AN EVALUATION OF ELECTRONIC WASTE MANAGEMENT PRACTICES IN THE ETHEKWINI METROPOLITAN AREA, KWAZULU-NATAL

Dissertation submitted

By

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DECLARATION OF INDEPENDENT WORK

I, Zanele Patricia Dlamini, student number _____, hereby declare that this research document submitted to the Central University of Technology, Free State, is my own independent work. I declare that it has not previously been submitted for assessment to any institution by myself or any other person in fulfilment of any requirement to attain any qualification. I declare that all the sources that I have used or quoted have been indicated and acknowledged by means of citations and complete references**.**

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STUDENT SIGNATURE **DATE**

ABSTRACT

Unprecedented advancements in lifestyle and modern technology have necessitated newer and better electronic and electrical appliances. These appliances and devices have penetrated every aspect of our lives; however, not much consideration has been given to what happens to these items once it has reached its end of use or have become obsolete. Therefore, as the world moves at an ever-increasing pace towards technological advancements, there is an urgent demand to deal with increasing volumes of waste from electrical and electronic equipment (WEEE) and digital devices. Fast-changing features and the increasing availability of improved products force consumers to dispose of such devices more rapidly than ever before. When such items are discarded, they become part of the e-waste stream.

This study investigated current practices in handling and disposing of e-waste and the extent to which such devices are recycled in the eThekwini Municipality area. Awareness of the need to properly dispose of such waste was assessed. To conduct this investigation, companies that provide e-waste collection services and those that recycle/discard this type of waste were identified and data were collected via self-administered questionnaires after permission had been granted to access respondents. South African e-waste policies and legislation and eThekwini Municipality by-laws on waste management were reviewed, while academic journals, books, and magazine articles were perused for secondary data collection. The data are discussed and illuminated by various tables and graphs in this dissertation.

The results indicated that 70.59% of the participating organisations had guidelines and procedures in place regarding the handling of electronic waste, but only 11.76% of these companies had a clear guideline that stated that a registered e-waste recycler should be responsible for the removal and recycling of e-waste. These recyclers should submit a disposal certificate to the client. It was found that outdated and unused equipment was used by 23.52% of the companies and that no procedural guidelines were in place to monitor disposal practices and volumes. It was found that e-waste was often stored for long periods without consideration of the possible risks this might

pose. Also, 5.88% of the respondents reported that electrical and electronic equipment that was no longer functional, was crushed and disposed of at general waste landfill sites. Only 41.18% of the companies had been authorised to dispose of their e-waste.

The study concludes that emerging technologies will continue to advance and create new streams of WEEE. Improved waste management strategies for this type of waste thus need to be adopted and implemented by all generators of such waste. There is also an urgent need to create awareness of the risks associated with e-waste as this will reduce mismanagement and the negative impact e-waste will have on the environment when inappropriately discarded. Education regarding e-waste disposal will also enable organisations to make informed decisions and formulate strategies to better manage such waste. A shift towards a circular economy and improved methods to manage e-waste such as the recycling of discarded e-waste to recover valuable resources is essential for the creation of a risk-free and sustainable environment.

Key words: *e-waste; electrical and electronic equipment; waste from electrical and electronic equipment, recycling*

LIST OF ACRONYMS

CRT	Cathode ray tube
EU	European Union
eWASA	e-Waste Association of South Africa
EEE	Electrical and Electronic Equipment
EPA	Environmental Protection Agency
EPR	Extended Producer Responsibility
ERA	E-waste Recycling Authority
ICT	Information and Communications Technology
KZN	KwaZulu-Natal Province
NEMA	National Environmental Management Act 107 of 1998
NEMWA	National Environmental Management Waste Act No. 59 of 2008
NWMS	National Waste Management Strategy
SDGs	Sustainable Development Goals
USA	United States of America
SA	Republic of South Africa
WEEE	Waste from Electrical and Electronic Equipment

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CHAPTER 1
BACKGROUND TO THE STUDY

1.1 INTRODUCTION

Electronic waste, commonly known as e-waste, is the term given to all electronic and electrical appliances that have reached end-of-life. Garlapati (2016) argues that e-waste as a term that includes various forms of electric and electronic apparatus that have ceased to be of any value to their owners. The EU WEEE directive defines it as “electrical or electronic equipment which is waste, including all components, sub-assemblies and consumables” or any items that have a battery or power cord (Perkins et al., 2014).

