similar. Significant values in Levene statistic ($p < 0.05$) implies that the study location variations are significantly different. It can be seen from Table 4.21 that there is a significant difference between all parameters examined physical, chemical and heavy metals.

**b) Correlation Analysis**

Table 4.22 below presents the results of correlation coefficient (r) examined amongst the heavy metal concentrations and pH values from the overall mean of the various study locations. Significant positive correlation was determined between Fe and pH ($r = 0.727$), Fe and Zn ($r = 0.831$), Pb and Zn ($r = 0.976$), Pb and Fe ($r = 0.779$), Ca and Zn ($r = 0.980$), Ca and Fe ($r = 0.823$), Ca and Pb ($r = 0.958$), Mn and Zn (0.851), Mn and Fe ($r = 0.574$), Mn and Pb ($r = 0.863$) and between Mn and Ca (0.750) at $p < 0.01$. More so, positive correlation at $p < 0.05$ between Cd and Zn ($r = 0.482$) and Cd and Mn ($r = 0.426$) as well as between Cd and Pb ($r = 0.648$), Cd and Ca ($r = 0.517$), Cu and Zn ($r = 0.654$), Cu and Pb ($r = 0.653$), Cu and Ca ($r = 0.571$), Cu and Mn ($r = 0.863$), Ag and pH ($r = 0.738$) and Ag and Fe ($r = 0.673$) at $p < 0.01$. Other significant positive correlations were obtained between K and Fe ($r = 0.408$), K and Pb ($r = 0.424$), K and Cu (0.459),

Ni and pH (r = 0.408), Ni and Cd (r = 0. 471), and Na and Fe (0.514) at $p < 0.05$. Furthermore, positive correction at $p < 0.01$ were obtained between K and Mn (r = 0.551), K and Ag (r = 0.628), Ni and Zn (r = 0.960), Ni and Fe (r = 0.830), Ni and Pb (r = 0.932), Ni and Ca (r = 0.972), Ni and Mn (r = 0.731), Ni and Cu (r = 0.606), Na and Zn (r = 0.870), Na and Pb (r =0.926), Na and Ca (r = 0.881), Na and Mn (r = 0.0772), Na and Cd (r = 0.700), Na and Cu (r = 0.654) and Na and Ni (r = 0.843).

**Table 4.26:** Correlation coefficient values for heavy metal concentrations from the four study sites in Lagos

| | | pH | Zinc | Iron | Lead | Calcium | Manganese | Cadmium | Copper | Silver | Potassium | Nickel | Sodium |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | Pearson Correlation | 1 | .344 | .727** | .245 | .302 | .165 | -.112 | .057 | .738** | .262 | .408* | -.078 |
| | Sig. (2-tailed) | | .100 | .000 | .249 | .151 | .441 | .601 | .792 | .000 | .215 | .048 | .719 |
| Zinc | Pearson Correlation | | 1 | .831** | .976** | .980** | .851** | .482* | .654** | .345 | .380 | .960** | .870** |
| | Sig. (2-tailed) | | | .000 | .000 | .000 | .000 | .017 | .001 | .099 | .067 | .000 | .000 |
| Iron | Pearson Correlation | | | 1 | .779** | .823** | .574** | .352 | .291 | .673** | .408* | .830** | .514* |
| | Sig. (2-tailed) | | | | .000 | .000 | .003 | .091 | .168 | .000 | .048 | .000 | .010 |
| Lead | Pearson Correlation | | | | 1 | .957** | .863** | .648** | .653** | .246 | .424* | .932** | .926** |
| | Sig. (2-tailed) | | | | | .000 | .000 | .001 | .001 | .247 | .039 | .000 | .000 |
| Calcium | Pearson Correlation | | | | | 1 | .750** | .517** | .571** | .300 | .303 | .972** | .881** |
| | Sig. (2-tailed) | | | | | | .000 | .010 | .004 | .155 | .150 | .000 | .000 |
| Manganese | Pearson Correlation | | | | | | 1 | .426* | .863** | .223 | .551** | .731** | .772** |
| | Sig. (2-tailed) | | | | | | | .038 | .000 | .294 | .005 | .000 | .000 |
| Cadmium | Pearson Correlation | | | | | | | 1 | .273 | -.219 | .261 | .471* | .700** |
| | Sig. (2-tailed) | | | | | | | | .197 | .303 | .217 | .020 | .000 |
| Copper | Pearson Correlation | | | | | | | | 1 | .014 | .459* | .606** | .654** |
| | Sig. (2-tailed) | | | | | | | | | .948 | .024 | .002 | .001 |
| Silver | Pearson Correlation | | | | | | | | | 1 | .628** | .383 | -.074 |
| | Sig. (2-tailed) | | | | | | | | | | .001 | .064 | .733 |
| Potassium | Pearson Correlation | | | | | | | | | | 1 | .388 | .251 |
| | Sig. (2-tailed) | | | | | | | | | | | .061 | .237 |
| Nickel | Pearson Correlation | | | | | | | | | | | 1 | .843** |
| | Sig. (2-tailed) | | | | | | | | | | | | .000 |
| Sodium | Pearson Correlation | | | | | | | | | | | | 1 |
| | Sig. (2-tailed) | | | | | | | | | | | | |

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

### 4.4.5 Contamination Factors and Geoaccumulation Index

The contamination factor (CF) assessment values for the examined heavy metals in the two seasons are presented in Table 4.27. Solus MRF and Alakija scrap site recorded low CF during the dry season, while at Olusosun landfill the CF values of 1.47 and 1.37 were recorded for Lead (Pb) and Cadmium (Cd) respectively. The figures indicate that the Olusosun site has moderate CF of Pb and Cd, and low contamination factors of Zinc (Zn), Iron (Fe), Manganese (Mn), Copper (Cu) and Nickel (Ni). More so, in the same season at Owode Onirin scrap market, the CF values of 3.39 and 1.39 were recorded for Pb and Cu respectively. It shows that Owode Onirin has moderate contamination factor of Pb and Cu, while Zn, Fe, Mn, Cd CF values were low. When the four sites were compared during the dry season, Solous MRF was the least contaminated site because it has insignificant contamination factor values for all the metals (Zn=0.00, Fe=0.00, Pb=0.00, Mn=0.00, Cd=0.00, Cu=0.01 and Ni=0.00).

Alternatively, the contamination factors in some of the study were slightly higher in the wet season. For instance, at Olusosun landfill, the CF values 3.78 and 3.52 were obtained for Pb and Cu respectively. These values indicate that the landfill was moderately contaminated with Pb and Cu. At Owode onirin study site, the highest contamination factor value was recorded for Pb with 6.09 meaning that the site is highly contaminated. More so, the CF values for Cu and Zn on the same location were 1.05 and 2.30 respectively. From the table below, it can be seen that Pb contamination was very high, while Zn and Cu were moderate. It is important to note that Solous MRF and Alakija scarp sites were the least contaminated during the wet season.

From this study, it can, therefore, be argued that Alakija scrap site is not contaminated at all in the two seasons, which may be because it is a new e-waste scrap site. More so, Solus MRF is not also polluted in the two seasons. This is due to the conversion active from a landfill to MRF. However, the case of Olusosun landfill and Owode were different as moderate and high contamination factors were observed in the two seasons which may be because of the constant informal activities that daily take place in the two sites.

**Table 4.27:** Contamination factor for dry and Wet seasons

| Study sites | Heavy metals | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Zinc (Zn)** | **Iron (Fe)** | **Lead (Pb)** | **Manganese (Mn)** | **Cadmium (Cd)** | **Copper (Cu)** | **Nickel (Ni)** |
| **Dry Season** | | | | | | | |
| Olusosun | 0.04 | 0.01 | 1.47 | 0.01 | 1.37 | 0.3 | 0.00 |
| Owode-Onirin | 0.20 | 0.00 | 1.39 | 0.00 | 0.23 | 3.49 | 0.00 |
| Soluos | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 |
| Alakija | 0.09 | 0.00 | 0.22 | 0.00 | 0.00 | 0.72 | 0.00 |
| **Wet season** | | | | | | | |
| Olusosun | 0.67 | 0.01 | 3.78 | 0.03 | 0.73 | 3.52 | 0.02 |
| Owode-Onirin | 1.05 | 0.02 | 6.09 | 0.05 | 0.97 | 2.30 | 0.02 |
| Soluos | 0.06 | 0.01 | 0.14 | 0.00 | 0.23 | 0.01 | 0.00 |
| Alakija | 0.05 | 0.01 | 0.14 | 0.00 | 0.00 | 0.01 | 0.01 |

Source: Fieldwork data (2016 and 2017)

**Note**: CF < 1 refers to low contamination factor; 1-3 indicates moderate contamination factor; 3-6 shows considerable high contamination factor and; CF = 6: very high contamination.

The Geoaccumulation Index (I-geo) values of the heavy metals examined are revealed in Table 4.28. During the dry season, Owode Onirin study site has the highest Cu I-geo value of 1.21, while Olusosun landfill and Owode Onirin have the I-geo values of 1.33 for Pb and 1.23 for Cu respectively during the wet season. have the I-geo values of 1.33 for Pb and 1.23 for Cu respectively during the wet season.

**Table 4.28**: Geoaccumulation Index (I-geo) values for heavy metal concentrations in soil collected from the study sites during the dry and wet seasons

| Study sites | Heavy/trace metal | | | | | | |
|---|---|---|---|---|---|---|---|
| | Zinc (Zn) | Iron (Fe) | Lead (Pb) | Manganese (Mn) | Cadmium (Cd) | Copper (Cu) | Nickel (Ni) |
| **Dry Season** | | | | | | | |
| Olusosun | -5.08 | -8.33 | -0.03 | -7.63 | -0.13 | -2.22 | -9.48 |
| Owode-Onirin | -2.92 | -8.48 | -0.11 | -5.22 | -2.49 | 1.21 | -9.82 |
| Soluos | 0.00 | -8.83 | 0.00 | 0.00 | 0.00 | -7.33 | 0.00 |
| Alakija | -0.06 | -8.64 | -2.75 | -8.70 | 0.00 | -1.07 | -9.20 |
| **Wet season** | | | | | | | |
| Olusosun | -1.17 | -7.11 | 1.33 | -5.64 | -0.45 | 1.23 | -6.12 |
| Owode-Onirin | -0.62 | -6.49 | -0.47 | -4.85 | -0.63 | 0.62 | -651 |
| Soluos | -4.56 | -7.38 | -0.09 | -8.89 | -2.68 | -7.51 | 0.00 |
| Alakija | -4.89 | -7.26 | -0.09 | -9.29 | 0.00 | -6.75 | -8.29 |

**Source**: Fieldwork data, 2016 and 2017

**Pollution Load Index Determination**

The PLI values recorded for all the study locations shown in Table 4.29 below were less than 1. It should be noted that the PLI value of > 1 signifies pollution, while PLI value < 1 indicates no pollution. The table suggests that Olusosun landfill site is polluted with Pb (1.47) and Cd (1.37), while Owode Onirin is polluted with Pb (1.39) and Cu (3.49) in the dry season. Also, in the wet season, Olusosun shows the PLI values of 3.78 (Pb) and 3.52 (Cu), while Owode Onirin has the PLI value of 1.05 (Zn), 6.09 (Pb) and 2.30 (Cu).

Therefore, from the table, it can be seen that not all soil samples in Lagos were polluted during the dry and wet seasons

**Table 4.29**: Pollution Load Index from the four study sites

| Study sites | Heavy metals | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Zinc (Zn) | Iron (Fe) | Lead (Pb) | Manganese (Mn) | Cadmium (Cd) | Copper (Cu) | Nickel (Ni) | **Pollution Load Index** |
| **Dry Season** | | | | | | | | |
| Olusosun | 0.04 | 0.01 | 1.47 | 0.01 | 1.37 | 0.3 | 0.00 | 0.00 |
| Owode-Onirin | 0.20 | 0.00 | 1.39 | 0.00 | 0.23 | 3.49 | 0.00 | 0.00 |
| Soluos | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 |
| Alakija | 0.09 | 0.00 | 0.22 | 0.00 | 0.00 | 0.72 | 0.00 | 0.00 |
| **Wet season** | | | | | | | | |
| Olusosun | 0.67 | 0.01 | 3.78 | 0.03 | 0.73 | 3.52 | 0.02 | 0.25 |
| Owode-Onirin | 1.05 | 0.02 | 6.09 | 0.05 | 0.97 | 2.30 | 0.02 | 0.31 |
| Soluos | 0.06 | 0.01 | 0.14 | 0.00 | 0.23 | 0.01 | 0.00 | 0.00 |
| Alakija | 0.05 | 0.01 | 0.14 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 |

**Source:** Fieldwrk data, 2016 and 2017

## 4.5 E-waste resource collection as a source of sustainable livelihood for the urban poor in Lagos

The section examines the e-waste resource collection as a significant source of livelihood for the urban poor in the city of Lagos. It can be seen from Table 4.1 that the informal e-waste pickers are the primary actors involved in the collection of e-waste within Lagos. This is so, because, in the state, the waste agency has not made provisions for the collection and disposal of e-waste from households. Based on the lack of collection from households, the sector is now so unique because many professionals and unemployed youths are currently involved in e-waste picking, and the government is also interested in integrating it into the formal sector to reduce the use of hazardous methods.

### 4.5.1: E-waste resource collection, an overview in Lagos

The demographic information of the e-waste collectors is presented in Table 4.30. The factors considered in this section are sex, the region of origin, age group, marital status, level of education, family size and primary source of income (occupation). All respondents that participated in this study were males. It might be because the job is laborious and involves hours of walking and pushing heavy e-waste in the carts. Also, it might even be because in Africa most men see it as their duties to provide for their households.

Furthermore, Figure 4.16 reveals that all participants were above the age of 18 years which implies that they could participate in the study without consent from their parents or guardian. Of the total population, the highest participants with an estimated figure of 34% were between the age of 28-37 years, while 4.1% were between the age of 58 years and above. These figures indicate that the majority of the respondents were youths who are full of energy and are striving to provide for themselves and families. It might also be due to a lack of employment opportunity. However, it can be argued that the strength to go around collecting or picking waste decreases as the collectors' age increases.

Concerning region of origin, of the total respondent, 69% of were from the Northern part of the country, while 9% were South-Western part of the nation (see Figure 4.17). The result depicts that majority of the resource collectors were male migrant who came to the city of Lagos to search for economic opportunity and who are now socially marginalised due to their job description and race. This assertion is supported by a male participant and middlemen interviewed at Abule-Egba scrap site who state that:

> "*…as you are looking at this place now en, honestly speaking, you will think hum hum, somebody who is ignorant will think that that these people, you know like the way people do regard people that these are Mallams (a term used to refer to adult male from the northern part of Nigeria) but if you really come in and see what is happening en, this is a very big business"* (Per com., 2016 r).

Figure 4.18 presents the marital status of the e-waste collectors. The chart suggests that 50% of the respondents were married to one wife (monogamy) and 2% were divorced. The data indicates that many of the respondents were married and had families that must be supported. Concerning education, 35.4% of the total respondents hold a primary school certificate, while 16.8% attended Arabic school. This result implies that with the level of education, securing jobs in the formal sector may be very challenging. However, since the majority of the respondents had primary school certificate training may be required to integrate them into the formal industry.

Figure 4.20 shows the family size of the e-waste collectors. From this result, the highest proportion of family dependants estimated at 38% were between 7-9, and 6% of the participants indicated that their family size was > 10. It should be noted that these dependants comprise both

nuclear and extended families. Of the 291 respondents, 84% were full-time scavengers while 16% were scrap dealers (Figure 4.21). This result indicates that e-waste collection is the primary source of income for the respondents working in the informal sector.

**Table 4.30** Demographic and Social factors of the informal e-waste collectors in all study sites

| Variable | Category | Frequency | Percent |
|---|---|---|---|
| **Sex** | Male | 291 | 100.0 |
| **Age Group** | 18-27 | 78 | 26.8 |
| | 28-37 | 100 | 34.4 |
| | 38-47 | 50 | 17.2 |
| | 48-57 | 51 | 17.5 |
| | 58 and above | 12 | 4.1 |
| **Region** | South-South | 33 | 11.3 |
| | South-East | 32 | 11.0 |
| | South-West | 25 | 8.6 |
| | North-East | 71 | 24.4 |
| | North-West | 66 | 22.7 |
| | North Central | 64 | 22.0 |
| **Marital Status** | Single | 69 | 23.7 |
| | Married Monogamy | 144 | 49.5 |
| | Married Polygamy | 67 | 23.0 |
| | Widow/Widower | 6 | 2.1 |
| | Divorce | 5 | 1.7 |
| **Level of Education** | Never went to school | 53 | 18.6 |
| | Primary | 103 | 35.4 |
| | Secondary | 85 | 29.2 |
| | Others (Arabic) | 49 | 16.8 |
| **Family size** | <4 | 75 | 25.8 |
| | 4-6 | 85 | 29.2 |
| | 7-9 | 111 | 38.1 |
| | >10 | 20 | 6.1 |
| **Occupation** | Scrap seller | 46 | 15.8 |
| | Scavenger | 245 | 84.2 |