In South Africa, WEEE is defined as electrical and electronic equipment (EEE) waste. Such devices use electricity to perform their functions and such waste comprises those devices that were discarded by their owners. Lydall et al. (2017) state six e-waste categories are found in South Africa, namely:

- temperature exchange equipment
- screens and monitors
- lamps
- large equipment (e.g., dish washing machines, stoves, etc.)
- small equipment (e.g., microwaves, electric kettles, and toasters)
- information technology (IT) and telecommunications devices and equipment.

Each product of the six e-waste categories has a different lifetime profile, which means that each category, if handled or recycled inappropriately, has unique waste volumes, economic value, and potentially adverse environmental health impacts. éé et al. (2015) observed that collection and logistical processes and recycling technology differ for each category as consumers’ attitudes vary when disposing of electrical and electronic equipment.

As lifestyles and modern technology advance, the need for electronic and electrical appliances increases every day. Such equipment and devices have become pivotal to

every aspect of our lives, yet not much consideration has been given to their disposal once they have become obsolete or broken. As the world shifts inexorably towards ever-increasing technological advances, its capacity to deal with huge volumes of electrical and electronic equipment (WEEE), or e-waste, is declining (Orlins & Guan, 2016).

Chatterjee (2012) states that the accelerated advancement of digital features and the availability of improved technological products force their increasingly rapid disposal. Faster monetary growth, together with urbanisation and a growing interest in consumer goods, has also increased both the utilisation and manufacturing of electrical and electronic equipment (EEE). However, although their use is beneficial to humanity, they also have a negative impact on humans, animals and the environment as they contain metals that are toxic (Garlapati, 2016).

In 2016 the global volume of discarded e-waste was around 44.7 million metric tonnes (Mt), or 6.1 kg per inhabitant (Baldé et al., 2017). This volume increased in 2019 to approximately 53.6 Mt. The global quantity of e-waste is increasing at an alarming rate and it is estimated that the volume generated in 2030 will exceed 74 Mt. According to research conducted in 2017, the continents that generate the highest volumes of e-waste are Asia at 18.2 Mt and Europe at 12.3 Mt. The lowest volume of e-waste was generated on the African continent at 2.2 Mt. (Forti et al., 2020).

Most people are not aware of the potential negative impact of the rapidly increasing use of electrical and electronic products, particularly as many are disposed of on landfill sites or incinerated regardless of the hazardous materials they contain. Needhidasan et al. (2014) are adamant that improper handling and disposal of such waste have the potential to damage the environment. The improper disposal of electronic waste therefore causes grave concern, because many components in the products are toxic and not biodegradable.

Schluep (2010) argues that the main issues related to the improvement of current e-waste management practices on the African continent and elsewhere are synthesised in the *Durban Declaration on eWaste Management in Africa* guidelines that were presented during the WasteCon 2008 conference. It was agreed that every country

requires its own processes to define its specific roadmap, but the general recommendations that were proposed are the following:

- Improve cooperation among stakeholders;
- Establish an institutional framework;
- Create awareness at all levels of governance and the general public;
- Support markets;
- Collect and manage data;
- Develop a legal framework; and
- Develop a qualified and efficient e-waste recycling sector.

1.2 Problem Statement

Electronic waste is one of the most rapidly-growing pollution problems worldwide. The consistent advent of new designs, smart functions, and technology during the last 20 years has caused the rapid obsolescence of many electronic items (Kiddee et al., 2013). As e-waste is categorised as hazardous waste, the law does not allow its disposal at general waste landfill sites that are usually operated by municipalities. This waste requires special disposal practices, but these lead to increased disposal costs for the generators of such waste.