**Source**: Fieldwork data, 2016

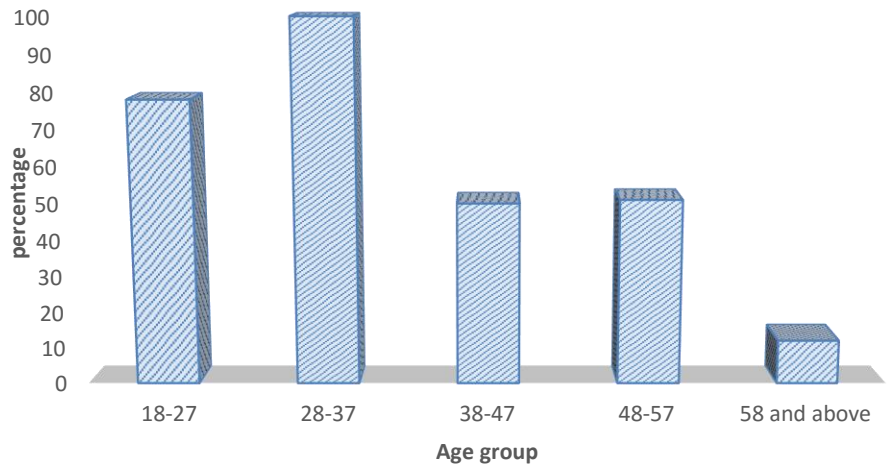



**Figure 4.16**: Age group of respondents

**Source**: Table 4.30

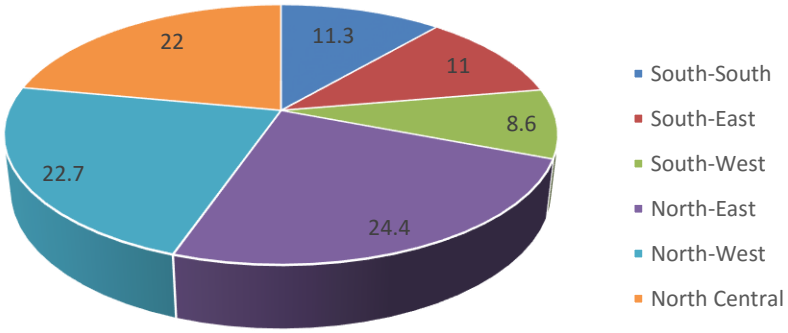



**Figure 4.17**: Respondents region of Origin

**Source**: Table 4.30

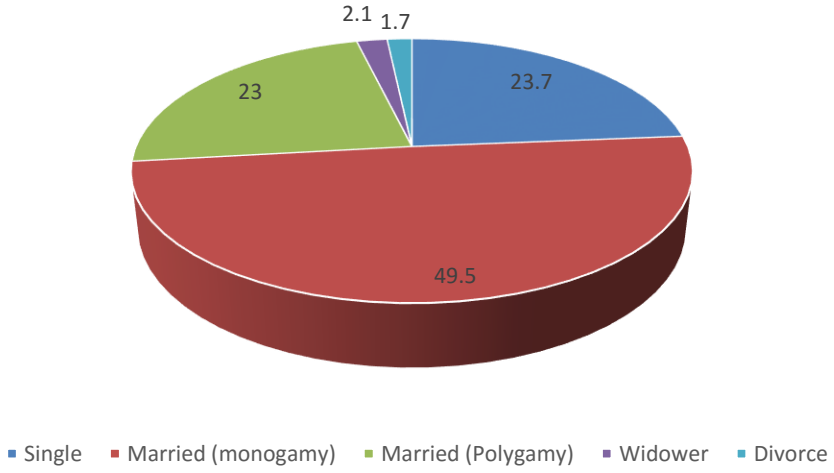



**Figure 4.18**: Marital Status of Respondents

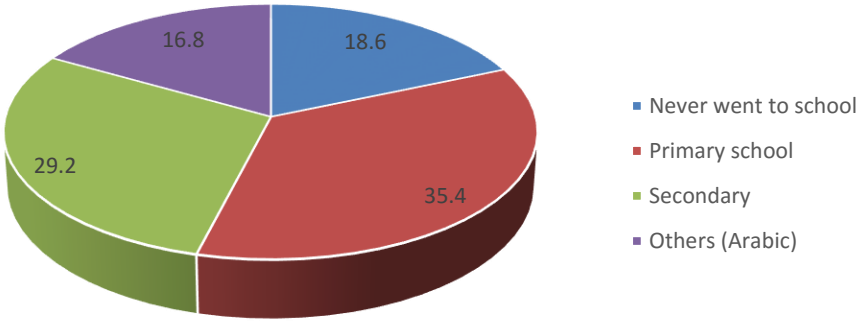



**Figure 4.19:** Respondents education background

**Source**: Table 4.30

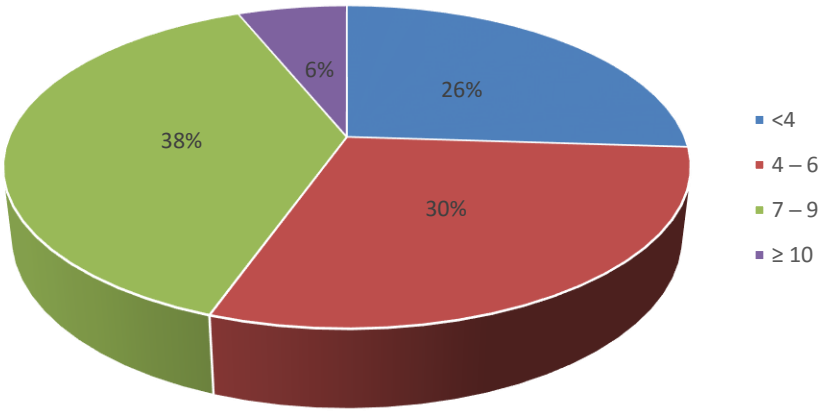



**Figure 4.20**: Family size of respondents

**Source**: Table 4.30

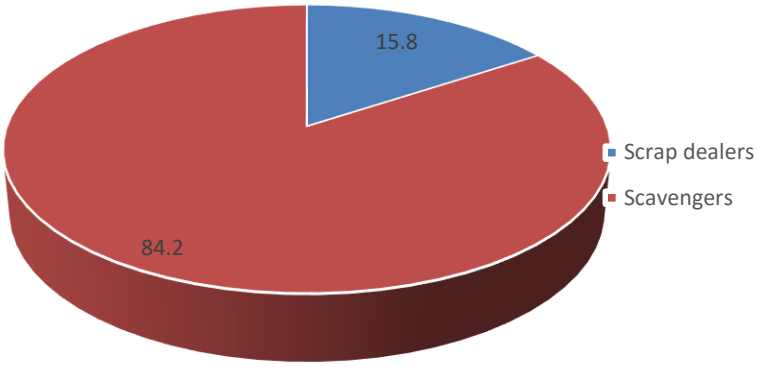



**Figure 4.21**: Respondents main source of income

**Source**: Table 4.30

### 4.5.2 Techniques of e-waste resource collectors

Table 4.27 suggests the techniques employed by the e-waste resource collectors at various study locations. Figure 4.23 shows that 64% works for others which may be private companies, middlemen or individuals and only 36% of the total population collects waste for themselves. The figure was supported by comments from two participants who implied that waste resource collection is not just a form of survival strategy but a business hub that createsd employment for the poor and provide a way of generating regular income. A condemn buyer from Alaba international state that:

> *"Some recycling companies have agents at the dump sites that represent them, also there are buyers/middlemen. The waste pickers have also established prices for each material they just weigh and sell to the buyers*" (Pers.com, 2016 s)

This was further supported by another male participant from the Abule-Egba scrap yard who said:

> "*Like me for example, I work here, you understand although I have my ogas (bosses); ..., When we see condemns (scraps), we do buy them, after that we pieces (dismantle) them. All we need from the scraps are panels, there are companies that do buy them. … hum… I don't know the name of the company. But like that panel of a thing, aluminium, iron and the rest, there are particular companies that buy them*". (Pers. Com, 2016 t).

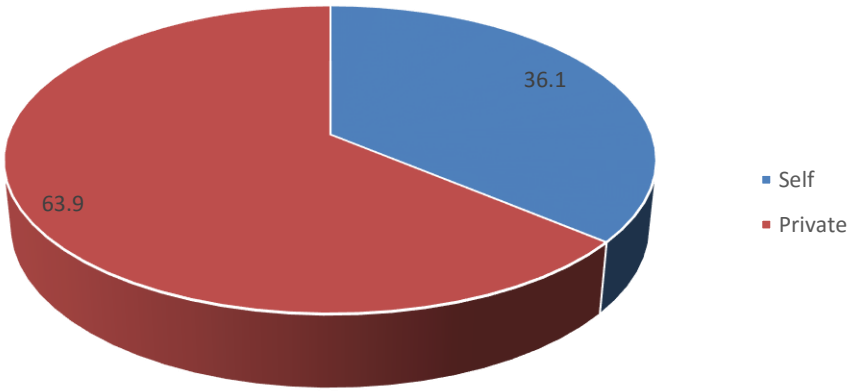



**Figure 4.22**: E-waste collectors' mode of operation

**Source:** Table 30

As regards where e-waste is collected, Table 4.31 suggests that 49% receives and buys e-waste from the electronic markets and 23% scavenges waste from the dump sites. This result reveals that more e-waste was collected from electrical electronics markets than else were. E-waste collection from dumpsites may be due to indiscriminate disposal of e-waste on illegal dump sites which are very common in Lagos.

Most respondents, estimated at 31%, indicated that they collect small household appliances and all forms of other e-waste while 18% acknowledge that they pick or buy ICT equipment (see appendix 6 for the list of devices). Majority of the respondents were aware that e-waste is hazardous but only a few (7.9%) revealed that they were not aware of the harmful nature of e-waste. This may be because some of the respondents did not participate in workshops organised by the waste agencies on e-waste.

Concerning the numbers of days used for collection of waste, 68% of the respondent showed that they collect waste six times a week and 15% showed they pick waste every day. Furthermore, 70.8% recovered valuable materials through manual dismantling or breaking, while 7.6% indicated that they burn e-waste to recover useful materials. It should be noted that burning of e-waste has been discouraged by the Federal and State Ministries of Environment and it is stated in the e-waste policy regulation provided by NESREA. From this result, it can be seen that only a few e-waste collectors still burn e-waste products to get valuable components and this is contrary to what is stated in the e-waste regulations. However, during the field observation, no burning activities were noticed in any of the study locations.

**Table 4.31:** Responses on e-waste resource collection techniques

| | Question | Frequency | Percent | Valid percent | Cumulative percent |
|---|---|---|---|---|---|
| Valid | **Who do you collect waste for?** | | | | |
| | Self | 105 | 36.1 | 36.1 | 36.1 |
| | Private contractor | 186 | 63.9 | 63.9 | 100.0 |
| | **Total** | 291 | 100.0 | 100.0 | |
| Valid | **Where do you collect waste from?** | | | | |
| | Household | 82 | 28.2 | 28.2 | 28.2 |
| | Dumpsite | 66 | 22.7 | 22.7 | 50.1 |
| | Electronic stores/shop | 143 | 49.1 | 49.1 | 100.0 |
| | **Total** | 291 | 100.0 | 100.0 | |
| Valid | **Which of the items below do you collect?** | | | | |
| | Large household appliance | 59 | 20.3 | 20.3 | 20.3 |
| | Small household appliance | 89 | 30.6 | 30.6 | 50.9 |
| | ICT equipment | 53 | 18.2 | 18.2 | 69.1 |
| | All forms of e-waste | 90 | 30.9 | 30.9 | 100.0 |
| | **Total** | 291 | 100.0 | 100.0 | |
| Valid | **Do you use PPE during collection, recycling and disposal?** | | | | |
| | Yes | 19 | 6.5 | 6.5 | 6.5 |
| | No | 272 | 93.5 | 93.5 | 100 |
| | **Total** | 100 | 100 | 100 | |
| Valid | **How often do you collect waste?** | | | | |
| | Everyday | 45 | 15.5 | 15.5 | 15.5 |
| | 6 times a week | 198 | 68.0 | 68.0 | 83.5 |
| | 5 times a week | 48 | 16.5 | 16.5 | 100.0 |
| | **Total** | **291** | 100.0 | 100.0 | |
| Valid | **How do you remove valuable materials?** | | | | |
| | Breaking/Dismantling | 206 | 70.8 | 70.8 | 70.8 |
| | Burning | 23 | 7.9 | 7.9 | 78.7 |
| | Application of chemicals | 28 | 9.6 | 9.6 | 88.3 |
| | Loosening with screw | 34 | 11.7 | 11.7 | 100.0 |
| | driver | 291 | 100.0 | 100.0 | |
| | **Total** | | | | |

**Source**: Field data, 2016 and 2017

On health issues perceived during collection, recycling and disposing of e-waste the respondents were allowed to write down the challenges. The majority (95%) of the respondents complained of body aches and strains which is caused by walking for long hours around the market for the collection of scraps, eye irritation (24%) from burning and dismantling. The result suggests that many of the respondents wrote more than one health issues. This might be because the majority of e-waste collectors do not wear any form of personal protective equipment (PPE) as shown in Table 4.31 only 6.5% of them wore any PPE. This claim is also supported by field observation and picture taken during the study. Table 4.33 further presents some of the health and environmental implications of the heavy metals found in soils.

**Table 4.32**: Health issues encountered by e-waste resource collectors at all study locations

| **Health issues** | **Percentage (%)** |
|---|---|
| Body ache and strain | 95 |
| Chest pain | 55 |
| Skin rashes | 65 |
| Common flu | 70 |
| Headache | 39 |
| Common Fever | 45 |
| Eye irritation | 24 |
| Fatigue | 37 |

**Source**: Fieldwork data (2016)

**Table 4.33:** E-waste pollutants that were found in the soil samples

| **E-waste elements/ Pollutants** | **E-waste Components** | **Ecological source of exposure** | **Environmental Hazard** | **Route of exposure** | **Health hazards** |
|---|---|---|---|---|---|
| Lead | Printed circuit boards, cathode ray tubes, light bulbs, televisions (1.5–2.0 kg per monitor), and batteries | Air, dust, water, and soil | Lead, barium and other heavy metals leaching into ground water and release of toxic phosphorus<br>Air emission of the same substances. | Inhalation, ingestion, and dermal contact | causes damage to endocrine, blood, kidney and reproductive systems in humans. |
| Cadmium | Switches, springs, connectors, printed circuit boards,<br>batteries, infrared detectors, semi-conductor chips, ink or toner photocopying machines, cathode ray tubes, and mobile phones | Air, dust, soil, water, and food<br>(especially rice and vegetables) | Air emission through forest fires and volcanoes | Ingestion and inhalation | It mainly affects the kidney and bones and can also accumulate in livers. |
| Zinc | Cathode ray tubes, and metal coatings | Air, water and soil | It can affect drinking water, air and soil | Ingestion and inhalation | Excess of Zinc can cause abdominal pains. Mouth and throat irritation |

### 4.5.3 Economic Impacts of e-waste on the livelihood of the resource collectors

All respondents agreed that the amount they get from selling valuable materials depended on the volume of scraps they recovered. 68% of the respondents acknowledged that copper is the most valuable material they collect because it is easily seen and very expensive to sell while 2% of the respondents revealed that aluminium, gold and plastics were the least recovered valuable materials of importance.

Two participants (a scrap collector and a dealer) told the researcher how much they buy valuable materials from e-waste collectors and the market values per kilogram. This is what a male e-waste scrap collector at Alaba International market said:

> *"Madam, when we collect or buy condemns, we separate them into parts. Examples of the condemns we buy are fans, stabilizers, radios, etc. After we break them, we then separate into metals and non-metal. Many of the separated scraps are then sold to companies'. We scale the scraps before selling them. Here in this market, a kilo of copper is sold for N1300.00 ($3.56), a kilo of aluminium is N500 ($1.37) and Zinc is N300 ($0.82) per kilo*" (Pers Com., 2016 u).

However, in Abule-Egba scrap market, another respondent argues that the prices were different from what the researcher was told at Alaba International market. He pointed out that:

> "*Somebody who tells you that they are selling copper for that price is not correct because in this scrap market, we sell copper for I think N800.00 ($2.19) per kilo and that zinc, people who buy it from us (middlemen) we sell for like N100.00 but we don't know the amount they sell it to other buyers…. like I have 2 kilos of zinc and I just sold them to a guy at N100.00 per kilo*" (Pers com, 2016 v).

35% of the respondents indicated that their monthly income is N40,000.00 {($109.59) a dollar = N365 as at the time of this research}, while only 9.6% revealed that they earn less than N20,000 (54.79). This amount varied because few of the participants told the researcher that they work for bosses who determined their wages. The local and international market prices of scraps as stated by the respondents are indicated in table 4.34.

**Table 4.34:** Lagos and International prices of scrap metals

| **Metals** | **Price per kilogram in Lagos (US Dollar)** | **International price per kilogram (US dollar** |
|---|---|---|
| Copper | 3.56 | 6.67 |
| Aluminum | 1.37 | 2.17 |
| Zinc | 0.82 | 3.37 |
| Steel | 0.18 | 1.47 |
| Gold | n.a | 40,408 |
| Iron | 0.27 | 0.28 |

n.a- not available

**Source**: Fieldwork data (2016); (Market insider, 2018)

The participants were asked if the money made from the resource recovery were enough to sustain the family, 53.3% indicated no but 46.7% responded yes. The result was supported by a participant at Abule-Egba-Egab who said that:

> "*..., in every business there is a secret, I cannot tell you how much I make from these condemns. All I can tell you is that when we collect the condemns (scraps), we dismantle them and separate into metals and non-metal and we scale them before we sell. The wages we get in this business depends on your level… just like me now I can use myself as an example, I just came into this business and I have not lasted up to a month … but for now, is my ogas that still caters for my feeding, although the car I have, I bought it before I came into the business. Sometime I feel like quitting but I just tell myself to continue and I believe that I will make it. Also for example, some of these guys you see here sleep in some of the shacks you are looking at just to make ends meet, until they can make enough money*" (Pers. Com., 2016 w).

From the above comment, it can be seen that in the e-scrap business, there are hierarchies. People who recently started the business may earn less than those that have stayed longer. It may also be due to an individual's bargaining power. On investment, 44.0% do not have any form of investment while 19% showed that they have financial portfolios. This might be because some earn more from the scavenging business than others or might have inherited some investment from their parents.

66% have access to clean water while 34% do not. 52% revealed that they pay water bills or fees while 48% responded that they do not pay water bills or taxes. Most of the respondent revealed their houses are connected to electricity while 31% did not have access to power. 76% showed that they pay electricity bills while 24% explained that they do not pay for electricity. The people who do not pay for electricity maybe some of those that lived in shacks or in new areas where electricity supply has not been connected. Another reason for the high number of those who pay

electricity bill may be because they live in areas with damaged transformers in Lagos and are obliged to pay electricity bills until the transformers are connected. 54.0% agreed that they pay bills for their waste while 46.0 responded in the negative. Those who do not pay the waste bill maybe disposing of waste in illegal dumps since there are many of them in Lagos. It might also be that they collect waste from their homes and dispose of them during work.

On private sector participation, 62% of the respondents supported the idea of the government involving the private sector in the management of e-waste in the city of Lagos while 38% did not like the idea. Lack of support from these respondents may be because many private sectors do not treat their workers fairly and will control the time they resume and close from work. 70% indicated that the government should integrate the informal sector into a formal organisation to be able to manage e-waste effectively, but 30% revealed they do not want the industry to be incorporated into the formal organisation. It might be because they do not want to or are scared of losing their livelihoods as it is the only means of survival they have. Other respondents (40%) revealed that integrating them into the formal sector would give them job security and steady income to take care of their household, 31% agreed that it would only serve as a regular means of monthly income, while 9.3% disclosed that it would give them a steady means of income.

**4.5.4: Some challenges encountered by the e-waste collectors in the city of Lagos**

Table 4.35 illustrates some challenges encountered by the informal e-waste collectors. Only 17% of the participants indicated that lack of PPE was one of the obstacles hindering e-waste collection. The equipment is needed to protect them against the dangers (operational or human hazards). One of the participants appealed to the government to come to their aid by providing them with the necessary equipment as it will reduce the risk of accidents during recycling in the field. He pointed out that:

> "*the government should come and help us by giving us the necessary protective equipment like boots, nose mask, protective goggle, hand gloves etc. because our work is very dangerous"* (Personal Com., 2016x).

This appeal suggests that the informal e-waste collectors are aware of the threats posed by the types of waste they collect. Another serious challenge faced by the participants is social discrimination by the general public due to the nature of their job. This can be seen in the discussion with one of the participants in session 4.5.1. 31% of the participants said they had been relegated, abused and some of them are now so ashamed of their occupation within the society. Besides, 12% of the waste collectors mentioned that they face attacks from some waste authority staff. For example, a participant from LAWMA said that the agency owns the landfills/ dumpsites so the e-waste collectors should not be allowed to pick waste from there. This discussion is seen above in section 4.4. Since these are the most active stakeholders in e-waste management, their roles should be recognised and appreciated by the government.