E-waste is both hazardous and valuable, and it poses grave risks if not handled in an environmentally sound manner. There are a few companies and individuals that recycle the precious materials found in such equipment, but the biggest challenge currently is to find a market for all the components derived from electronic waste. It is therefore important that this type of waste is managed and disposed of effectively, even after recyclable components have been recovered (Wong et al., 2007).

Gupta (2014) argues that, if recycling is done incorrectly, significant hazardous emissions are still generated. This poses severe risks to health and the environment. Health and safety risks associated with informal recycling include occupational health risks for waste pickers and health risks for affected communities and even the general public. These risks can originate from the nature of the waste and the processes of collecting, processing, recycling, and the disposal of such waste. Hazardous emissions

when such waste is incinerated or burnt are released into the atmosphere, and these can affect human health (Sitaramaiah et al., 2014).

E-waste is a global, interregional, and domestic problem. It is estimated that 75-80% of the 20-50 million tons of e-waste generated annually is shipped to countries in Asia and Africa for recycling and disposal (Perkins et al., 2014). Most African countries are now aware of and concerned about the dangers associated with poor management of e-waste. However, the legal and infrastructural framework to achieve sound management is still far from being realised by the majority of African countries. Although most African countries have ratified the Basel Convention that prevents illegal transboundary shipment of e-waste, most have not domesticated this agreement in the form of appropriate legislation for various waste streams (Baldé et al., 2017).

1.3 Aim and objectives of the study

The aim of the study was to assess the current status of handling and disposal of e-waste in the eThekwini Metropolitan area in KZN. The objectives of the study were to:

- Evaluate the extent of recycling of e-waste to establish the scope of its impact;
- Assess current practices regarding handling and disposal of e-waste and identify gaps that should be emphasised in relevant guidelines;
- Determine which pieces of the legislation, by-laws, and guidelines are currently implemented by the eThekwini Metropolitan Municipality; and
- Compile guidelines for e-waste disposal in the form of a brochure/leaflet for distribution by the Waste Management Education Section of the Cleansing and Solid Waste Unit of the eThekwini Municipality.

1.4 Delimitations of the Study

The research focus was on the eThekwini Metropolitan area and no other areas were included. Only the organisations which were willing to participate were included in the study, therefore the results of the study do not represent the whole area.

The researcher administered one questionnaire in each organisation. The participants who represented the organisations were persons responsible for waste or asset management.

There are not many recycling companies based in the study area and some departmental head offices that were responsible for the disposal of electronic as reported by other organisations were situated outside the study area. Some recycling companies were not willing to share information and be part of the research therefore it makes it difficult to quantify the exact volumes recycled.

1.5 STRUCTURE OF THE DISSERTATION

As this document is compiled in article format, some duplication will occur. For example, the methodology is addressed in Chapter 3 and in some subsequent chapters as well, and a review of related literature is also integral to each chapter. Results, conclusions, and recommendations are also addressed as required per article. The cited sources are referenced at the end of each chapter/article.

Chapter 1: General Background

Chapter 1 introduces the topic, defines electronic waste (e-waste), outlines the challenges associated with increasing waste generation, and highlights the fact that e-waste can lead to adverse health and environmental effects, particularly when such waste is inappropriately disposed of. The problem statement, the aim and objectives of the study, the delimitations that impacted the study, and the layout of the different chapters are also presented.

Chapter 2: Literature Review

Chapter 2 presents a review of the related literature. Electronic waste is defined in detail and its composition, volumes, and the health and environmental implications of e-waste are discussed. International, national and regional policies and legislation that are applicable to e-waste disposal are also discussed while current handling methods in various countries are illuminated.

Chapter 3: Research Methodology

This chapter provides a brief overview of the study area. The research methodology that was used is described with specific attention to the sampling methods and the data collection and analysis processes.

Chapter 4: Current E-waste Handling Methods (Discussion of 1st Questionnaire)

This chapter focuses on questionnaire results. It evaluates e-waste management in the eThekwini Municipal area and covers the types of electric and electronic waste mostly used and disposed of, the hazardous components of e-waste, the volumes generated by different consumers, and the procedures and guidelines used by different organisations who handle and dispose of e-waste.

Chapter 5: E-waste Recycling Practices in the eThekwini Metropolitan Area (Discussion of 2nd Questionnaire)

This chapter focuses on the findings elicited by Questionnaire 2 for a discussion of the results. It assesses recycling activities currently employed for electrical and electronic equipment waste disposal. The types of services offered by different recycling companies, the volumes that are recycled, as well as the types of equipment being recycled are discussed.

Chapter 6: Conclusions and Recommendations

This chapter reports on the findings of the study. Conclusions are drawn and recommendations for effective electrical equipment and electronic waste disposal in the study area are offered.

1.6 Conclusion

E-waste is an environmental problem that is experienced globally. The fast-paced renewal of electrical and digital equipment and devices causes the rapid obsolescence of many such items. This study assessed current e-waste management practices in the eThekwini Metropolitan area and offers recommendations to improve this system where it poses a threat to human health and the environment.

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CHAPTER 2
E-WASTE MANAGEMENT AND IT'S IMPACT ON THE ENVIRONMENT

2.1 What Is Electronic Waste or e-waste?

Electronic devices and electrical equipment (EEE) are designed to function for a limited period of time after which they cease to function (they reach their end of life) or they become obsolete (i.e., they function sub-optimally). When such equipment and devices are no longer functional, they are discarded by the owner and become waste (WEEE or e-waste). The terms electronic and e-waste refer to all items of electrical and electronic equipment (EEE) and their parts that are discarded by owners as waste without the intention of re-use (Step Initiative, 2014).

E-waste is also referred to as WEEE (waste from electrical and electronic equipment), electronic waste, or e-scrap in different regions and under different circumstances around the world. Such waste includes a wide range of products such as any household or business items containing a circuit or electrical components with power or battery supply (Baldé et al., 2017). Various organisations that are responsible for the management of e-waste have different definitions for e-waste as shown in Table 2.1.

Table 2.1: E-waste definitions

Reference	Term Definition
European Directive 2002/96/EC Directive 75/442/EEC, Article I(a)	Such waste comprises "…electrical and electronic equipment, including all components, sub-assemblies, and consumables which are part of the product at the time of discarding". Directive 75/442/EEC, Article I(a), defines such waste as "…any substance or object which the holder discards or is required to discard in compliance with national legislative provisions."
Basel Action Network (www.ban.org)	"E-waste includes a wide and developing range of electronic appliances ranging from large household

	appliances such as refrigerators, air-conditioners, cell phones, stereo systems, and consumable electronic items to computers discarded by their users".
Organisation for Economic Co-operation and Development (OECD) (www.oecd.org)	"Any household appliance consuming electricity and reaching its life cycle end".

Source: Gaidajis et al., 2010: 193

Electronic waste which, includes household appliances, consists of various substances that can pose a hazard to the user. An example of a hazardous chemical that is found in most electronic waste is lead (Needhidasan et al., 2014).

2.1.1 Composition of electronic waste

About 60 chemical elements, many of which are hazardous, are found in various electronic and electrical devices. These chemicals include lead, cadmium, chromium, mercury, copper, manganese, nickel, arsenic, zinc, iron, and aluminium (Grant et al., 2013). These metals are used in circuit boards, semi-conductor chips, cathode ray tubes, coatings, and batteries. Many other potentially hazardous materials are also used in manufacturing processes such as organic compounds that are used as fire retardants. These are most notably found in product fluids, lubricants, and coolants (Heacock et al., 2015). Several such hazardous products are also used in electronic devices such as cellular phones and computers, and when they are inappropriately discarded these chemicals and metals pose a threat to humans and the environment through contamination of air and water.

2.1.2 Sources of e-waste

E-waste occurs when electrical hardware and electronic items are disposed from government offices, the public and private sectors, and academic and research institutions. Household consumers also contribute to the generation of a significant

volume of electronic and electrical waste (Chatterjee, 2012). Needhidasan et al. (2014) identify three categories of WEEE that account for almost 90% of such waste:

- Large household appliances (42%);
- Information and communications technology equipment (33.9%); and
- Consumer electronics (13.7%).