**Table 4.35**: Responses on challenges encountered by informal e-waste collectors

| Challenges | No of Respondents | Percentage (%) |
|---|---|---|
| Lack of personal protective equipment | 7 | 17 |
| Social Discrimination by the public | 13 | 31 |
| Attacks from government officials | 5 | 12 |
| Inadequate training/workshops by LASEPA | 5 | 12 |
| Exploitation by middlemen | 3 | 7 |
| Instability in the prices of valuable materials | 6 | 14 |
| Irregular collection of e-waste at the market | 3 | 7 |
| Total | 42 | 100 |

**Source**: Fieldwork data, 2016

More so, 12% of the participants complained about lack of training and workshops by the agency in charge of creating awareness about e-waste. This may be attributed to the reason why many of the e-waste collectors handle e-waste in a dangerous manner such that it affects the ecosystem and the collectors' health. Exploitation by middlemen is a common challenge in this field. It is because many companies have e-waste collectors at most dumpsites who collect scraps on their behalf this was confirmed by a staff of LAWMA in a discussion above.

The table also indicates that 7% of the e-waste collectors complained about the issue of middlemen exploitation. For example, the researcher asked from one of the scrap collectors about the amount he or she collects and the names of the companies they sell to, but the collector said those decisions are made by his ogas (boss) see the discussion in (Pers. Com., 2016 t & w above). Moreover, it was observed that the business depends on hierarchy and individuals bargaining power. The association should, therefore, be able to look into this area so that the collectors can also benefit from the jobs they carry out.

Price instability is another issue that should be looked into, 14% of the respondents complained about this. It is because, from the different scrap and dump sites, the prices for the recovered materials varied. For example, in the discussion above in Pers.com, (2016 u & v), different informal collectors mentioned different costs which implies that customers may go and buy scraps at different location and price but price stability will not allow customers to move around. Lastly, 7% indicated that LAWMA collection in the market has not been frequent.

Another participant at Alaba International market pointed out that.

> "*Collection of waste by LAWMA is not frequent and that is the reason why we give waste to collectors/condemn buyers for a token. LAWMA should try to improve on the number of days they come to collect waste in the market. If LAWMA cannot meet the needs of the public, reliable private companies should be contracted and this*

*will reduce the stress while LAWMA supervises and monitors the private companies*" (Pers. com, 2016 y).

From the above comment, it can be seen that LAWMA has created a clean Lagos initiative to ease the problems of that waste collection within the state. This initiative has also integrated some members of the informal sector groups into this sector, and this has provided livelihood only for few of them.

The researcher asked for further suggestions on the issues of e-waste management and one interviewee said:

> *"… hmmm my own advice to government is if government …, if government would like for example now, this business is an individual business, but if government can come now and bring them together and say okay like most of these companies, I mean those big companies that buys the condemns, I believe that before they come to the scrap markets to buy scraps they must be paying something to the government but the government can still come into the scrap markets and know how to organise them. Okay now, let assume the company buys 300, if government comes in, they will look at the companies if they are paying taxes. The government will be able to subsidise for them like for example if the business owners are selling at N300 to each company the government may ask the companies to at N200 thereby subsidising N100 for each companies you understand. Also, the government should create an enabled scrap market environment, so that it can attract more customers and create more jobs. Government should also provide the necessary PPE (like boots, nose mask, eye goggle etc.) for the scrap collectors. As you are looking at this place honestly …."* (Pers. Com, 2016 z).

This suggestion, therefore, implies that the informal traders want the government to collaborate with the scrap dealers' associations and other recycling sectors. It will make the industry more organised and recognised widely by many formal recycling companies. Also, it will allow easy integration of the informal sector through education, training and workshops into the formal organisation. The PPE needed will be provided, and recycling will be carried out correctly.

### 4.6 Summary

This chapter has presented the results of the findings of this study. Firstly, the chapter identified the active stakeholders involved in the management of e-waste waste in the city of Lagos the various institutions ranging from the Federal to the State agencies in the Ministry of Environment and the various laws, regulations and policies that are linked directly or indirectly to e-waste management from the various environmental laws. Institutional challenges involved in the management of e-waste were also examined. Thirdly, the environmental implications of e-waste from the concentrations of heavy metal, pollution load index factor and contamination factors of the soil samples from some two recycling and dumpsites were also observed. Lastly, the livelihoods of the informal waste collectors, techniques of collections, economic aspects of the scrap collections and the challenges they encountered were discussed. It was found that

Nigeria as a country and the Lagos state have different agencies that manage e-waste and also have various regulations and policies that can be used to embattle e-waste management.

However, it can be argued that the major challenges observed were due to poor enforcement, compliance and monitoring of the laws by the supervisory agencies. It can further be argued that the numbers of laws and policies will not be effective if enforcement and compliance monitoring is not properly attended to. It has been revealed that the concentrations of some heavy metals that are dangerous to the health of scavengers and the ecosystems are higher than the stipulated limits in the soils from the dumps and scrap sites which will in turn affect the livelihood of the collectors, such that more money will be spent on health care of the workers also the water and air pollution will have to be controlled so as not to affect the general public. Most of the e-waste collectors complained on some of the challenges encountered which ranged from social discrimination through to public and government assaults. It is further argued that the government has to corroborate with the scrap dealers' association such that their roles can be acknowledge and recognised by the waste institutions and the general public.

In view of the above findings, the Lagos state government can empower the Local councils through institutional (waste agencies, initiatives and authorities) and design legal frameworks that will include the operations of the informal e-waste sectors in the city's policy planning and development. Furthermore, the state and the local council may partner with private recycling companies to educate, carry out trainings, workshops and awareness programmes and provide the necessary protective equipment needed during recycling. Integration of the informal e-waste pickers as well as public participation in e-waste management will make its collection, transportation, recycling and final disposal productive and efficient. The next chapter therefore discusses the fin dings from the empirical evidence.

# CHAPTER FIVE

# ANALYSIS AND DISCUSSION

## 5.1 Introduction

The chapter details the analysis and discussion of the empirical findings. The purpose of this chapter is to critically examine and interpret the research findings of this study in the light of the research objectives. This chapter is structured and broadly divided into five sections. The first section examines sustainable e-waste management in Lagos, Nigeria. In this section, the following sustainable approaches were considered: material flow analysis, extended producer responsibility (EPR), the involvement of local council, decentralisation of duties of the agencies, the participation of skilled personnel and capacity building. Subsection two looks at the inventory of the various institutional challenges. The section categorise the difficulties mentioned by the participants into three namely, infrastructural, behavioural and educational, and policies, legislative and regulatory. The implication of heavy metals in the environment and on the health of the pickers and the general public is discussed. More so, e-waste as a means of sustainable livelihoods and a means of wealth creation is also looked into. Lastly, the efficiency of the take back scheme in the city of Lagos was also scrutinised.

## 5.2 Sustainable e-waste management in Lagos, Nigeria

From the empirical findings of this study, it can be observed that Nigeria has different institutions and regulatory frameworks that can be used to manage solid waste as well as the environment. Lagos State, also, for example, identified e-waste as a challenge and have created different regulatory and policy frameworks that can be used to handle its management. The results suggest that most of the approaches adopted in the city of Lagos are not yet sustainable in the management of e-waste. From the field based evidence, failure in the responsibilities of each agency suggest that weak institution in the city of Lagos is a severe challenge hindering e-waste management. Lu et al., (2015) are of the view that e-waste treatment was developed in the early 1990s with the aim of manually dismantling and recovering valuable materials in a very crude manner for profit purposes. However, they further observed that the handlers also engaged in unsustainable and lack of environmentally friendly processes such as open burning, acid leaching and incineration that result to dangerous pollution of soils and water affect the health of the handlers. Due to these unsustainable treatment process, many developed and a few developing countries including Nigeria have developed some sustainable institutional frameworks that can be used to manage e-waste effectively (Balde et al., 2017; Lu et al., 2015; Kahhat et al., 2008). Hence, the results from these findings indicate that the three institutions need to develop an operational framework that can be used to manage e-waste sustainably because some of the enacted policies and regulation proposed and adopted in Lagos have not been adequately implemented and monitored by the agencies involved.

Kahhat et al., (2008) argue that in a bid to develop a sustainable e-waste system, the principle surrounding material flows analysis framework of e-waste should be known. This implies that before waste institutions in Lagos State can effectively manage e-waste, the volume of ICT

equipment and other electrical gadgets flowing into the city must first be accounted for or addressed. In doing this, each unit in the e-waste department must know their appropriate role. This corroborates the views of Balde et al. (2017) and Cointreau (2006) that most cities in developing countries cannot account for the volume of e-waste that flows into their countries due to institutional problems. Furthermore, Nnorom and Osibanjo (2008) have also observed that precise statistics on the material flow of e-waste in developing economy such as Nigeria is hard to get because in the national waste statistic, secondary and waste products do not appear in the production, sales and traded-in goods. It is therefore essential for the e-waste unit in LASEPA and NESREA to know the statistics on e-waste generation, disposal and flow in the city of Lagos. The approach will enable the state to the plan the suitable treatment that will be effective for the management of e-waste and be able to build different facilities that can provide safety for workers and the environment at large (Ka-Yan Lau et al., 2013).

Previous studies have shown that material flow analysis approach has been applied in some parts of the United States, China and Japan along with e-waste policy and these countries have recorded strong impact in the management of e-waste. Furthermore, Moriguch and Hashimoto (2016), for example, are of the view that countries in the OECD have improved material flow analysis by applying input-output analysis methods which have now been a compulsory part of their national and international e-waste policy. By adopting this approach, the city of Lagos may include the material flow analysis input-output in it e-waste policy draft. The agency can also create a particular unit that will oversee the monitoring of e-products flowing into Lagos as well as create an enforcement unit that will present reports to this unit on a weekly or monthly basis. It implies that the state will have to create an inventory of all e-waste products (e.g. computers, televisions, laptops, iron etc.) that comes into the city through the seaports, airports or borders. An e-waste inventory, for example, is the first step required in piloting a material flow analysis. The inventory for e-waste as designed by UNEP (2007) comprises five methods, and the requirements are summarised in Appendix 6. The table suggests that the sale data results from production, import and export statistics whereas the stock data can be determined from the percentage volume of specific EEE from household or industries. However, the average time of a product varies and hinge on the individual's attitude and custom.

The time step method in e-waste according to Streicher-Porte (2006) may be designed by calculating the significant variance between private and industrial stock within two consecutive years in addition to the sales made during that same time. This method can be applied in the different e-waste market in Lagos where outdated/irreparable and new items are imported and sold (Ka-Yan-Lau et al., 2013). Also, the market supply method in e-waste calculation involves the use of figures which originate from e-waste generation and sales. E-waste invention is evaluated from the past production and sale data by concluding the presumed lifecycle of a product. Previous studies have shown that the market supply method has been used globally to assess e-waste generation; hence, the approach may be adopted in the city of Lagos (Streicher-Porte et al., 2005; Jain and Sareen, 2006; Kumar and Shrihari, 2007). However, this method may be complicated for now since the state did not have sales statistics on e-waste market items. Thus, it is imperative to do a market survey on the import and sale statistics in all the e-waste market within the state to design a right material flow analysis approach.

Moreover, the Carnegie Mellon method developed by Matthews et al. (1997) is a problematic e-waste data calculation method because it involves knowing the past sales record, the lifespan of the item, recycling and storage details of the e-products. This method is different from the market supply method as it deals with past consumption attitude of the customers concerning reuse, storage, recycling and landfill options (UNEP, 2007). Based on the information needed in this method, it may currently be difficult for the city of Lagos to adopt or use the Carnegie Mellon Method except it starts keeping records of e-waste imported and produced in the state. Besides, the approximation 1 method, sometimes referred to as the Consumption and Use method, is a suitable e-waste calculation method that can be used if figures on stock and average lifespan for EEE are available (EEA, 2002). Lastly, the Approximation 2 method involves the use of sales data and accepts that the auctions of a new device and an old appliance will be trashed of. This method is beneficial because no past information or figure is required (UNEP, 2007). The claim that the procurement of new appliance results to the same as the outdated makes the method applicable to large and inundated markets. If the city of Lagos can adopt any of the e-waste inventory method identified, it will be straightforward to document the e-waste stream activities and the relationships among the consumers. Hence, documentation of the site activities at every phase and calculation of each recovered material from e-waste scraps are essential.

Furthermore, another sustainable approach that has been written in the Lagos State e-waste policy draft is the extended producer's responsibility (EPR) scheme. From this research finding, it was observed that the plan is also documented in the National e-waste regulations since 2011, but its implementation was only active from August 2017. According to the national regulations, the objectives of the EPR scheme are: "*to reduce waste streams from post-consumer products; to provide clear and measurable targets regarding prevention, reuse or recycling; and to encourage manufacturing of environmentally friendly products by incorporating waste prevention, reuse and recycling considerations into product design*". From the objectives, it can be observed that it will help the agency improve the criteria needed for the recovery and recycling programmes on valuable e-waste resources as well as help to promote the development of Producer Responsibility Organisation (PRO) or stewardship organisations. The scheme has been committed to NESREA implementation and enforcement.

In addition, this research finding observed from the review of the recent Lagos State e-waste policy draft that LASEPA also included EPR as the most attractive way to manage e-waste within the city. The scheme becomes imperative because of its many advantages which include "waste prevention and reduction, product reuse, increased use of recycled materials in production, reduced natural resource consumption, internalisation of environmental costs in product prices, and energy recovery when incineration is considered appropriate" (Lagos State e-waste policy, 2015). According to the existing e-waste policy document, the EPR scheme is to be combined with other recycling training programmes with different stakeholders within the society. The aim of implementing the Lagos EPR programme is to propose a take-back policy on e-waste management. However, it may be difficult to manage the EPR programme because it imposes financial responsibility on the electrical, electronic producers, but it does not require the producer to maintain the end-of-life of its products. Instead, it only mandates the recycling companies to cater for the recycling and disposal of e-waste. Williams et al., (2008) are of the view that if the producers bear the financial cost of electrical and electronic products, the

consumers will be paying the price of collection and recycling of these products. The scheme further illustrates that the consumers are paying for the products as well as paying for the end-of-life products and still do not know how to properly dispose of e-waste after it is damaged or faulty. The benefit of the EPR scheme is that it shifts the responsibility of recycling and disposing of end-of-life e-waste from the Lagos State government to the electrical producers. The EPR policy is, therefore, one of the best and operational ways to manage e-waste effectively if the scheme is applied correctly. From these findings and the reviewed literature shown in chapter two of this thesis, the enforcement of the EPR framework by LASEPA in the city of Lagos will enable the electrical producers to collect or take back more e-waste from their products. Also, e-waste will be reused and recycled, and the unrecyclable ones can be incinerated. Similar studies have been reported in South Korea, Hong Kong, Switzerland, China, Japan and several European countries (Ka-Yan Lau et al., 2013; Kahhat and Williams, 2012; Kahhat et al., 2008). Since Lagos State have different agencies involved in the management of solid waste, the active collection of e-waste will depend on the appropriate distribution of obligations, expertise and financial allocation of revenues between the state and the local government councils.

More so, it is essential for the state to involve the local council in the collection of e-waste for effective and efficient collection, recycling, final disposal and policy enforcement purposes. It is necessary because, from the findings in this study, only the state government deals with the collection of solid waste in the city of Lagos. Since the local council is a lot closer to the residents and are familiar with the various illegal dump sites in each respective ward, the state needs all the support it can get from the council. E-waste management committee should also be set up in the council centres so that the state can propose an effective regulatory framework that will involve the local councils and wards within the state. However, since there is a policy on e-waste, the responsibilities of each committee should be spelt out (Institutional Arrangements-Pakistan, 2010). This will help the local councils to know how to enforce laws and orders that will reduce illegal activities and indiscriminate disposal of waste. The local councils therefore also need to report any suspicious activities and unlawful dumping of hazardous waste on any parts of its environment to the state government as stated in the EIA Decree No 86 of 1992.

Besides, e-waste NGOs, private waste collecting sectors and initiatives too can be involved in e-waste management in the City of Lagos. The involvement will make e-waste collection well-organised as more e-waste would be obtained from households and reported. Also, this will further enable the general public to dispose of their e-waste and not store to them at home nor dispose of them along with other forms of e-waste. From the findings of this study, e-waste is only collected from commercial and government organisations. Besides, at the time of this study, only one recycling company is involved in the collection and recycling of e-waste in Lagos State. This is not effective and efficient enough, given the population and the number of establishments in the city (Water, 2018). However, the company only collects e-waste from government and private institutions within the state. Therefore, it can be argued that the state government should invite more private e-waste management companies to ease service delivery from LAWMA and enable it to face its regulatory and monitoring duties.

Decentralisation of duties to the various agencies in the city of Lagos is very important. More so, for other e-waste collectors in Lagos, there is a need to disseminate the rules and regulations to

them through the various agencies. This will require the regulatory bodies to re-organise the institutions, provide staff organogram and job descriptions to each agency/company that will be involved in the collection, recycling and disposal services. Other conditions such as enforcement, monitoring and control structures should also be put in place to check the activities of the non-governmental e-waste collection, recycling and disposal companies (Water, 2018). According to the national e-waste regulations, the recycling facilities and staff safety, as well as the use of protective equipment, should be examined before working in the facility. However, any e-waste recycling companies that do not adhere to the instructions in national regulations and the Lagos State e-waste policy should be prosecuted, or such facilities should be shut down.

More so, the waste institution should develop a capacity building that will strengthen the skills of the staff as this will contribute to the planning and financial management of the institutions. It is therefore essential that quality training is given to the team and other stakeholders involved in e-waste management (Waters, 2018). This training will enable them to handle, recycle and dispose of e-waste in a way that will be safe and as stipulated in the national e-waste regulations. The state government should also employ more skilled e-waste personnel because lack of human resources was one of the significant challenges mentioned by the staff from the waste institutions during this study. This is discussed in the next section.

### 5.3 The inventory of challenges affecting e-waste management in Lagos

From the responses expressed by some of the e-waste collectors, dealers and the e-waste agencies staff through the survey and interview discussions, the challenges hindering the effective management of e-waste within the city of Lagos is presented in Figure 5.1. These challenges were further categorised into three groups, and they are; infrastructural challenges, for example, lack of urban space or land for e-waste warehousing, recycling facilities and landfills; inadequate equipment, inadequate skilled human resources and financial constraints. Behavioural and educational challenges such as mentality and behaviour, lack of awareness and information. Lastly, legal, policy and regulatory challenges like poor monitoring and compliance and weak enforcement and accountability.

**a) Infrastructural Challenges**

The issue of infrastructure is austere because the agency does not have warehouses to store collected e-waste from the government and commercial organisations. This might be because Lagos State is geographically small and approximately 787.8 square kilometres of Lagos land area is made up of lagoons and creeks. The issue of unavailability of land is preventing the state government from building e-waste recycling facilities, buying e-waste recycling plants as well building appropriate landfills. Similar problems on lack of space in solid waste management have been reported by Asase et al., (2009) and supported by McAllister (2015). It can, therefore, be argued that the problem is further compounded by the inability of the government to include urban solid waste (e-waste) management into its urban development and planning policy. Thus, leading to the illegal disposal of waste around the city which is also defacing the scenery of the town. However, this failure arises from poor intuitional frameworks because the government is aware of the constant population increase in the city of Lagos and should, therefore, put measures in place to address the issues of e-waste management. Furthermore, it should be noted

that urbanisation will continuously increase the volume of waste generated in any city as discussed in chapter two of this thesis. But improved governance will help to expand the lack of infrastructure in the management of e-waste.

In many developing countries such as Nigeria, for example, inadequate funding is another serious challenge in the management of waste. It can be seen from the field-based finding that waste management budget from both federal and state governments is low and this factor contributes to a lot of challenges in waste management in Nigeria. These findings align with those of Igbinomwanhia and Ohwovoriole (2011) who observed that similar budget challenge in Benin city, Nigeria slowed down solid waste management in the city. More so, it was found that the failure or unwillingness of some members of the public to pay the state disposal agency also contributes to financial constraints in the city. Igbinomwanhia and Ohwovoriole (2011) argue that insufficient income by some members of the public is the reason for their unwillingness to pay for waste disposal, leading to unlawful waste disposal. Additionally, misappropriation of funds by the members of staff contributes to this financial challenge. This is because sometimes the budgets presented are not used for the right purposes, funds may be embezzled or diverted for another project. Insufficient funding, for example, could affect the purchase of recycling plants and other appropriate equipment and technology for e-waste recycling. Inadequate funding also affects staff strength since the state government cannot afford to pay salaries, the low creation of e-waste recycling awareness programmes, inadequate monitoring and enforcement of regulations and policies etc.

The problem of funding can be ameliorated by generating revenues from waste collection, sales of sorted valuable recycling materials, getting private waste companies to invest in solid waste management in the city of Lagos and donations from local and international organisations. A previous study by Lohri et al., (2014) on solid waste management in Bahir Dar, Ethiopia shows that financing solid waste in many developing countries is not sustainable. The assumption is based on Guerrero et al., (2013) who observed that the waste management system in many developing countries is rarely evaluated through cost-revenue accounting as waste service is seen as "publicly financed" independent of the cost. It, therefore, accounts for the reason why Lagos State finds it difficult to include the local council in it waste management planning.

Furthermore, the state government has been very slack in creating public awareness in the area of e-waste management. A critical factor that affects public perception in the control of the waste system in any society is general knowledge on why, what and how its implementation can be actualised (De Feo and De Gisi, 2010). Read (1999) claims that a significant barrier, that is generally acceptable and known to impede the success of solid waste management is inadequate public knowledge. The assertion is as a result of the weak institutional framework, because it may be difficult for the public to participate in a recycling programme if the information is not disseminated accordingly through the proper channel. The present study observed from the waste agencies that the general public had not been informed about e-waste management. Those aware are the staff of some government, private and e-waste informal dealers. It is, however, crucial that the right institutions be developed to create public awareness on how to dispose of and recycle e-waste in the city. The public knowledge on e-waste management will allow for proper disposal of e-waste due to its hazardous nature and not along with other general waste.

Inadequate public knowledge in the city of Lagos has further been attributed to low human resources, which affects the quality of service delivered regarding e-waste collection in the state.

From the field based evidence, it was found that if there were more hands in the unit of e-waste, since its creation in 2011, by now almost every member of the public should have been aware of the benefits and dangers posed by e-waste. More so, the volume of the e-waste sent to the landfills and dump sites would have been reduced by the informal e-waste collectors, repairers and dealers. In the municipal solid waste collection, Matter et al., (2013) and Ka-Yan Lau, et al., (2013) observe that household waste comprises the primary constituents, hence there is a need to educate members of the public on e-waste management. Waste agencies should also create awareness in schools from primary to tertiary level of education, as this will enable the students to inform their parents about the issues surrounding waste management. More so, schools should include environmental education in their curriculum or form societies on waste management to promote awareness programmes on waste. The state agencies have to meet up with the local council to organise community awareness programmes, workshops, seminars, radio, printed as well as television adverts that should be used to inform the members of the public on e-waste management.

**b) Behavioural and Educational Issues**

These were other significant concerns raised by both the formal and informal e-waste stakeholders during the research. Previous studies by Tarasova et al., (2012), Che et al., (2013) and Park and Berry, (2013) reveal that public behaviour and attitudes can hinder solid waste management if institutions fail to educate, create awareness campaign, enforce regulations and policies, allow public participation as well as give out incentives to the public. Participants from the agency complained that the recycling bins given to some organisations were used for the storage of other personal items while some disposed of wrong waste items into wrong containers. This could be that the individuals were absent during the recycling awareness programme or feel they should be compensated, e.g. giving incentives for recycling. A case study in Shanghai, China shows that inadequate education, distance from recycling centres, small recycling bins, lack of public participation and disposal challenges contributed to the recycling and disposal of solid waste behavioural issues in the city (Zhang et al., 2012). However, further studies by Massawe et al., (2014) and Neo (2010) have emphasised the importance of education in bridging the gaps between "having the right attitude and actualising that in behaviour". Recycling of e-waste may be difficult for now as the waste agency may not be able to provide economic incentives to the public. The agencies have thus encouraged the private e-waste collecting company to compensate some of the government and private organisations that are participating in the recycling programme.

Furthermore, social discrimination is a severe problem, especially in the informal sectors. In the course of this study, it was observed by the researcher that the groups of informal e-waste pickers had been stigmatised, marginalised and regionalised to a particular race, religion and group within the Federal Republic of Nigeria. This is because, in the city of Lagos, the informal e-waste collectors have not been integrated into the formal sector. The study found that majority of the e-waste pickers are from the northern part of the country and many of them were called

different names such as mallams, aboki and condemned buyers. Some of the e-waste collectors also feel cheated because they have to pass through an intermediary or a boss who determines the wages they get, even though they go around the city collecting the scraps. In a bid to create a sustainable livelihood for the urban informal e-waste collectors, it is essential for the informal sector to be formalised. According to ITU (2016), if the e-waste informal sector is formalised and it is sustainably managed, it will create jobs for the unemployed youths and raw materials will be recovered and generated from the abandoned equipment. Previous studies by Ezeah et al., (2013) supported by Bonner (2008), have shown that the informal recycling sector in Latin America is the most advanced in the world because the industry is widely recognised and organised into cooperatives or association. However, it was further observed during this research that in the city of Lagos, various associations of e-waste dealers and scrap dealers' association had been formed. Staff from the waste agencies also confirmed this claim. The concept is a proper development, and with the creation of the new initiatives in Lagos, the informal sector may soon be socially accepted.

**c) Policies, Legislative and Regulatory Issues**

From the findings in this study, it was observed that Lagos State have several regulations, policies and laws/decrees that address the issues of solid waste management particularly e-waste but the primary challenge is poor implementation, enforcement and monitoring by the regulatory agencies. The results further corroborate the findings of Simatele and Etambakonga (2015) who suggested that weakness in institutional and policy frameworks account for lack of effective management of solid waste in developing countries, particularly in sub-Saharan African countries. In this study, it was found that LAWMA is now the new solid waste management regulatory agency, while LASEPA enforces the compliance and monitor the legal and policy frameworks. The empowerment of LAWMA as a regulatory body in the management of solid waste in Lagos will contribute to the improvement of waste management since it was formerly in charge of the solid waste collection, recycling and disposal until it was handed over to the Clean Lagos Initiative in 2017. Also, lack of effective and efficient waste regulations and policies due to duplication of responsibilities by the agencies which has resulted to poor management should be avoided, and the public should be informed and aware of the principles guiding e-waste management within the state.

It was further observed that the new regulatory agency has created an enforcement unit which will permit it to enforce the Sanitation Laws on individuals, cooperate bodies, organisations and anyone that fails to comply with the Lagos State Environmental Sanitation Laws. This is because legislation and policy frameworks are effective and efficient if adequately enforced (Ogawa, 2017). Besides, a compliance unit was also created such that there will be an investigation into complaints from the general public, private organisations and other stakeholders. The department would also mediate between aggrieved public and private sectors, give out abatement notices, daily investigation reports and documentation of all waste activities. This is a critical development as there are some illegal activities taking place in many legal and illegal dumpsites within the city of Lagos that can affect the general public and the events have to be reported for further action. From the field-based findings, it was detected that some residents had reported some illegal activities such as the burning of waste which causes water and air pollutions in their

areas. The agency also claimed to have visited some of the sites and educated the waste pickers on the danger their activities could pose to the environment. More so, the waste collectors also confirmed that LASEPA has been teaching and creating awareness on such events, the dangers e-waste poses and how they can handle e-waste recycling properly.

Given the above discussions, this study, therefore, argued that the agencies need to minimise institutional challenges by clearly defining the roles of each agency. They should also employ skilled hands and train the staff in the enforcement unit, develop strategic e-waste plan, ensure continuity in the implementation of solid waste legislation and policies, develop means of generating funds from e-waste collection, recycling and disposal from households, government and public organisations to complement the waste budgets. More so, they should educate and create public knowledge and awareness on e-waste, ensure community development programmes on waste and public participation.

### 5.4: The implications of heavy metals in soils from dump and scrap sites in Lagos

The physical parameter of soils collected during the dry and wet seasons in this study revealed that the soil colours differed from site to site. The soil samples colour variation might be because of the burning activities that usually take place on some of the sites, as well as the other landfill where scrap recycling activities take place. For example, the soil in the dismantling and scrap recovery site of Owode Onirin was observed to be dark brown during the dry season and black during the wet season. It may be explained by the fact that the automobile section at the scrap sites dispose of oil from the automobile scrap engines into the soil and also carry out the indiscriminate burning of cables and tyres. The burning activities are similar to what was reported by Petricca (2017) and Aina (2017) as observed on the site. Also in Solous MRF reddish-yellow during soil were collected in the dry season and weak red during the wet season. A possible explanation for this might be because the dump site has been converted into a material recovery facility (MRF), as well as continuous sand filling activities. Another possible explanation for this might be the high level of sulphate and iron present in the soil. Alakija scrap site soil was dark greyish brown during the dry season and dark greenish grey during the wet season. The reason for this is that the area is a wetland zone, where algae and other microflora grow. The findings from this study are likely to be related to the results of Brady and Weil (2006) which found that soil colour is mainly formed by the minerals and the organic matter content present in the soil. Therefore, it was concluded from the study that yellow or red earth indicates the presence of oxidised ferric iron oxides (e.g. Solous), while dark brown or black colour in the soil as seen in Olusosun shows that the land has a high organic matter content. It should be noted that wet soil will be darker than dry soil.

The soil odour for all the samples collected from the four study sites during the dry season was odourless, and these were within the WHO and LASEPA standard. On the other hand, during the wet season, all soil samples except the ones collected from Owode Onirin were within the recommended limits. This discrepancy could be attributed to the fact that the scrap market has been abandoned for a very long time by the Lagos State Solid Waste Agency. Another possible explanation for this is that, during the field survey, it was observed that waste was littered all around the market, people were also seen defecating and urinating around the market premises.

This unpleasant soil odour shows that soils from the market were not within the recommended standard and this might also affect the quality of air in the market. The foul smell may also cause air and water pollution. The findings from this study are similar to what was observed by Ojekule et al., (2016) who found that there is groundwater pollution around Owode Onirin scrap market. The mean soil temperature from the study locations shows that the soils were not above the stipulated regulatory limits. Although the temperature range did not show much fluctuation, the values were below the recommended soil standard (35-400C) by WHO and LASEPA. More so, according to NIMET, the Lagos State temperature around the dry season is estimated at 23.4-300C while the wet season is 21.9-29.30C. This may probably be sbecause different water bodies surround the city. However, there was a significant difference ($p \leq 0.001$) between the two season. The result from this study is slightly contradictory to previous studies. Yet, no significant differences were found between temperature and the study sites.

In this study, the dry season results range from strongly acidic to slightly acidic (Strongly acidic 5.1-5.5; Slightly acidic 6.0-6.5) while the wet season varies from slightly alkaline to moderately alkaline (slightly alkaline- 7.4 – 7.8; moderately alkaline- 7.9 – 8.4) (USNRCS, 2018). The mean pH value shows a significant difference ($p \leq 0.001$) during the two seasons. This result is somewhat surprising because the current study found that the pH of the soils collected from all the study sites has high values during the wet season. Results from this study further corroborate the findings of Yahaya et al., (2009), who reported low pH during the dry season and high pH in the wet season. Previous studies have however linked low pH in the soil will to the release of heavy metals. Further analysis showed that there was no significant difference ($p > 0.05$) between the pH of the soil and study locations. It agrees with the findings of Sonko et al., (2016), who revealed no significant difference between the soil pH and study locations.

During the wet season, the percentage moisture contents were higher than what was obtained in the dry season. A possible explanation for this is attributed to the volume of rainfall in the wet season. Besides, the decrease in soil moisture content in the dry season is reasonable and could probably be due to high soil moisture evaporation which occurs during this season. There was a significant difference between the moisture content of the two seasons ($p < 0.05$). Further statistical analysis revealed that there was a significant difference ($p < 0.05$) between the soil samples and study locations. A possible explanation for this might be that all the four study locations may be of the same soil types that are characterised by low pH. This result, therefore, shows that there is an agreement between this present finding and some previous studies (Homyak et al., 2018; Murray-Tortarolo et al., 2016).

From the chemical analysis result, nitrate value was very high in Solous MRF during the wet season. This result may be explained by the fact that the soil type in this study site is clay. A research by Oyiboka (2014), revealed that Solous MRF has about 21% clay content and that the high concentration of clay impedes the free migration of leachate in the study site. Another possible explanation might be because the study site is now landfilled with other soil types and rock particles that consist of nitrates deposits. The overall mean results for both seasons were within the WHO and LASEPA standards. Chemical analysis revealed that the soil nitrates for the two seasons were within the recommended limits. A further statistical analysis shows that there is

a weak variation ($p = 0.057$) between the two seasons. However, there was a significant difference ($p<0.05$) in nitrates between the four study sites.

In this study, soil phosphate was found to be high in the dry season and low in the wet season in three study sites (Olusosun, Alakija and Owode-Onirin). These results seem to be consistent with other research which found that concentrations of phosphates were low in the wet season due to leaching and that soil phosphate accumulated during the dry season when evaporation exceeded precipitation (Bi et al., 2018; Gross et al., 2015). What is surprising is that the phosphate content was found to be high in the soil samples collected from Solous MRF. A possible explanation for this might be because the soil type is clay in nature and this impedes migration of leachate. No significant difference ($p>0.05$) between the two seasons and no signification variation between phosphate and the four study sites.

During the dry season, sulphates were not present in the soil samples collected from Olusosun landfill and Alakija scrap site. The highest sulphate values for the dry season and the lowest wet season were found in the soil samples collected from Solous MRF. The observed increase in Sulphate during the dry season could be attributed to low pH in the study site. Further statistical analysis revealed no significant difference between the sulphate concentrations for the two seasons. Also, no significant difference was evident in sulphate and the four study sites.

The percentage Organic Carbon contents from the four study sites were higher in the wet season than in the dry season. A one-way ANOVA revealed that significant difference was evident between ($p < 0.05$) the % Organic Carbon contents and the study sites. The differences between the wet and dry seasons may be attributed to the high volume of rainfall as well as the topography of the study sites. However, there was a significant difference between the % Organic Carbon Contents for the two seasons. The percentage of organic matter contents were lower during the dry season but higher in the wet season. There was a significant difference ($p <0.05$) between the % organic matter content from the two season. A possible explanation for the higher organic matter content may be due to decomposition and composting processes of the animal waste, plants/vegetable matter and polymer or plastic materials. Alloway and Ayres (1997) suggested that organic matter plays a vital role in soil structure, water retention, cation exchange and the formation of complexes. Studies by Lancrop Laboratories (2013) and Isimekhai et al., (2017), show that poorly drained soil consists of higher organic matter content because low oxygen concentration reduces decomposition activities. On the other hand, further statistical tests revealed a significant difference between the % organic matter contents and the study sites. These results are in agreement with the findings of Isimekhai et al., (2017) and Yahaya et al., (2009).

The heavy/trace metal analysis result shows that the concentrations are not the same in all study sites. From the findings, it was evident that the mean concentrations of Fe were higher than all other metals in all study sites in the two seasons. Interestingly, the mean concentration values of Fe in the two seasons exceed the WHO and LASEPA standard of 5.0mg/kg. The highest concentration of Fe during the dry season was obtained in soil samples from Olusosun landfill while the highest during the wet season was found in Owode Onirin. The least concentrations of

Fe for both seasons were seen in Solous MRF. Although the concentrations at Solous MRF were low for the two season, it did exceed the regulatory limits for Lagos soils. When the concentrations of Fe from all four study sites were compared for the two seasons, surprisingly, it was observed that the wet season concentrations were higher than the dry season. This result may be explained by the fact that the wet season soil samples were collected during the early rainfall season. This finding is contrary to previous studies of Yahaya et al., (2009) and Khadijah et al. (2017), who suggested that metals are higher during the dry season than during the wet season. A further statistical analysis revealed that Fe differed significantly ($p < 0.001$) in total concentrations from the dry and wet seasons. No significant difference was detected between the four study sites and Fe.

The concentration values of Zn detected suggests that the metal exceeded the WHO and LASEPA standard of < 1mg/kg. Although, no Zn concentrations were discovered in the soil samples collected from Solous MRF during the dry season, however, during the wet season the Zn concentration shows that 6.03±0.14mg/kg was present in the site. A possible explanation for this increase may be due to the sand filling activities which continuously take place on the site or due to conversion from dumpsite to a material recovery facility. Also, it can be seen from the results that concentration values of Zinc at Alakija scrap site was higher during the dry season and lower during the wet season. This result further supports previous studies which argue that the concentration values of metals are higher in the dry season than in the wet season (Oluyemi et al., 2008 and Isimekhai et al., 2017). The concentration values for Zn were higher during the wet season than the dry season at Olusosun landfill and Owode Onirin scarp market, and this does not support the previous research. When the dry season mean results were compared to the wet season, there was a significant difference ($p < 0.05$) in the concentration values of the two seasons. A one-way ANOVA analysis also shows that there was a significant difference ($p < 0.05$) between the study sites and Zn.

Lead (Pb) was not detected in Solous soils collected during the dry season, but there was a slight increase in the wet season soils. This inconsistency may be due to conversion purpose. It should, however, be noted that the concentration of Pb detected in both seasons were within the WHO and LASEPA limits which imply that the site is not polluted with the metal. On the other hand, the mean concentration values of Pb in Alakija scrap site is lower in the wet season and slightly higher in the dry season but did not exceed the limits. A possible explanation for this might be due to leaching that is capable of removing heavy metals from the scrap site and the outcome of precipitation which may enable the dilution of soil solution during the wet season. It may also be attributed to the fact that the scrap is a new and illegal scrap. Soil samples collected from Olusosun landfill and Owode Onirin scrap market revealed that the concentrations of Pb were elevated in the wet season in both study sites than the dry season. A possible explanation for this might be that the soil samples were collected early in the season. Another reason for this is that soil type at the disposal site may vary and the activities at the scrap market might have influenced the concentrations values of Pb (Isimekhai et al., 2017). This study, therefore, argues that the high level of Pb is dangerous to the health of the scavengers and the environment. The overall mean concentration shows that there was a significant difference ($p < 0.05$) between the two

seasons. Further analysis revealed significant difference ($p < 0.001$) between the study sites and Pb.