A WEEE directive specifies ten different categories of waste from electrical and electronic equipment in Table 2.2.

Table 2.2: Electronic waste categories and their labels

No.	Category	Label
1.	Large household appliances	Large HH
2.	Small household appliances	Small HH
3.	IT and telecommunications equipment	ICT
4.	Consumer equipment	CE
5.	Lighting equipment	Lighting
6.	Electrical and electronic tools	E & E Tools
7.	Toys, leisure, and sports equipment	Toys
8.	Medical devices (with the exception of all implanted and infected products)	Medical equipment
9.	Monitoring and control instruments	M & C
10.	Automatic dispensers	Dispensers

Source: Widmer et al., 2005

2.1.3 E-waste: A growing global problem

E-waste is a growing problem globally and has infiltrated every aspect of our daily lives. Most people do not consider what happens to these items or gadgets when they discard them or when they upgrade to new technology. This type of waste has become a problem due to the volumes being generated and the fact that such items contain both toxic and valuable materials (Needhidasan et al., 2014). Wath et al. (2010) mention that the major problem with e-waste management it is its increasing volume.

It is thus vital to find environmentally sustainable disposal strategies when such waste is disposed of.

The following sections will review the challenges posed by e-waste, the rate of its generation, regulations and relevant policies, the illegal exportation of e-waste, and its impact on health and the environment.

2.2 Health and Environmental Impact of E-Waste

Various metals and chemicals are used in the manufacturing of electrical equipment and digital devices. These chemicals, that often occur in minor quantities in individual gadgets, are there for various purposes. For instance, they provide mechanical support and strength, enhance electrical and thermal conductivity, and resist flames and weathering conditions, to mention a few. These components pose minimal adverse effects on human health when the EEE is intact. However, upon exposure to the environment through recycling activities (such as dismantling, size reduction, and burning or heating) certain chemical emissions are released into the environment (Ahiwar & Tripathi, 2021). E-waste contains some substances that can be hazardous, and these toxins can have a harmful effect on human health and the environment.

Neira et al. (2013) observed adverse effects which include: fatal loss, prematurity, low birthweight, and congenital malformations; abnormal thyroid function and thyroid development, neuro- behavioural disturbances, and genotoxicity. A large number of components in electrical devices contain lead, cadmium, mercury, polyvinyl chloride (PVC), brominated flame retardants (BFRs), chromium, beryllium, and other chemicals. Long-term exposure to these substances can damage humans' nervous system, kidneys, bones, and the reproductive and endocrine systems while some of these chemicals are carcinogenic (Needhidasan et al., 2014).

2.2.1 Impact of e-waste on human health

Hazardous elements contained in e-waste can, when released, enter the human body in three different ways: through the respiratory tract, the skin, or through the mucus of the mouth and the digestive tract. Health afflictions such as brain disorders, kidney, renal and neurological damage, hearing impairment, lung disease, and fragile bones

are illness that have been observed among people in Bangladesh (Mohammad, 2016). The various elements found in e-waste cause different diseases; for example, nickel causes skin damage and asthma, while barium causes muscle weakness and changes in the heartbeat rate (Primula, Fulekhas, & Bhawana, 2012).

The presence of various hazardous substances embedded in e-waste such as lead, cadmium, mercury, polychlorinated biphenyls (PCBs), and secondary e-waste toxins that are produced during the processing and recycling of e-waste have been found in well-known e-waste dumps such as Guiyu in China, Agbogbloshie in Ghana, the National Capital Territory (NCT) region in India, Shershah (Karachi) in Pakistan, Lagos in Nigeria, and Dhaka in Bangladesh (RajyaSabha, 2011; Sthiannopkao & Wong, 2013). A list of health effects in humans caused by exposure to hazardous chemicals found in various e-waste items has been reported in many studies. A summary of these effects is presented in Table 2.3.