The concentration values of Mn shows that the metal exceeded the stipulated regulatory limits of 0.2mg/kg given by WHO and LASEPA. It can be seen that the wet season concentration values of Mn were higher in Olusosun landfill, Owode Onirin scrap market and Solus MRF than in the dry season. This finding is contrary to previous studies which suggested that metal concentrations are higher during the dry season. This discrepancy could be attributed to the various activities that have taken place in the different study sites during the different seasons. The concentration values of Mn obtained from Alakija scrap site shows that although Mn concentration value was lower in the wet season and also exceeded the WHO and LASEPA standards but an increase in the level of Mn could have negative health implication on the environment and the health of its handlers. The overall mean concentration also shows that the wet season concentration exceeded the dry season concentration value. However, there is no significant difference ($p > 0.05$) between the Mn concentrations of the two season.

Other metals analysed were Ca, Na, Ni, Ag, Cu, K and Cd. The metals were within the required regulatory limits. The samples from the dry and wet seasons differed significantly ($p < 0.05$) in total concentrations of Ca, Ni and Ag, where the total level was higher in the wet season than in the dry season. More so Cd, Cu, K and Na showed significant difference at $p < 0.001$ and Ag and Ni at 0.05 between the study sites.

A significant positive correlation exists between most heavy metals in all the investigated areas. In this study, positive correlation exists between pH and three metals; Fe, Ag and Ni at $p < 0.01$, $p < 0.01$ and $p < 0.05$ respectively. Many of the other metals relations were significant ($p < 0.01$) for Fe, Pb, Ca, Mn, Cd, Cu, Ag, K, Ni and Na. on the other hand, Cd, K, Ni and Na show significant positive correlation ($p < 0.05$). A possible explanation for these positive correlations might be that the metals originate from either the same anthropogenic source or parent material. These results corroborate the findings of Onjefu et al., (2017), Adesuyi et al., (2015) and Adeyi and Torto (2014) who revealed that common source of pollution input of heavy metals is possible across different sampling sites in different parts of the same geographical location. A further explanation is that the same effects of trans-boundary pollution associated with dust deposition and air could have affected the study sites. However, no significant correlation was observed for Zn in this present study. This is in agreement with the findings by Adesuyi et al., (2015) and may be due to elemental intake through atmospheric deposition. This study, therefore, suggests that significant positive correlations in metal concentrations found in soil samples are because the metals were derived from common sources.

Soil samples collected from Solous MRF had contamination factor (CF) values less than one (< 1) during the dry and wet seasons, which indicates there is low contamination in this site. A possible explanation could be because the site has been converted from the dump site to a material recovery facility. This study implies that if e-waste is managed formally, the concentrations of heavy and hazardous metals would be reduced in the environment. More so, in Alakija scrap site the CF values were less than one during the two seasons, meaning low

contamination of heavy metals in the site. This might be because the site is an illegal scrap site and dismantling and sorting activities started recently. The CF in the Olusosun landfill was above 1 for Pb and Cd during the dry season and Pb and Cu during the wet season. The result shows that the study site had moderate contamination level during the dry season and moderately contaminated during the wet season, while low contamination factor was obtained for the other metals. It may probably be due to the informal recycling activities which take place on this site. It can be argued that the level of these metals may increase soon if the informal recycling activities are not reduced from the site. Owode Onirin scrap market recorded values higher than 1 for Pb and Cu during the dry season and Pb, Cu and Zn in the wet season. It can be seen that during the dry season, Pb and Cu had a moderate level of contamination in the study site, while in the wet season, Pb had very high contamination level, with CF value greater than 6 and Zn and Cu show moderate contamination level. According to EPA (Adeyi and Torto, 2014), Pb is very dangerous because it is absorbed slowly in the soil, usually deposited in the upper soil surface and it is not readily leached. The mean Pb concentrations in this study show significant lead contamination in two of the study sites.

The I-geo values vary from metal to metal and site to site. The I-geo index values show that only Cu at Owode Onirin scrap market attained moderately contaminated level during the dry season. On the other hand, during the wet season, Pb at Olusosun landfill and Cu at Owode-Onirin scrap market reached the moderate contamination status. This shows that not all soils investigated in Lagos, Nigeria is polluted, but some sites are more polluted than the others.

### 5.4.1 Environmental pollution and health impacts of heavy metals in Lagos

Given the above analysis, it was found that the soil samples collected from the study sites are polluted. For example, during the wet season, the soil odour of samples collected from Owode-Onirin was unpleasant and was not within the WHO and LASEPA limits. Srivastava et al., (2014), have argued that there are problems associated with soil odours as leachate migration from such soils can affect groundwater. Unpleasant smell in this study site may affect the quality of air inhaled by those working in the scrap market and people residing around the place. Furthermore, burning of e-waste products in order to retrieve valuable material may also lead to air and soil contaminations which will, in turn, affect the health of the informal workers resulting to health issues such as respiratory, skin and eye problems (Li et al., 2007; Yu et al., 2006). Also, low soil pH which makes the soil acidic due to sediments from e-waste heavy metals may result in acid leaching that can cause water pollution in the environment. Aquatic lives may also be affected if there is flooding, this is because the heavy metal sediments may be washed into streams and rivers around the dumpsite and e-waste recycling sites (Wong et al., 2007). It should also be noted that there have been several complaints by people residing around some of the study sites mainly Olusosun landfill, Solus dumpsite and Owode Onirin scrap market on the issues of air pollution which is due to several burning activities. Although Lagos State has documented and implemented legislation on how the informal sector should handle e-waste recycling due to institutional failures in the enforcement of these decrees the crude activities are still ongoing as many of the informal workers pick waste without protective equipment.

Furthermore, lead (Pb), one of the most hazardous e-waste components was higher than the stipulated WHO and LASEPA soil limit in two of the study sites during the two seasons. Moderate and high contamination factors of lead in some study sites were observed. It should be noted that sites with average contamination factors may increase if not adequately monitored as this may have a grave impact on the lives of the informal workers and those residing around the sites. Lead is very toxic and can cause impairment to the central and peripheral nervous systems in human. Previous studies have shown that lead may cause severe brain damage in children and disruption of the kidney, circulatory and respiratory systems (Maheshwari et al., 2013). Also, lead can also alter trace elements in antioxidant enzymes and essential biomolecules, as well as interrupt their activities. Moreover, the concentrations of zinc (Zn) was higher in three study sites during the dry season and higher in all locations in the wet season. Zn shares the same properties with cadmium, and the excess level may cause severe health danger to human health (such as prostate cancer) and the environment (Igharo et al., 2015).

However, moderate contamination factor of cadmium was observed in one of the study sites during the dry season, and this may further accumulate leading to health issues like liver and DNA and kidney damages. Abdel-Moneim et al., (2012), are of the view that the body should only be exposed to a limited amount of cadmium because the metal does not undergo complete metabolic breakdown. This is because it is poorly defecated and the rest that cannot be excreted is stored in the liver leading to oxidative stress. Other heavy metals that were not within the set-aside limits are iron and manganese. Previous studies by Solı´s-Vivanco et al., (2009) and Zeng et al., (2009), for example, have revealed that the Mn poisoning has been associated to damaged motor skills, mental illnesses, and metabolic processes. This is because manganese most significant sources are through food and water. Since high concentration level of Mn is found in the soils around the recycling sites, there is a possibility of it affecting the groundwater source and plants which in turn will affect the workers and the general public. Increase in the concentration of iron can result in oxidative stress which is caused by Fenton (replacement of iron by protein) reaction (Valko and Morris, 2005).

From the above discussion, it was observed in the cause of this study that the workers were not mindful of their safety as many of them were not putting on any personal protective equipment during e-waste picking/collection, dismantling and recycling processes. This is similar to the observations of Igharo et al., (2015) and Duan and Eugster (2007). Lack of policy enforcement and monitoring of the e-waste informal recycling activities in Lagos State is the cause of this challenge. A number of studies have described the damaging effects of exposure to some of the heavy metals found in the soils collected from the study sites on men, women, pregnant women and children (ITU, 2016; Igharo et al., 2015a). A few studies have also shown the impacts of heavy metals on cytogenetic modifications and other severe health issues, such as damage of immune system, cardiovascular, gastrointestinal, premature delivery, reduced neonatal lung function and neurobehavioral changes in the childhood (ITU, 2016; Igharo et al., 2015b; Lueng et al., 2008).

However, due to lack of enforcement of regulations and policies environmental and health impact of e-waste has increased in the city of Lagos as well as in other developing countries. Therefore, it is essential for the Lagos State government to promote research in the field of e-

waste and the available policy. Awareness creation by the agency on the dangers associated with the health of the people and how they can be protected from the adverse effects need to be done. The agencies should also train the policy and decision makers on how to enforce and monitor e-waste policy and regulations. Lastly, the agency in charge of e-waste policy and regulations should also work with the Ministry of Health to recognise the potential health threat of e-waste poses to the public. The environmental and waste agencies should coordinate the activities of the informal and formal e-waste sectors (Balde et al., 2017; ITU, 2016).

**5.5 E-waste as a means of sustainable livelihood for urban poor in Lagos.**

From the empirical evidence, it was observed that the informal e-waste collectors are the most active members involved in e-waste management in Lagos, since they contribute immensely to the environment by reducing the volumes of e-waste sent to dump sites and landfills through recovery and management ranging from picking to the refurbishing of e-waste from households, markets and dumpsites (Nzeadibe, 2009). E-waste resource collection or scavenging in the city of Lagos is a survival strategy, and it may be due to the unemployment which results from its dense population. These results, for example, validate the findings of Simatele and Etambakonga (2015) and Sentime (2014) who contended that informal waste collection and recycling is a strategy of survival in many urban city households in developing countries. The study found that many of the informal collectors have a low education level, this may be one of the reasons why it is daunting to secure a better job. Oten-Ababio (2012) supported by Holmes (1999), observe that for an individual to get an excellent formal job opportunity, a higher level of education is a determining factor. It also accounts for the lack of integration of the informal sector into the formal industry.

This current study found that the male gender majorly dominates the e-waste informal collection sector because no female collector was sighted during this study. It could be because the job is difficult, as it requires more energy to push the cart, walk miles to collect waste and to dismantle manually using hammer, chisels and screwdrivers. Nzeadibe (2008), is of the opinion that female e-waste picker may not be involved in e-waste collections because of some socio-cultural issues like gender preferences and fear of been antagonised by their male counterparts. While some previous studies have shown that in the informal sectors, there were more males than females, (Simatele et al., 2017; Amankwaa, 2013; Oteng-Ababio, 2012), however, females were usually in charge of sales of the sorted scrap or administrative units. In most sub- Saharan African countries men are egoistic because they claim it is their responsibility to provide for their households. More so, it can be seen from these findings that majority of the respondents are from the northern region of Nigeria, who are mostly Muslims and many do not allow their wives to work or fend for the family according to their religious beliefs. These results corroborate the findings of Nzeadibe (2009), who observed that no female scavengers were found picking waste from landfill in the city of Enugu in Nigeria.

Furthermore, the most exciting finding in this study is that many of the resource pickers are youths, aged between 18 and 40 years. In the light of this, it can be argued that young people have dominated the informal sector which could be as a result of the high unemployment and underemployment rates (33%) in the city of Lagos (National Bureau of Statistics, 2017). The

implication of this is that many young people in the city of Lagos are without a job and have to look for a way to create livelihoods for themselves and families. Also, the majority of the respondents are married and have children and other family members they have to support. Nzeadibe (2009), suggests that young people are picking waste for the following reason: to help or raise a family; it is a flexible and stable occupation, they decide when to go to work and; make enough money that can meet their needs. Besides, the high unemployment rate in the city of Lagos may also be attributed to its growing population as well as rapid urbanisation, leading young people to create an alternative means of survival which will help them generate income to obtain the necessities of life. According to Aliyu and Amadu (2017), it is argued that urbanisation is demographically determined in Nigeria and that urban population growth in the city of Lagos is estimated at 5.8%. This, however, has to be addressed as the growing population will outweigh the available social amenities increasing solid waste (e-waste) generation, health risk, unemployment and inadequate housing.

It is important to note from this study that many of the informal e-waste collectors sell sorted and unsorted e-waste scraps to the middlemen or work for bosses who sometimes exploit them. The middlemen do not go in search of the scraps but depend solely on the e-waste resource collectors to go in search of metals, and they buy from them. For example, the valuable materials are sorted firstly into metals and non-metals, afterwards, each metal and non-metal is further classified into aluminium, coppers, plastics, zinc, iron etc. As it can be seen from the empirical findings, that there are fixed prices for each valuable materials and they vary from sites to sites. After weighing, the middlemen pay the scavengers for the scraps which are sold to dealers who store in bulk and later sell to big recycling companies at prices higher than the amount paid to the collectors. The dealers make most of the gain in this business because they understand the values of the scraps, they have ample capital to finance the market and have created an existing network for the industry as some of the scraps are sold to international companies which export the wastes outside Nigeria. These results match those observed earlier by Amankwaa (2013) and Oteng-Ababio (2012). However, this study observed that not all scraps are exported, some are sold to local blacksmiths, goldsmiths, artisans, welders, jewellery sellers, iron and steel markets /companies etc. who in turn develop them into iron pots, cutlasses, hoes, gates, cooking utensils as well as jewellery (Nzeadibe and Iwuoha, 2008). These findings, therefore, suggest that the e-waste business is a big market that is locally and internationally recognised.

Another interesting finding from this study is that e-waste resource collection provides a form of sustainable livelihoods to the scavengers as the majority (90%) of the respondents stated that they earn more than the stipulated minimum wage official monthly wage of N18,000.00 ($49.31). Although it was observed that many of the scavengers do not keep records of their activities on a daily basis, but the income earned from the job help them provide necessary things of life for their households. Some of the respondents were happy that they could afford to pay their children education fees with the little they earn. This study, therefore, argues that e-waste picking is profitable as it enables the scavengers to support their immediate families and dependent relative, seeing that Nigeria practices the extended family system (Labeodan, 2016; Mallum, 1986).

### 5.5.1 Sustainable wealth creation and accumulation from e-waste collection

From the above analysis, it can be seen that many of the scavengers were able to provide financial support for their households and dependent relatives. However, one may want to ask the question of how many of these scavengers were able to invest financially or acquire personal properties from this job? From the empirical evidence, it was observed that over 50% of the respondents have savings or financial investments and also own one form of landed properties or more, although a few respondents could not invest because of the number of the individuals depending on them. It may also be because most of the scavengers do not keep records of their daily earning and spending. Another reason may be because of the price variation of the materials that the collectors can pick.

From the field-based evidence, it was further observed that a few bosses and intermediaries earn more than the scavengers. Some of them were not willing to disclose the amount they make from the sales of scraps bought from the collectors neither did they divulge the names of the companies they sell them to. This could be because they were scared that the researcher was working with state government agencies and they did not pay taxes. Besides, some also denied the stipulated prices of materials given by some waste pickers by lowering the costs. In another interaction with some of the e-waste dealers and scrap sellers, it was revealed that some make profits of up to N500,000.00 ($1,370.00) monthly from the sales of second-hand electronics and various scraps, although this does not cut across all of them as their earnings vary, according to negotiation power, numbers of customers and availability of the scarps and the volume of scraps they can sell. These findings, support the views of other researchers (Simatele et al., 2017; Oteng-Ababio, 2012) that many of these dealers and middlemen make more than a salary earner depending on the position of the individual.

From the above observations, it is therefore essential to note that if the resource collectors are integrated into the formal institution, they will not be exploited by middlemen and bosses. More so, there will be a proper record keeping on earnings, and this will reduce the spending rates as income will no longer be daily. Furthermore, more of the scavengers will be able to save and invest as this will better their livelihoods. Many will be able to send their children to affordable school to acquire good education and also provide financially for their immediate and extended relatives. On the other hand, the middlemen and bosses will not be able to escape tax payment. With the integration, the rate of unemployment will gradually reduce in the city of Lagos, and those working in the sector will not be socially discriminated.

## 5.6 Effectiveness of formal take-back scheme in Lagos, Nigeria

From the empirical findings, the majority of the informal participants argued that they have not heard about the scheme and the researcher explained the meaning to them. Afterwards, when the researcher asked them about the best way to discard e-waste, many of the respondents indicated the take back scheme. Previous studies described the take-back scheme as a method that is globally used to execute the e-waste/WEEE extended producer responsibility programme. Sthiannopkao and Wong (2013) buttressed by Savage et al., (2006) are of the view that for the take-back scheme to be effectively executed, e-waste collection centres should be situated in urban areas/local councils, retailer take-back and guaranteed producer take-back

stores. This scheme is one of the strategies proposed by LASEPA in the Lagos e-waste policy document for effective management of e-waste in the city. However, from the empirical findings, there is a lack of awareness creation on the strategy, and it is significant to most urban cities in many developing countries (Dwivedy et al., 2015; Nnorom and Osibanjo, 2008). This problem is due to the weak institutional framework, and there is a need for the agency to inform the public about what the scheme is about and how it can be used to curb the menace of e-waste.

More so, the agency needs to partner with the electronic manufacturing companies and the e-product importers to build up an infrastructure so that the takeback scheme can achieve its aims. This will mean that the producers, assemblers, importers, distributors and traders will ask consumers to return old products and add some amount to get a newer model. However, from the reviewed documents, it was observed that the state government is willing to establish a funding mechanism known as e-waste fund initiative. This mechanism aims to allocate financial incentives to stakeholders who are eager to return the old model of their e-products. It should, therefore, be noted that the motivation will depend on the model of the product. One could be wondering if this programme will be sustainable. Previous studies have shown that given out incentive is one of the strategies that help in recycling; however, this may stop if no incentives are attached to the program (ITU, 2016; Marshall and Farahbaksh, 2013). This was also confirmed by one of the staff of LAWMA who believed that the companies/producers of such products should be able to give out incentives to those who are actively participating in recycling.

Apart from awareness creation and giving incentives, the e-waste takeback centres or facilities should also be built very close to the stakeholders' resident. This nearness will encourage and motivate individuals to participate in the e-waste take-back programme as they do not have to travel to distant centres for recycling or exchanging of their products. According to McAllister (2015), it was argued that respondents participate more in recycling programmes if the centres are within their vicinities. Many previous studies have also suggested that this is a good strategy, as it will attract more people to take part in the programme and high level of takeback will be attained (Dwivedy et al., 2015; Atasu et al., 2012; Nnorom and Osibanjo, 2008). The collection centres should be well equipped such that the environment will be safe for the workers and the public. The e-waste take-back centre, for example, may be divided into the following: repair, reuse, disassembly, recycling and disposal sections (Ylä-Mella et al., 2014) This will enable effective management of e-waste as the disposal will be done in an environmentally sound manner. Furthermore, the collection centres must have a target on the volume of e-waste that should be collected, separated for recovery purposes and recycling, and the figures should be documented and reported to the agency in charge of waste management.