Table 2.3: Chemicals in e-waste and their effects on humans

Chemical	Main Source	Effects on environment and human health
Lead (Pb)	Glass of cathode ray tubes (CRT) in television sets/computer monitors; acid batteries; Polyvinyl chloride (PVC) cables.	• Lead accumulates in bodies of water and soil leading to poisoning. • Can enter the human body through food such as fruit, vegetables, meat, grain, and seafood. • Lead can cause health effects such as disrupting the biosynthesis of haemoglobin and anaemia; kidney damage; miscarriage; increase in blood pressure; disruption of the nervous system; brain damage; and declined male fertility.
Beryllium	Connectors, mother boards, and finger clips	• When inhaled, beryllium compounds can lead to an irreversible and sometimes fatal scarring of the lungs causing berylliosis or chronic beryllium disease (CBD). • Can affect other organs such as the lymph nodes, skin, spleen, liver, kidneys, and heart.

Polychlorinated biphenyls (PCBs)	Electrical transformers; capacitors of TV sets; monitors and radio PVC.	• Chloracne and related dermal lesions have been reported in workers exposed to PCB's. • Other side-effects are pigmentation disturbances of skin and nails, erythema, thickening of the skin, and a burning sensation. • Reproductive function may be disrupted by exposure to PCBs. Neuro behavioural and development deficits have been reported in new-born babies exposed to PCBs.
Mercury (Hg)	Batteries; flat screen TV sets; switches; relays; computer housing.	• When products containing mercury are not properly disposed, mercury is released into the air, ground or water. This chemical is very persistent in the environment, and it never breaks down. Exposure to mercury can affect thinking, memory, attention, language, fine motor skills, and visual-spatial ability.
Barium	CRT and vacuum tubes	• Health risks for people working with e-waste include paralyses and, in some cases death.
Chromium	Steel housing of CPU; chrome plating in metal ceramics.	• The uptake of too much chromium can cause health effects such as skin rashes, upset stomach, ulcers, respiratory problems, a weakened immune system, kidney and liver damage, alteration of genetic material, lung cancer, and even death.
Cadmium (Cd)	Switches; solder joints; housing coatings; cathode ray tubes; rechargeable batteries.	• High exposure to cadmium can occur when people live close to e-waste sites. When cadmium is released into the environment and people breathe it, they can suffer from severe lung damage and this can lead to death. • Cadmium accumulates in kidneys and causes damage to filtering mechanisms in the liver. • Other health problems are diarrhoea, stomach pains, severe vomiting, damage to the nervous system, and damage to the immune system.

Nonylphenol (NP)	Insulators; housing and casings.	• The toxicity of NP is low in humans; however, it is highly irritating and corrosive to the skin and eyes. • In terms of the environment nonylphenol is highly toxic to fish, aquatic invertebrates, and aquatic plants.

Source: Huang, Nkrumah, Anim, & Mensah, 2014

2.2.2 Impact of mismanaged waste on the environment

The toxic substances are present in electrical and electronic equipment (EEE), for instance heavy metals, brominated flame retardants, and polychlorinated biphenyls. Materials produced during informal recycling activities such as polycyclic aromatic hydrocarbons, polychlorinated dibenzo-p-dioxins, and polychlorinated dibenzofurans also contain toxins. Chemicals used for extracting metals, for example acids like HCl, H_2SO_4, HNO_3, $HClO_4$, and NaClO, are often emitted in the environment as primary, secondary, and tertiary emissions leading to an increase in the levels of toxic pollutants in the ecosystem (Kumar et al., 2019; Orlins & Guan, 2016; Quan et al., 2015).

Environmental contamination occurs when improper recycling and disposal processes are used and particularly when e-waste is illegally disposed of. Illegal disposal activities can lead to both direct and indirect exposure through the soil, air, dust, and water around e-waste recycling sites. According to Lundgren (2012), toxic substances are released when the following emissions occur:

- Leaching from dumping activities;
- Particle matter from dismantling activities;
- Ash from burning activities;
- Fumes from mercury amalgamate, de-soldering, and other burning activities;
- Waste water from dismantling and shredding facilities.