### 5.7 Implications

The study has presented the results of the findings. The research identified the active stakeholders involved in the management of e-waste in the city of Lagos and the various institutions. The institutions ranged from the Federal to the State agencies in the Ministry of Environment and the different laws, regulations and policies that are linked directly or indirectly to e-waste management from the various environmental laws. The research found that Nigeria as

a country and Lagos State have different agencies that manage e-waste and also have multiple regulations and policies that can be used to reduce e-waste hazards. Institutional challenges involved in the management of e-waste were also examined. It can, therefore, be argued that the significant difficulties observed were due to weak enforcement, compliance and monitoring of the laws by the supervisory agencies. It can further be argued that the number of laws and policies will not be adequate if the issues of enforcement and compliance and monitoring are not adequately attended to.

The environmental implications of e-waste from the concentrations of heavy metal, pollution load index factor and contamination factors of the soil samples from two recycling and dump sites were also observed. It is seen that the concentrations of some heavy metals dangerous to the health of scavengers and the ecosystems were higher than the stipulated limits in the soils from the dumps and scrap sites. This will, in turn, affect the livelihood of the collectors, such that more money will be spent on health care of the workers, also the water and air pollution will have to be controlled so as not to affect the general public.

The livelihoods of the informal waste collectors, techniques of collections, economic aspects of the scrap collections and the challenges they encountered were discussed. Most of the e-waste collectors complained about some of the obstacles faced which ranged from social discrimination to public and government assaults. It is further observed that the government has to collaborate with the scrap dealers' association so that their roles can be acknowledged and recognised by the waste institutions and the general public.

Given the above analysis, the Lagos State Government can empower the local councils through institutional (waste agencies, initiatives and authorities) and design legal frameworks that will include the operations of the informal e-waste sectors in the city's policy planning and development. Furthermore, the state and the local council may partner with private recycling companies to educate, carry out training, workshops and awareness programmes and provide the necessary protective equipment needed during recycling. Integration of the informal e-waste pickers, as well as public participation in e-waste management, will make its collection, transportation, recycling and final disposal productive and efficient.

# CHAPTER SIX

# SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

## 6.1 Introduction

This chapter aims to bring together some of the significant issues that were raised in tackling the problems of e-waste management in the city of Lagos. The study has engaged with the various literature and stakeholders involved in e-waste management in the city and further examined the participation of each sector. In this study, the different agencies' responsibilities, success stories and challenges were also investigated. The non-integration of the informal e-waste collectors into the formal sectors and how it could hamper their livelihoods were explored. Also, the most effective ways to manage e-waste were also looked into and have been discussed in the previous chapters. This chapter is, therefore, the final summary connecting some of the empirical findings, conclusions and further suggestion to the government and various stakeholders involved in the management of e-waste in urban Lagos. The chapter is divided into four subsections. The first subsection presents the summary of the critical finding observed from the empirical results by providing answers to the various research questions, aim and objectives of this study. Secondly, the different conclusions obtained from the research questions and empirical findings of this study were discussed. Thirdly, based on the research findings and limitations, the third section offers some recommendations to the government agencies and e-waste handlers. The study suggests ways by which e-waste issues can be effectively managed through useful policy implementations, monitoring and enforcement. Also, how integrating the informal sector into the formal waste management sector will serve as a source of livelihood to the urban poor. The last section provides suggestions for futures research.

## 6.2 Summary of Key Findings

This study has explored the institutional and policy frameworks, challenges of e-waste and how its management can offer livelihood opportunities to the informal e-waste collectors in the city of Lagos, Nigeria. The research found that the only ational institution involved in the management of solid waste in Nigeria, is the Federal Ministry of Environment and the agency responsible for e-waste management under this institution is NESREA. Furthermore, two agencies (LAWMA and LASEPA) under the Lagos State Ministry of Environment are in charge of e-waste management and policy frameworks in the state. The roles of each agency at the national and state levels were examined in chapter four of this thesis. However, the results from this study show that the agencies have not indeed discharged their duties as such and this explains the reasons for the poor intuitional frameworks within the state. More so, it was observed that due to the gaps that exist in the responsibilities of these agencies, LAWMA has handed over the role of the solid waste collection in the city of Lagos to a new initiative, known as the Clean Lagos Initiative so that it can assume the state solid waste management regulatory role. In addition, the most apparent finding that emerges from this study is that there are different types of legislation, regulations and policies on solid waste, particularly on e-waste management in Lagos, Nigeria. However, it was further observed that the weakness in the

enforcement of the policies and regulations are as a result of the failures on the part of the institutions.

The research further examined and analysed some of the institutional challenges that affect e-waste management in Lagos State. Some of the problems that affect solid waste (e-waste) management in the city of Lagos were listed in chapter four. The noticeable barriers observed were classified into three significant subheadings, and they are infrastructural, attitude and information, and policy and regulatory challenges. These were categorised based on the field evidence collected from participants from the federal and state agencies and the informal e-waste collectors. They are of the view that these challenges are the main barriers obstructing the management of e-waste in Lagos. However, that these challenges were further subdivided into other sub-topics and they have also been discussed.

Furthermore, the health and environmental implications of the physical, chemical and heavy metals detected from e-waste recycling and dump sites were analysed. Soil samples were collected from four study sites during the dry and wet seasons in Lagos. The results show that some study locations were polluted with heavy/trace metals like Zn, Fe, Mg and Pb and the values obtained were higher than the stipulated LASEPA and WHO limits. More so, Fe was the topmost metal found in the four sites in both seasons. On the other hand, it was seen that the sites were more polluted during the wet season than in the dry season, but these do not cut across all the sites. A further statistical analysis, ANOVA revealed that the mean concentrations of heavy metals in soils collected from the two seasons were not similar. It shows that the temperature, pH, percentage moisture content, percentage organic carbon and organic matter are significantly different in the dry season when compared to the wet season. Also, six out of the eleven heavy metals (Zn, Fe, Pb, Ca, Ag and Ni) varied significantly between the dry and wet seasons.

Another ANOVA test for the variance to show if there were significant differences between the mean concentrations of heavy metals and the study sites were also carried out. It was found that four physicochemical parameters; percentage moisture contents, Nitrates, percentage organic carbon and % organic matter differed significantly across all study sites while nine of the heavy/trace metals also varied substantially across the four study sites in the two seasons. This is shown in chapters four. The correlation coefficient (r) was examined amongst the heavy metal concentrations and pH values from the overall mean obtained from the different study locations. A significant positive correlation was determined between some metals (Fe, Ni and Ag) and pH, and amongst the heavy metals but no significant relationship existed for Zn. This study has found that generally, the positive correlation that exists between the heavy/trace metals is because the metals originate from the same anthropogenic sources or parent materials.

The investigation of soil contamination factor (CF) shows that soils from two of the study sites (Alakija and Solous) were less than one (< 1) which indicates that the sites were not polluted in both seasons. Meanwhile, at the Olusosun dump site, the soils were slightly contaminated by Pb, Cd, and Cu in the dry and wet seasons. Furthermore, Owode-Onirin scrap market site has the highest Pb CF of six (6) and moderate CF of Zn during the wet season, an average CF of Pb and Cu was observed in the dry season in the same site. The I-geo shows that only Cu at Owode

Onirin scrap market attained moderately contaminated level during the dry season while Pb at Olusosun landfill, as well as Cu at Owode-Onirin scrap market, reached the reasonable contamination limit. The pollution load index at Olusosun and Owode-Onirin indicate that some heavy metals were above one (1) during the dry and wet seasons implying that the soils were highly polluted. It was then concluded that not all soil samples investigated in the city of Lagos, Nigeria were polluted, nevertheless some sites are polluted than the others.

The investigation of heavy metals in soils shows that these metals could have severe health and environmental impacts on the scavengers and the general public. For example, the unpleasant odour from Owode-Onirin and burning of e-waste product to retrieve valuable material from other study sites could affect the quality of air inhaled by those working in the scrap market and people residing around the site. Health conditions that could arise from these metals are respiratory, skin, eye, kidney, liver damages, prostate cancer as well abdominal and body aches. Environmental impacts occur mainly through acid leaching, resulting in water pollution leading to deaths of aquatic lives due to heavy metals washed down into streams and rivers around the dumpsites from e-waste recycling sites. Likewise, the burning of e-waste affects the environment and pollutes the atmosphere, and the heavy metals leached into the soil also harm plants and other vegetation.

This study has identified that e-waste resource picking can serve as a mean of livelihood for the urban poor if they are adequately integrated into the formal waste management sector, because presently, the informal sectors are the primary stakeholders involved in the management of e-waste in the city of Lagos. The study further observed that e-waste scavenging creates jobs for many unemployed youths due to the high unemployment rate in the city. It was noted from this study that there were no women in the e-waste scavenging sites which is because, in Africa, most men are taught to fend for their families and do not allow their wives to participate. Another apparent reason for unemployment is the growing urban population in Lagos. The urban population has, however, overwhelmed the city's basic amenities. The study has generally found that although many of the respondents practice the extended family system, over 90% of them were able to provide basic needs for their families and over 50% were able to save and investment from their incomes. It was further observed that many of the resource collectors are not allowed to sell the sorted scraps to the recycling companies but are cornered by the middlemen. These intermediaries dictate the prices of the material collected, and they earn more than the e-waste pickers who toil through the city.

The study has revealed that an effective take-back scheme will help the city collect, separate and recycle more e-waste. The plan is used in the extended producer responsibility programme and has been proven to be effective in many cities in some developed and developing countries. For the scheme to be useful in the city of Lagos, this study suggests that collection centres should be closer to the general public as this will motivate people to take e-products for recycling as well as to reduce the volumes of e-waste going to dump or landfill sites. More so, the take-back centres should be well structured into collection, sorting, reuse, recycling and final disposal sections. The health and safety of the workers should also be considered when building the facilities so that the hazardous substance from the waste does not affect them and the environment where they work.

From the above discussion, it can be seen that the research questions, aim and objectives of this study have been empirically explored, and the research objectives have been achieved. It can, therefore, be concluded that the responsibilities of the agency involved in the management of e-waste should be clearly defined so as not to clash with that of other agencies. More so, until the agency in charge properly enforces the policies and regulations, e-waste will continue to constitute a nuisance in the environment. Furthermore, except the agency in charge of e-waste create more awareness, educate and empower the informal sectors and the general public on the threat the waste poses, the aim of the take-back scheme and recycling programmes will be neglected.

### 6.3 Conclusions

From the research questions and findings of this study, the following conclusions have been reached.

(i) The city of Lagos is the highest receiver of e-waste in Nigeria and in West Africa and it houses the largest information communication technology (ICT) market (Ikeja computer village) in sub-Saharan Africa. This market accounts for the high influx of e-waste especially ICT equipment in the city of Lagos.

(ii) There are two agencies under the Lagos State Ministry of Environment that manage Solid waste (e-waste) and they are; LAWMA and LASEPA. LAWMA was formerly in charge of waste collection and disposal but it has recently assumed waste management regulatory role while LASEPA is in charge of drafting, implementing, monitoring and enforcing legislation, regulations and policies in Lagos State.

(iii) Solid waste management agency along with a private e-waste recycling company is in charge of collecting and disposing of unwanted and damaged e-products from government and private offices within the city of Lagos while the informal e-waste collectors are the highest stakeholders involved in the collection, sorting, recycling and disposal of e-waste from markets and households in Lagos.

(iv) Lagos State has a number of policies, regulations and legislation on solid waste management that can also be used in the management of e-waste. In addition, LASEPA has recently drafted e-waste policy because of the influx of e-waste into the state.

(v) Although there are laws and regulations on solid waste (e-waste) management in the city of Lagos, the enforcement and monitoring have been very low. The agency in charge needs to improve its strategies and ensure that legislation and policies are properly enforced such that it will not endanger the environment and lives of the e-waste collectors and the general public.

(vi) There were different institutional barriers hindering the management of solid waste by the agencies, these challenges include financial, infrastructural, technological, poor

enforcement and monitoring of regulations and policies, inadequate equipment, poor collections, lack of awareness and inadequate public education on e-waste, etc.

(vii) LAWMA has handed over the role of the solid waste collection, sorting, recycling and final disposal to a new initiative known as Clean Lagos Initiative. The initiative has plans to recruit over 1, 200 informal waste pickers and unemployed persons to help carry out its aims and objectives.

(viii) Most of the soils analysed during the dry and wet seasons were polluted with heavy/trace metals such as lead, zinc, iron and manganese. However, the wet season's heavy metals concentrations were higher than those collected in the dry seasons. The concentrations of these metals also exceeded the stipulated limits for LASEPA and WHO. The contamination factor also shows that the soils heavy metal pollution varies from sites to site. All the I-geo were less than one but the pollution load reveals that lead is the most abundant contaminant in the sites.

(ix) The Lagos State Waste Authority does not have a warehouse for the storage of collected e-waste but has converted one of it transfer loading station at Simpson to a temporary storage and sorting site. The warehouse should be built and sited away from residential areas.

(x) The government has lately created a new e-waste landfill site situated in Ogijo, along Ikorodu road. This site is managed by a private company, known as MSC.

(xi) The State Waste Management Agency does not have a recycling plant for e-waste recycling at the moment but it has partnered with a private organisation in order to establish it within the state and far from residential areas.

(xii) The informal e-waste collectors use crude and dangerous methods for dismantling e-waste. Many are involved in this job because of the high unemployment rate in the city of Lagos and the need to make a good livelihood. They are still socially marginalised because the majority of them are from the northern part of Nigeria and only a few of them are formally educated. They are also being cheated by the middlemen, meanwhile, they are the most active group in the collection and picking of e-waste.

(xiii) Many of the e-waste collectors and recyclers are at risk because they do not use any form of personal protective equipment and this poses serious health challenges to many of them since they use dangerous methods to retrieve valuable materials from e-products.

(xiv) Over 50% of the informal e-waste collectors were able to support their families and other relatives with the money they earn from waste picking, recycling and disposal. Some were able to save up financially and other acquire landed properties.

(xv) The integration of informal e-waste collectors into the formal sector will curb environmental and health hazards in the city of Lagos. This will bring about empowerment to the informal e-waste collectors, their livelihood will be improved and the sector will be able to compete with other economic sectors as the social discrimination would have been eradicated.

(xvi) E-waste take-back by electronic producers, retailers, dealers and the local government councils will reduce the volume of e-waste littered on the streets of Lagos and in landfills.

In summary, the challenges of e-waste management in the city of Lagos are not different from what is currently being experienced in other urban areas in most of sub-Saharan Africa and other developing countries. Therefore, there is need to create awareness and educate the general public and other stakeholders dealing in e-waste on how it should be handled, recycled and properly disposed of.

### 6.4 Recommendations

In view of the empirical findings, analysis and conclusions of this study, it is argued that e-waste management in the city of Lagos is still at it developing stage and there is need for effective planning, development of sustainable storage and recycling facilities, purchase of e-waste recycling plants and incineration systems for e-waste disposal and landfill sites such that will not be a threat to the environment and the lives of the residents around the sites. Hence, in order to effectively manage e-waste in a sustainable and environmentally sound manner in Lagos State and also to provide viable livelihoods for the urban informal resource collectors through integration into the formal sector, the research study, therefore, recommends the following:

(a) Since the city of Lagos is faced with institutional weaknesses in the management of e-waste, it is necessary for the agencies under the State Ministry of Environment to be familiar with their responsibilities such that none will interfere with the other. The implication of this is that the Clean Lagos Initiative involved in the waste collection will focus solely of collecting, recycling and disposing of waste, LAWMA the regulatory agency, also will focus on supervising and monitoring the initiative in charge of waste management while LASEPA will adopt, implement and enforce the necessary e-waste legislative and policies.

(b) In spite of all the e-waste regulations, policies and legislative frameworks in Lagos State and Nigeria as a country, the enforcement is still very poor. There is, therefore a definite need for the state legislative arm to review these regulations and policies such that e-waste management will align with the 5Rs, which is the major principle of NESREA.

(c) The infrastructural challenges which hinder the creation of warehouse for storage of e-waste collected and issues of landfill sites for disposal can be solved by building facilities in areas that will be accessible for collection trucks to dispose of e-waste but far from residential and conservation areas due to its health and environmental implications.

Although Lagos is geographically small and densely populated, there are still vacant lands that can be used to build these facilities.

(d) Financial challenges can be addressed if the State government increases solid waste management budget. Also, the agency in charge of waste collection should ensure that the general public pays for disposal weekly or monthly after collection.

(e) The coordinator assigned to each wards by the initiatives should pass information on the days for e-waste collection in various areas, also take-backs centres should be built closer to the neighbourhood. In addition, the community should be informed by its ward leaders on where and days to put e-waste outside for collection/disposal.

(f) The LASEPA should be encouraged to keep records of e-waste that enters the state through her seaports, airports and borders. This is because presently neither the states nor the country can give an account of the volume of e-waste that is imported into the state and this is a common phenomenon in many developing countries.

(g) The e-waste collectors should be encouraged to use personal protective equipment during collection, separation, recycling and disposal. This will reduce the health risks from heavy/trace metals.

(h) The major limitation of this study is that many of the heavy/trace metal concentrations during the wet season were higher than what was observed during the dry season and this was different from previous research results. It is therefore important for LASEPA and NESREA to keep monitoring the heavy metal concentrations in the soils of the state during the two seasons.

(i) The local councils along with the state government must provide legal frameworks for informal urban e-waste collectors.

(j) In addition, the stakeholders and the general public should be informed by LASEPA about e-waste regulations and policy, and the role they have to play to achieve the policy's aims and objectives.

(k) The state government should integrate the informal e-waste collectors into the formal sector so as to reduce the danger the informal sector poses to the environment and to the health of the public. They should be trained and educated on how to use new technology for e-waste management. This will also improve the livelihoods of the collectors because they will have a stable income and will be free from the middlemen.

(l) The waste agency along with the local councils in Lagos in consultation with all stakeholders must make them aware of the risk e-waste poses to their health and the environment as well as its disposal.

(m) The Ministry of Environment should partner with the State Ministry of Health such that they can create health awareness on the different diseases associated with e-waste hazardous components.

(n) The state government should assist in making sure that the cost of retrieved e-waste valuable materials is fixed across the state such that the middlemen will not be able to cheat the e-waste resource collectors.

(o) The Local government councils in Lagos state should be carried along in the management of e-waste and should also be involved in the regulations and policy drafts.

### 6.5 Recommendations for Further Research

E-waste management challenges in the city of Lagos is not different from what is observed in the rest of the urban areas in Nigeria. Although many previous studies have explored the challenges of general solid waste management in some urban, areas in Nigeria only a few have examined the challenges of e-waste. Furthermore, there are no studies on seasonal variations of heavy metal concentrations from e-waste recycling and dismantling centres in many of the urban areas. Due to some gaps that still exist in the management of e-waste in the city of Lagos, non-integration of the informal sector into the formal sectors and some of the limitations experienced in the course of this study, such as time constraints, distance and resources, there is a need for further research in the following areas.

1) Based on the limitations observed in the results obtained from physical, chemical and heavy/trace metals parameters, a future study should be conducted during the wet and dry seasons in the same study sites, to confirm if similar finding would be discovered.

2) Research focusing on how to generate e-waste data from the various facilities or recycling centres where the proposed take-back programmes will take place should be created, because it will enable the city of Lagos to account for the volumes of e-waste brought to the centres for recycling, repairs, separations and disposal to be recorded.

3) There is a need to research the various roles of the different agencies on e-waste since e-waste is a new phenomenon in the city of Lagos and there is a new initiative in charge of collecting, sorting, recycling, reusing and disposal of solid waste. It is necessary to know how the new initiative plans to manage e-waste in the city of Lagos and how it will be collected from households.

4) Further research needs to examine more closely the relationships between the informal and formal e-waste management sectors and how the two can be integrated since the informal sectors are the most significant stakeholders presently involved in e-waste collection, recycling and disposal from households.

5) There is a need to look at the role of women in urban e-waste picking or collection in Lagos State. This is necessary because in the course of this research women were only seen in the agencies while men were seen collecting and buying e-waste from the electronic markets, scrap yards and landfills. The research should, therefore, prioritise the role of women empowerment in e-waste collection, sorting and recycling services not just limiting them to cleaning or sweeping the major highways within the city since the scrap collection business is now a lucrative way of providing livelihoods and support for the family.

6) Further experimental investigations are needed to estimate the environmental and health implications of e-waste on other sites where e-waste are stored and dumped and the health of the workers and the residents within such areas in Lagos.

7) It would be interesting to assess the effects of e-waste physical, chemical and heavy metal parameters on agricultural vegetation and aquatic lives within the scrap and landfill sites.

8) E-waste management may still be a big problem in Lagos because the state government has not involved the local councils in its policy and plans. It is, therefore, necessary to look at how the local councils can be of tremendous help to the state waste agency regarding e-waste management. And finally,

9) A future study investigating the roles of electronic manufacturers such as Samsung, LG, Techno, Lenovo, Sharps and other dealers in the take-back programmes should be explored, and this would be interesting.

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## LIST OF PPENDICES

## APPENDIX 1: ETHICS CLEARANCE CERTIFICATE

Research Office

**HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)**
R14/49 Olayinka-Olagunju

| | |
|---|---|
| **CLEARANCE CERTIFICATE** | **PROTOCOL NUMBER: H16/08/26** |
| **PROJECT TITLE** | From electronic waste to sustainable livelihood for the urban poor in Nigeria: A study of Lagos |
| **INVESTIGATOR(S)** | Mrs J Olayinka-Olagunju |
| **SCHOOL/DEPARTMENT** | GAES/ |
| **DATE CONSIDERED** | 19 August 2016 |
| **DECISION OF THE COMMITTEE** | Approved unconditionally |
| **EXPIRY DATE** | 05 September 2019 |

**DATE** 06 September 2016 **CHAIRPERSON** (Professor J Knight)

cc: Supervisor : Professor D Simatele

**DECLARATION OF INVESTIGATOR(S)**

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10004, 10th Floor, Senate House, University.

I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to completion of a yearly progress report.**

_____ Signature

_____/_____/_____ Date

**PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES**

## APPENDIX 2: QUESTIONNAIRES FOR E-WASTE COLLECTORS

**SCHOOL OF GEOGRAPHY, ARCHAEOLOGY AND ENVIRONMENTAL STUDIES**

**FACULTY OF SCIENCE**
**UNIVERSITY OF THE WITWATERSRAND**

**RESEARCH TITLE:**

*"FROM ELECTRONIC WASTE TO SUSTAINABLE LIVELIHOOD FOR THE URBAN POOR IN NIGERIA: A STUDY OF LAGOS"*

This questionnaire aims at collecting empirical data in partial fulfilment of the requirement for a PhD degree in Geography and Environmental Studies. It seeks to investigate the study of sustainable livelihood for the poor in Lagos, Nigeria. Your responses are strictly confidential to the maximum extent allowed by the law. Your cooperation is highly appreciated.

**CONFIDENTIAL**

| | |
|---|---|
| Interviewer | |
| Respondent Name/no | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Visit | D | D | M | M | Y | Y | Time |
| Date | | | | | | | |

***Method of questionnaire completion. Mark the appropriate boxes with a tick (√)***

**I-IDENTIFICATION OF QUESTIONNAIRE**

1. **Region of Origin**

| **Geopolitical zone** | **State** | | **Response (√)** |
|---|---|---|---|
| **South-South** | | **1** | |
| **South-East** | | **2** | |
| **South-West** | | **3** | |
| **North-East** | | **4** | |
| **North-West** | | **5** | |
| **North Central** | | **6** | |

2. **Location**

| LGA | Location | | Response (√) |
|---|---|---|---|
| **Apapa** | **Westminster** | **1** | |
| **Ojo** | **Alaba International** | **2** | |
| **Ikeja** | **Olusosun landfill** | **3** | |
| | **Computer village** | **4** | |
| **Alimosho** | **Solous landfill** | **5** | |

## II- QUESTIONNAIRE DESTINED TO E-WASTE PICKERS

### DEMOGRAPHIC DATA

3) What is your gender?

| | | |
|---|---|---|
| Male | 1 | |
| Female | 2 | |

4) What is your age Group?

| 18-22 | 23-27 | 28-32 | 33-37 | 38-42 | 43-47 | 48-52 | 53-57 | 58+ |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

5) What is your matrimonial status?

| Single | Married Monogamy | Married Polygamy | Living together like married partners | Widow/Widower | Separated | Divorced |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |

6) What is your level of education?

| Never went to school | Primary | Secondary | Tertiary | Others specify…… |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

7) What is the size of the family?

| < 4 | 4-6 | 7-9 | 10+ |
|---|---|---|---|
| 1 | 2 | 3 | 4 |

8) What is your main source of income?

| Salary earner | Trader | Scavenger | Hawker | Retired | Unemployed | Others, specify……. |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |

10) How much is your monthly income?

| | | |
|---|---|---|
| ≤ N3000.00 | 1 | |
| N5,000.00 | 2 | |
| N7000.00 | 3 | |
| N10,000.00 | 4 | |
| N15,000.00 | 5 | |
| ≥ 20,0000.00 | 6 | |
| Others specify | | |

## III. QUESTIONS ON SUSTAINABLE SOLID WASTE MANAGEMENT

### a. GENERAL SOLID WASTE MANAGEMENT

11) Is waste picking your secondary job?

| Yes | No |
|---|---|
| 1 | 2 |

12) Who do you pick waste for?

| State Authority | Local Authority | Private contractor | Others, specify ---------- |
|---|---|---|---|
| 1 | 2 | 3 | 4 |

13) What type of waste do you collect? *(**You may tick more than 1**)*

| Plastics | Aluminium Cans | Glass | Paper | e-waste scrap | Yard/garden | Other specify ---------- |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |

14) Where do you collect/pick waste from? *(**You may tick more than 1**)*

| Household | Offices | Schools | Dump sites | Electronic | Others |
|---|---|---|---|---|---|

| | | | | repairer's shop | specify |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |

15) Are you aware of recycling?

| Yes | No |
|---|---|
| 1 | 2 |

16) If yes, how did learn about it?

| Seminar | Internet | Schools | Friend | Others, specify---------- |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

17) Is the collected waste sorted/ separated from the place you pick it?

| Yes | No |
|---|---|
| 1 | 2 |

18) If yes, how are they separated?

| | | |
|---|---|---|
| Colour-coded bags | 1 | |
| Colour-coded waste disposal bin/can | 2 | |
| Labelled bags | 3 | |
| Labelled waste bin/can | 4 | |
| Pictorial, colour-coded waste bin/can | 5 | |
| Pictorial, colour -coded bags | 6 | |
| Others, specify ---------- | 7 | |

19) What type of labelling, colour-coding (if any) is used for marking segregation? Describe

| Waste type | Colour | Response | |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

| | | | |
|---|---|---|---|
| | | | |
| | | | |

20) If no, do you further separate waste before disposing?

| Yes | No |
|---|---|
| 1 | 2 |

What do you do with the recyclable waste?

| | | |
|---|---|---|
| Sell to manufacturing company | | |
| Sell to recycling companies | | |
| Keep for personal use | | |
| Dispose along with other waste | | |
| Others, specify | | |

21) How do you dispose the non-recyclable waste?

| Burning | Burying | Open dump | Others specify |
|---|---|---|---|
| 1 | 2 | 3 | 4 |

**b. QUESTIONS ON E-WASTE**

22) Do you know what e-waste or waste of electrical and electronic equipment is?

| Yes | No |
|---|---|
| 1 | 2 |

If yes, answer the following questions.

23) How does e-waste/second hand electronics end up in Lagos?

| | | |
|---|---|---|
| Developed country through sea port (Europe, US) | 1 | |
| Second hand from developing Asia (China, Indian, Malaysia) | 2 | |
| Second hand from other African Countries | 3 | |
| Others, mention---------- | 4 | |

24) How long have you been involved in e-waste collection/recycling?

| 1-5 | 6-10 | 11-15 | 16-20 | 21+ | Others specify |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | |

25) From where and whom do you collect electronic waste?

| Household | Offices | Landfill/open dumps | Others specify |
|---|---|---|---|
| 1 | 2 | 3 | |

26) What type of equipment do you use for waste collection?

| | | |
|---|---|---|
| Truck | 1 | |
| Push cart | 2 | |
| Wheel barrow | 3 | |
| Sack | 4 | |
| Others, specify-------- | 5 | |

27) What type of e-waste do you collect?

| Unused repairable/ non-faulty electronics | Damaged/unrepairable electronics | Both |
|---|---|---|
| 1 | 2 | 3 |

28) What do you do with unused repairable/ non-faulty electronics?

| Sell to a second hand dealer | Give or sell to a scrap dealer | Store at home | Dispose with general waste | Throw on dump site | Others, specify ---------- |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | |

29) What do you do with unused non-repairable electronics?

| Throw them on the dump | Remove valuable substances | Dispose with general waste | Give or sell to a scrap dealer | Others specify |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

30) Which of the items below do you collect as waste?

| Large house-hold appliances (1) | Small house-hold appliances (2) | IT and telecommunications equipment (3) | Consumer equipment (4) | Lighting equipment (5) | Batteries (6) | Others Specify --------- |
|---|---|---|---|---|---|---|
| Fridges ( ) | Irons ( ) | PCs (central unit)( ) | TVs (CRT) ( ) | Light bulbs ( ) | Accumulators( ) | |
| Air conditioners ( ) | Kettles ( ) | CRT monitors ( ) | TVs (flat panel) ( ) | Fluorescent tubes( ) | Car batteries ( ) | |
| Washing machines ( ) | Blenders ( ) | LCD monitors ( ) | Radios ( ) | Long life light bulbs (energy saving)( ) | One-way batteries () | |
| Freezers ( ) | Microwaves( ) | Laptops ( ) | Stereos ( ) | Rechargeable lamps( ) | | |
| Clothes dryers( ) | Hair dryers ( ) | Mobile phones ( ) | DVD players( ) | | | |
| Electric heaters( ) | Mixers( ) | Phones( ) | VCR players (video-cassette recorder)( ) | | | |
| Dish washers( ) | Fans( ) | Printers( ) | MP3-players( ) | | | |
| Grillers( ) | Vacuum cleaners( ) | Copy machines ( ) | Cameras( ) | | | |
| Electric/ Gas stoves( ) | Carpet sweepers( ) | Scanners( ) | Game consoles( ) | | | |
| (Steam) | Toasters( | Fax machines( ) | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Ovens( ) | ) | | | | | |
| Electric hot plate( ) | Popcorn makers( ) | Modems( ) | | | | |
| | Rice cooker | | | | | |
| | Water dispenser( ) | | | | | |
| | Cables | | | | | |
| | Extension boxes () | | | | | |
| | Soldering iron( ) | | | | | |
| | Electric lawn-mowers( ) | | | | | |
| | (Alarm) Clocks( ) | | | | | |

31) Which metal(s) components or materials are most valuable to you?

| Gold | Silver | Copper | Barium | Others, specify |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

32) How do you remove the valuable material from e-waste?

| Breaking/ dismantling | Burning | Application of chemical | Others, specify |
|---|---|---|---|
| 1 | 2 | 3 | 4 |

33) Are you aware that some hazardous fractions in e-waste need a special treatment in order to be safely disposed of?

| Yes | No |
|---|---|
| 1 | 2 |

**IV-QUESTIONS RELATING TO ENVIRONMENTAL ISSUES AND HEALTH OF E- WASTE PICKERS/COLLECTORS**

34) Do you perceive any health hazards after dealing with e-waste?

| Yes | No |
|---|---|
| 1 | 2 |

35) Do you use protective equipment and tools during waste collection, recycling and disposal?

| Yes | No |
|---|---|
| 1 | 2 |

36) If yes, mention them.

| |
|---|
| |

37) Mention some health problems you feel after handling/burning e-waste

| | | |
|---|---|---|
| Chest pain | 1 | |
| Cholera | 2 | |
| Diarrhoea | 3 | |
| Skin/nose/eye irritation | 4 | |
| Fever | 5 | |
| Cancer related ailment | 6 | |
| Kidney disease | 7 | |
| Liver disease | 8 | |
| Others, specify---------- | 9 | |

38) Are you aware of any environmental condition in areas where e-waste is dumped or disposed/burnt?

| Yes | No |
|---|---|
| 1 | 2 |

39) How best do you think e-waste can be managed?

| Landfill | Incineration technology | Burning | Take-back policy | Others, specify |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

40) If yes, mark any of the following

| | | |
|---|---|---|
| Polluted water (dirty water) | 1 | |
| Air polluted (poor visual appearance) | 2 | |
| Soil pollution (flooding) | 3 | |
| Plant pollution | 4 | |
| Others, specify---------- | 5 | |

**V- QUESTIONS ON POLICY AND MANAGEMENT**

41) Is hazardous e-waste disposed of separately from other municipal wastes?

| Yes | No |
|---|---|
| 1 | 2 |

42) Are you satisfied with the current level of e-waste management services offered overall in the city of Lagos?

| Yes | No |
|---|---|
| 1 | 2 |

43) Do you think the government is also doing enough in the management of e-waste in Lagos State?

| Yes | No |
|---|---|
| 1 | 2 |

44) If no, how can e-waste management be improved upon in Lagos?

| |
|---|
| |

45) Have you heard about take-back policy in e-waste management?

| Yes | No |
|---|---|
| 1 | 2 |

46) If yes, how?

| Friend | Internet | Seminar | Others, specify |
|---|---|---|---|
| 1 | 2 | 3 | 4 |

47) Has the State adopted an official policy to reduce the generation of e-waste and improve its management?

| Yes | No |
|---|---|
| 1 | 2 |

48) Is there a coordinating body or agency responsible to oversee and support the implementation of official policies toward improving e-waste management?

| Yes | 1 | |
|---|---|---|
| No | 2 | |
| I do not know | 3 | |

49) If yes, what is the name of the coordinating body?

| FEMA | 1 | |
|---|---|---|
| LASEPA | 2 | |
| LAWMA | 3 | |
| NESRA | 4 | |
| Others, mention | 5 | |
| No idea | 6 | |

50) Is the policy on e-waste implemented?

| Yes | 1 | |
|---|---|---|
| No | 2 | |

| | | |
|---|---|---|
| I do not know | 3 | |

51) What areas do you consider most lacking in e-waste management?

| |
|---|
| |

52) Does the waste management authority has any of the following?

| | | |
|---|---|---|
| E-waste collection/recycling centre | | |
| Curbside Recycling Programme | | |
| E-waste collecting truck | | |
| E-waste personnel | | |

53) Does thewaste management authorityhave programmes to educate and raise public awareness about reducing, reusing and recycling e-waste?

| | | |
|---|---|---|
| Yes | 1 | |
| No | 2 | |

54) If yes, which strategies have been more effective in creating environmental awareness and responsibility?

| |
|---|
| |

55) Has the programme been successful?

| | | |
|---|---|---|
| Yes | 1 | |
| No | 2 | |

56) If yes, describe.

| |
|---|
| |

57) What are the barriers you encountered?

| |
|---|
| |

**VI-SUSTAINABLE LIVELIHOOD**

58) How often do you collect/pick waste?

| | | |
|---|---|---|
| Daily | 1 | |
| Twice a week | 2 | |
| Thrice a week | 3 | |
| Weekly | 4 | |
| Others, specify | 5 | |

59) What do you do with the recovered valuables from the e-waste?

| Sell to electricians | Sell to electronic company | Sell to scrap dealer | Others specify |
|---|---|---|---|
| 1 | 2 | 3 | 4 |

60) How much do you realise from the sale of e-waste valuables?

| ≤ N100.00 | N500.00 | N1000.00 | N1,500.00 | ≥ N2000.00 | Others specify |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |

61) Is the money you realise enough to sustain you and your family?

| Yes | No |
|---|---|
| 1 | 2 |

62**)** How do you think the government can help the informal e-waste recycling sector?

| |
|---|
| |

63) What are your concerns about e-waste management in Lagos State?

| | | | |
|---|---|---|---|
| | | | |
| | | | |

64) Do you have any investment?

| | | |
|---|---|---|
| Properties | | |
| Stocks | | |
| Financial portfolio | | |
| Others, specify | | |

65) Do you pay any tax for land/house?

| Yes | No |
|---|---|
| 1 | 2 |

66) If yes, how much do you pay monthly?

| |
|---|
| |

67) Do you have access to clean water?

| Yes | No |
|---|---|
| 1 | 2 |

68) Do you pay any tax/fees for water?

| Yes | No |
|---|---|
| 1 | 2 |

69) If yes, how much do you spend for water monthly?

| |
|---|
| |

70) Is your house connected to the electricity supply network?

| Yes | No |
|---|---|

| | |
|---|---|
| 1 | 2 |

71) Do you pay any tax/fee for electricity?

| Yes | No |
|---|---|
| 1 | 2 |

72) If yes, how much do you spend for electricity monthly?

| |
|---|
| |

73) Do you pay any tax/fee for waste?

| Yes | No |
|---|---|
| 1 | 2 |

74) If yes, how much do you spend for waste collection monthly?

| |
|---|
| |

75) In order to make good livelihood in your environment, do you think the government should involve private sectors in the management of e-waste?

| Yes | No |
|---|---|
| 1 | 2 |

76) If yes, how will this improve your livelihood status?

| |
|---|
| |

***Thank you for your cooperation and your sincerity!***

**APPENDIX 3**
**SCHOOL OF GEOGRAPHY, ARCHAEOLOGY AND ENVIRONMENTAL STUDIES**

**FACULTY OF SCIENCE**
**UNIVERSITY OF THE WITWATERSRAND**

**RESEARCH TITLE:**

*"FROM ELECTRONIC WASTE TO SUSTAINABLE LIVELIHOOD FOR THE URBAN POOR IN NIGERIA: A STUDY OF LAGOS"*

This questionnaire aims at collecting empirical data in partial fulfilment of the requirement for a PhD degree in Geography and Environmental Studies. It seeks to investigate the study of sustainable livelihood for the poor in Lagos, Nigeria. Your responses are strictly confidential to the maximum extent allowed by the law. Your cooperation is highly appreciated.

**QUESTIONNAIRE DESIGNED FOR STAFF OF E-WASTE BUSINESSES**

**CONFIDENTIAL**

| | |
|---|---|
| Interviewer | |
| Respondent Name/no | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Visit | D | D | M | M | Y | Y | Time |
| Date | | | | | | | |

**Part A**

**DEMOGRAPHIC DATA**

***Method of questionnaire completion. Mark the appropriate boxes with a tick (√)***

1) What is your gender?

| | | |
|---|---|---|
| Male | 1 | |
| Female | 2 | |

2) What is your age Group?

| 20-29 | 30-39 | 40-49 | 50-59 | 60 and above |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

3) What is your matrimonial status?

| Single | Married Monogamy | Married Polygamy | Living together like married partners | Widow/Widower | Separated | Divorced |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |

4) What is your level of education?

| Never went to school | Primary | Secondary | Tertiary | Others specify…… |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

5) What is the size of the family?

| < 4 | 4-6 | 7-9 | 10+ |
|---|---|---|---|
| 1 | 2 | 3 | 4 |

6) What is your main source of income?

| Repairer | Second-hand dealers | Scrap Buyer | importer | Others |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

**Part B- E-waste involvement**

7) How long have you been involved in Used electrical electronic equipment business?

| 1-4 years | 5-8 years | 9-12 years | 13-16 years | 17-20 years | 20 years and above |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |

8) Do you belong to any association? Yes (1) No (2)

9) What is the name of your association? (1) Computer and Allied Product Dealers Association of Nigeria (2) Electrical Dealers Association of Nigeria (3) Scrap Dealers Association of Nigeria (4) National Association of Scrap & Waste Dealers Employers of Nigeria

10) Do you have license to import second hand good? Yes (1) No (2)

11) If yes, which institution issues it?

| Institution | | | Response (√) |
|---|---|---|---|
| LAWMA | | 1 | |
| LASEPA | | 2 | |
| NESREA | | 3 | |
| FEPA | | 4 | |
| Others | | 5 | |

12) If no, why?

13) What type of UEEE do you deal with?

| Phone | Television | Refrigerator | Laptops | Freezer | Others, specify |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |

14) Are there illegal importers of second hand products in this business? Yes (1) No (2)

15) How can they be controlled?

16) Which country(ies) do you import your goods from?

| | |
|---|---|
| Germany | 1 |
| Japan | 2 |
| United Kingdom | 3 |

| | |
|---|---|
| Unites States of America | 4 |
| Belgium | |
| China | |
| Others, specify | |

17) Do you agree that e-waste is a valued economic asset in Nigeria? Yes (1) No (2)

18) If yes, how? (1) Valuable materials can be recovered, sold or stored (2) It can be refurbished (3) It last longer than new electronics (4) 1 & 2 (5) Creation of jobs.

19) Are you aware that e-waste consists of hazardous components? Yes (1) No (2)

20) How did you learn about this?

| Seminar | Internet | Schools | Friend | Others, specify---------- |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

21) How do you dispose of e-waste/ unwanted electronics?

| Give to condemn buyers | Truck pushers | Designated dump site | Burning | Store in a safe place for reuse |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

**Part C- Public awareness on e-waste**

22) Are you satisfied with way e-waste is managed in Lagos? Yes (1) No (2)

23) Are you aware that the hazardous components in e-waste can also affect the environment? Yes (1) No (2).

24) How best can it be managed?

| Incineration | Sell to the company | Designated dump site | Open burning | Store in a safe place for reuse |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

25) Which government institution creates awareness on e-waste management in the market?

| LAWMA | LASEPA | NESREA | Others (specify) |
|---|---|---|---|
| 1 | 2 | 3 | 4 |

26) How often do they come around for awareness seminar?

| Monthly | Quarterly | Twice in a year | Once a year | Others, specify---------- |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

**Part D- Regulations and challenges**

27) Are you aware of government regulations on e-waste in Nigeria? Yes (1) No (2)

28) How did you learn about it?

| Seminar | Internet | Schools | Friend | Others, specify---------- |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

29) 1 Yes (1) No (2)

30) If no, how can it be enforced?

31) What is the name of the institution that implements the policies guiding e-waste in the state?

32) Are there barriers hindering the enforcement of e-waste regulations? Yes (1) No (2)

33) What are the barriers responsible for the effective enforcement of e-waste policy? (1) Corruption by official (2) inadequate funding (3) Lack of awareness

34) Have you heard of the take back policy? Yes (1) No (2)

35) Where did you hear about it?

36) Have you heard about Extended Producer Responsibility? Yes (1) No (2)

37) Where did you hear about it?

**Part E- Informal Recycling**

38) How do you think poverty can be alleviated among the informal e-waste recyclers/collectors?

39) Are there strategies that can promote sustainable livelihood for the poor in the country? Yes (1) No (2)

40) Mention some of these strategies. ----------

41) How can the formal and informal sectors be linked? ----------

*Thank you for your time and assistance*

**APPENDIX 4**
**SCHOOL OF GEOGRAPHY, ARCHAEOLOGY AND ENVIRONMENTAL STUDIES**

**FACULTY OF SCIENCE**
**UNIVERSITY OF THE WITWATERSRAND**

**RESEARCH TITLE:**

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**QUESTIONNAIRE DESIGNED FOR STAFF OF WASTE INSTITUTION.**

**CONFIDENTIAL**

| | |
|---|---|
| Interviewer | |
| Respondent Name/no | |

| Visit | D | D | M | M | Y | Y | Time |
|---|---|---|---|---|---|---|---|
| Date | | | | | | | |

**Part A**

**DEMOGRAPHIC DATA**

***Method of questionnaire completion. Mark the appropriate boxes with a tick (√)***

1) Which institution do you work for?

| Institution | | | Response (√) |
|---|---|---|---|
| LAWMA | | 1 | |
| LASEPA | | 2 | |
| NESREA | | 3 | |
| FEPA | | 4 | |
| Others | | 5 | |

2) What is your gender?

| | | |
|---|---|---|
| Male | 1 | |
| Female | 2 | |

3) What is your age Group?

| 20-29 | 30-39 | 40-49 | 50-59 | 60 and above |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

4) What is your matrimonial status?

| Single | Married Monogamy | Married Polygamy | Living together like married partners | Widow/Widower | Separated | Divorced |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |

5) What is your level of education?

| Never went to school | Primary | Secondary | Tertiary | Others specify…… |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

6) What is the size of the family?

| < 4 | 4-6 | 7-9 | 10+ |
|---|---|---|---|
| 1 | 2 | 3 | 4 |

7) What is your main source of income?

| Salary earner | Trader | Scavenger | Waste contractor | Retired | Unemployed | Others, specify……. |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |

**Part B - E-waste Management Issues**

8) Does your department deal with solid waste management? Yes (1) No (2)

9) Is e-waste part of the solid waste managed by your department? Yes (1) No (2)

10) Do you think e-waste management is a major problem in Lagos, Nigeria? Yes (1) No (2)

11) Does your institution separate e-waste from other solid waste before disposal? Yes (1) No (2)

12) Are you aware that e-waste poses environmental threats? Yes (1) No

13) If yes, mention them? ..... ……

**Part C -E-waste Importation**

14) Can your institution account for the volume of e-waste that enters through Lagos sea port? Yes (1) No (2)

15) How is it accounted for? (1) monthly (2) quarterly (3) annually

16) Is there any institution that examines the movement of e-waste containers into Lagos? Yes (1) No (2)

17) Does your institution have the list of electronic equipment's importers? Yes (1) No (2)

18) How is the registration done? ----------

19) Do you think there are illegal importers of e-waste in the state? Yes (1) No (2)

20) How best can illegal e-waste importation be corrected? (1) Enforcement of e-waste policy (2) Strict punishment the offenders (3) Destruction of illegal products

21) Is there any punishment/disciplinary action against e-waste illegal importers? Yes (1) No (2)

22) If yes, mention (1) Fine (2) Prosecution

23) Please give the name(s) of country(ies) that export e-waste to Nigeria? (1) United States of America (2) United Kingdom (3) Germany (4) Japan (5) China

24) Does your institution partner with other countries in the curbing of illegal e-waste trade? Yes (1) No (2)

25) Mention some of the international organization. ----------

**Part D Policy and Challenges**

26) Has the state adopted any policy on the management of e-waste? Yes (1) No (2)

27) If yes, has it been implemented and effective? Yes (1) No (2)

28) Do we have sustainable government agencies that can enforce environmental legislation? Yes (1) No (2)

29) What is the name of the institution that implements the policies guiding e-waste in the state?

30) Are there barriers hindering the enforcement of e-waste policies? Yes (1) No (2)

31) What are the barriers responsible for the lack of effective enforcement of e-waste policy? (1) human resource (2) inadequate funding (1& 2)

32) Has the state adopted any strategy (ies) for e-waste policy enforcement? Yes (1) No (2)

33) If yes, mention it ……

34) If no, why? …….

35) Have you heard about extended producer responsibility? Yes (1) No (2)

36) Is this part of the adopted economic instrument? Yes (1) No (2)

37) Have you heard about take-bake policy? Yes (1) No (2)

38) Is this one of the adopted policy for e-waste? Yes (1) No (2)

**Part E- Collection and disposal facilities**

39) Has your institution approved the siting of any e-waste disposal facilities in the city? Yes (1) No (2)

40) If yes, where?.....

41) Who maintains the Dumpsites? .....

42) Are you satisfied with the maintenance of the e-waste disposal facilities?

43) If yes, why? ……

44) If no, why?.....

45) What e-waste treatment/disposal facilities are operated in the city?

| Type of disposal facility | Location(s) | Number Operated |
|---|---|---|
| | | |
| | | |

46) Have communities around the disposal facilities complained of any nuisances?

47) If yes, what are their complaints?.....

**Part F- E-waste recycling**

48) Do you think e-waste recycling in Lagos is done under a healthy condition? Yes (1) No (2)

49) If no, how best can e-waste be recycled and disposed?

50) Are you aware that the health of the people handling e-waste are at risk? Yes (1) No (2)

51) Do you think people handling e-waste are aware of its hazardous nature? Yes (1) No (2)

52) If yes, how have they been informed? Yes (1) No (2)

53) If no, how can awareness be raised? ----------

**Part G- The informal sector**

54) How do you think poverty can be alleviated among the informal e-waste recyclers/collectors?

55) Are there strategies that promote sustainable livelihood for the poor in the country? Yes (1) No (2)

56) If yes, mention some of these strategies. ----------

57) How can the formal and informal sectors be linked? ----------

58) Is your institution in partnership with the private sectors? Yes (1) No (2)

59) If yes, mention them. ----------

*Thank you for your time and assistance*

**APPENDIX 5**
**INTERVIEW WITH OFFICIAL OF SOLID WASTE INSTITUTIONS**

**SCHOOL OF GEOGRAPHY, ARCHAEOLOGY AND ENVIRONMENTAL STUDIES**

**FACULTY OF SCIENCE**
**UNIVERSITY OF THE WITWATERSRAND**

**RESEARCH TITLE:**

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**CONFIDENTIAL**

| | |
|---|---|
| Interviewer | |
| Respondent Name/no | |

| Visit | D | D | M | M | Y | Y | Time |
|---|---|---|---|---|---|---|---|
| Date | | | | | | | |

**DEMOGRAPHIC DATA**

1) What is your gender?

| | | |
|---|---|---|
| Male | 1 | |
| Female | 2 | |

2) What is your age Group?

| 20-29 | 30-39 | 40-49 | 50-59 | 60 and above |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

3) What is your matrimonial status?

| Single | Married Monogamy | Married Polygamy | Living together like married partners | Widow/Widower | Separated | Divorced |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |

4) What is your level of education?

| Never went to school | Primary | Secondary | Tertiary | Others specify…… |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

Part B. Government Organisation

5) What is the name of the institution you work for?

| | | |
|---|---|---|
| LAWMA | | |
| LASEPA | | |
| FEPA | | |
| FEMA | | |
| NESRA | | |
| Others, specify | | |

6) What year was the institution formed? ----------

7) What is/are the goal of your institution? ----------
---
---

8) Do you think e-waste is a persistent problem in Lagos, Nigeria? Yes (1) No (2)

9) If yes, how is it a problem? ----------

10) How does e-waste enter the city? ----------

11) Are you able to provide e-waste collection services in all areas of the city?

12) If no, why are you unable to do this?.....

13) What considerations influence your decisions to serve or not to serve an area?
.....

14) How do communities without e-waste collection service dispose of their waste? .....

15) What considerations influence the siting of e- waste disposal facilities? .....

16) Are all the waste disposal sites/facilities approved by the ministry of environment?

17) If no, how many are approved?.....

18) Who maintain(s) the waste disposal facilities? .....

19) Do you have any other comments or questions with regard to what we have discussed?.....

20) Do you have criminal intelligence that can exchange and analyse criminal networks on e-waste? Yes (1) No (2)

21) Are they well trained? Yes (1) No (2)

22) If no, how can intelligence unit on e-waste be developed and trained? ----------

23) How can environmental crimes be prevented? ----------

24) Do you work together with the electronic producers?

25) If yes, please describe your interactions.

26) Do you collect or takeback e-products for any electronic producers/companies?

27) If yes, mention some of the items ----------

28) What are the challenges you think are affecting e-waste management in Lagos?

29) How do you think these challenges can be curb?

30) Do you think you have created awareness to the entire public on e-waste management?

31) If not, what is (are) causing the delay (s)?

32) Do you think that the recently drafted e-waste policy enforcement has started?

33) If not, what is the problem ----------

APPENDIX 6**: Categories of Electrical Electronic Equipment**

| **Categories** | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|
| **Types of EEE** | **Large household appliances (white goods)** | **Small household appliances (white goods)** | **ICT and telecommunications equipment (Grey goods)** | **Entertainment and Consumer equipment (Brown Goods)** | **Lighting equipment** |
| **Description** | (a) Large cooling appliances<br>(b) refrigerator<br>(c) freezer<br>(d) other appliances used for refrigeration, conservation and food storage<br>(e) washing machines<br>(f) water heater<br>(g) clothes dryer<br>(h) dish washing machine<br>(i) electric cooking utensil<br>(j) Electric stoves<br>(k) Electric hot plates<br>(l) Microwave oven | (a) Vacuum cleaner<br>(b) Carpet sweeper<br>(c) Other appliances for cleaning<br>(d) Appliances for sewing, knitting, weaving and other processing for textile<br>(e) Iron and other appliances for ironing, mangling | (a) Central data processing<br>(b) Main-frames<br>(c) Mini-computer<br>(d) Personal computers<br>(e) Laptop computers<br>(f) Notebook computer<br>(g) Notepad computer<br>(h) Printers<br>(i) Copying equipment<br>(j) Electrical and electronic typewriters<br>(k) Pocket and desk calculators<br>(l) Other products | (a) Radio sets;<br>(b) Television sets;<br>(c) Video cameras;<br>(d) Video recorders;<br>(e) Hi-fi recorders;<br>(f) Audio amplifiers;<br>(g) Musical instruments and<br>(h) Other products or equipment for the purpose of recording or reproducing sound or images, including signal or other technologies for the distribution of sound and image other than by | (a) Luminaries for fluorescent lamps with the exception of luminaries in households;<br>(b) Straight fluorescent lamps;<br>(c) Compact fluorescent lamps;<br>(d) High intensity discharge lamps, including pressure sodium lamp and metal halide lamps;<br>(e) Low pressure sodium lamp; and |

| | | | | | |
|---|---|---|---|---|---|
| | (m) Other large appliances<br><br>(n) Electric heating appliances<br>(o) Electric radiators<br>(p) Other large appliances for heating rooms, bed, seating<br>(q) Electric fan<br>(r) Air conditioner<br>(s) Other fanning, exhaust ventilation and conditioning equipment | and other care of clothing<br>(f) Toaster<br>(g) Fryers<br>(h) Grinder, coffee machine and equipment for opening or sealing containers or packages<br>(i) Electric knives<br>(j) Appliances for hair cutting, hair drying, tooth brushing, shaving, massage and other body care | and equipment for the collection, storage, processing presentation or communication of information by electronic means;<br>(m) User terminals and systems;<br>(n) Facsimile;<br>(o) Telex;<br>(p) Telephone;<br>(q) Pay telephone<br>(r) Cordless telephone;<br>(s) Cellular telephone<br>(t) Answering systems<br>(u) Other products or equipment of transmitting sound, images or other in-formation communication | communications | (f) Other lighting equipment for the purpose of spreading or controlling light with the exception of filament bulbs. |

| | | | | | |
|---|---|---|---|---|---|
| | | appliances<br>(k) Clocks, watches and equipment for the purpose of measuring, indicating or registering of time | | | |

**APPENDIX 7:** Categories 6-10 of Electrical Electronic Equipment

| **Categories** | **6** | **7** | **8** | **9** | **10** |
|---|---|---|---|---|---|
| **Types of EEE** | **Electrical and electronic tools (with the exception of large-scale stationary tools)** | **Toys, leisure and sports equipment:** | **Medical devices (with the exception of all implanted and infected products):** | **Monitoring and control instruments** | **Automatic dispenser** |
| **Description** | (a) Drills;<br>(b) Saws;<br>(c) Sewing machine;<br>(d) Equipment for turning ,milling, sanding, grinding, sawing, cutting, shearing, drilling, making hole, punching, folding, bending or similar processing of wood, metal and other materials.<br>(e) Tools for riveting, nailing or screwing or removing rivets, nails, screw or similar uses;<br>(f) Tools for welding, soldering or | (a) Electric trains or car racing sets;<br>(b) Hand-held video game consoles;<br>(c) Video games<br>(d) Computers for biking, diving, running and rowing;<br>(e) Sport equipment with electric or electronic components; and<br>(f) Coin slot machines. | (a) Radiotherapy equipment;<br>(b) Cardiology equipment;<br>(c) Dialysis equipment;<br>(d) Pulmonary ventilators Nuclear medicine equipment;<br>(e) Laboratory equipment for in-vitro diagnosis;<br>(f) Analyser;<br>(g) Fertilization tests equipment; and<br>(h) Other appliances for detecting, preventing, monitoring, treating, | (a) Spoke detector;<br>(b) Heating regulators;<br>(c) Thermostats; and<br>(d) Measuring, weighing or adjusting appliances for household or laboratory equipment. Other monitoring and control instruments used in industrial installations (for example, in control panels) | (a) Automatic dispenser for hot drinks;<br>(b) Automatic dispenser for hot or cold bottles or cans;<br>(c) Automatic dispenser for solid products;<br>(d) Automatic dispenser for money; and<br>(e) All appliances which deliver automatically all kinds of products. |

| | | | | | |
|---|---|---|---|---|---|
| | similar use;<br>(g) Equipment for spraying, spreading, dispersing or other treatment of liquid or gaseous substances by other means; and<br>(h) Tools for mowing or other gardening activities | | alleviating illness, injury or disability | | |

**APPENDIX 8**

| Data requirements for determining e-waste inventory **Calculation method** | **Data Requirements** | **Author(s)** |
|---|---|---|
| Sales | Stock | Average lifetime |
| Time set | | (Streicher-Porte, 2006) |
| Market supply | | (Streicher-Porte et al., 2005; Jain and Sareen, 2006; Kumar and Shrihari, 2007 |
| Carnegie Mellon method | | (Matthews et al., 1997) |
| Approximation 1 | | (European Environment Agency [EEA], 2002) |
| Approximation 2 | | (UNEP, 2007) |

**Source**: From Ka-Yan-Lau et al., (2013)