When e-waste is not managed or disposed of properly, the environment is impacted negatively, and this affects people's health. The health and safety of workers at informal recycling sites, those that dismantle electrical equipment, and communities living near dumping and landfill sites are most commonly compromised by e-waste. It

is important the laws regulating e-waste handling be updated, implemented, and enforced on a global scale to safeguard people's health and prevent environmental degradation.

2.3 Policies and Legislation Regarding E-Waste Management

In the past, e-waste regulations mainly focused on environmental protection, but recently e-waste guidelines have been adopted and enforced due to human health concerns (Grant et al., 2013). International Labour Organisation (ILO) (2019) reported that, in 2017, sixty-seven countries (66% of the world population) had legislation in place regarding various aspects of e-waste management. These laws focused primarily on protecting the environment and did not consider e-waste as a resource.
As of October 2019, 71% of the world's population has been regulated by e-waste legislations. Globally, 78 countries currently have policies, legislation, or regulations in place that govern e-waste, which is an increase of 5% from 2017 (Forti, 2020). However, the challenge is that such policies are not legally binding in many countries. Across African and Asia there are only 19 countries that have legally binding legislation on e-waste, five countries have an e-waste policy that in non-legally binding, and 31 countries have policies that are still being developed (Groupe Speciale Mobile Association (GSMA), 2020). Even where legally binding policies were passed as legislation, enforcement is still a key issue.

2.3.1 The Basel Convention

The Basel Convention is an international environmental policy that aims to control trans-boundary movements of hazardous waste and their disposal. Needhidasan et al. (2014) state that this convention was adopted to reduce the movements of hazardous waste among countries and to prevent dumping of hazardous waste by developed countries in less developed countries. This law has banned the export of hazardous waste to poorer countries since 1992, but the practice continues unabated.

The main objectives of the Basel Convention are to:

- Minimize the generation of hazardous waste;

- Guide the effective disposal of hazardous waste within the country of generation in an environmentally sound manner;
- Establish enhanced controls on exports and imports of hazardous waste; and
- Prohibit the entry of shipments of hazardous waste into countries that lack the legal and technical capacity to dispose of it in an effective manner.

2.3.2 E-waste management in Africa

The problem associated with WEEE management in Africa came to public awareness in the early 2000s. The term e-waste is often used instead of WEEE on the African continent. Schluep (2012) mentions that e-waste was mostly unknown and often misunderstood as virtual waste produced on the Internet, rather than as a physical waste stream. This perception changed in 2005 when the Basel Action Network documented the illegal export of e-waste to Nigeria and raised awareness of the risks of the subsequent informal recycling and dumping of such waste (Puckett et al., 2002).

2.3.2.1 Bamako Convention

The Bamako Convention, which came into effect in 1998, is a treaty signed by African nations that prohibits the import of any hazardous waste, including radioactive waste. Sadly, although African governments are becoming aware of risks associated with e-waste, many have not implemented the Basel and Bamako conventions into their national legal frameworks. Fortunately, the 2006 Nairobi Declaration on E-waste marked an important milestone, and this was followed by the 2008 Durban Declaration on E-waste Management in Africa. The latter states that every country should devise its own processes in response to the growing e-waste problem (Schluep, 2012).

However, e-waste legislation to manage such waste is still lacking in most African countries. Only a few countries, namely Egypt, Ghana, Madagascar, Nigeria, Rwanda, South Africa, Cameron, and Cote D'Ivoire have promulgated e-waste legislation, whereas East African countries, namely Tanzania, Rwanda, Uganda, Burundi, Kenya, and South Sudan, have adopted a regional e-waste strategy to achieve sustainable e-waste management (East African Communications Organisation, 2017).

2.3.2.2 The Durban Declaration on E-waste Management in Africa of 2008

The problems related to the improvement of e-waste management practices experienced in the African continent were synthesised in the *Durban Declaration on e-Waste Management in Africa* during the WasteCon conference in 2008 (Lundgren, 2012). It was agreed that every country should devise its own processes and actions in response to the e-waste problem. This Declaration also calls for the establishment of an African regional platform and/or an e-waste forum in cooperation with established African networks and international bodies. It urges countries to review existing legislation, improve compliance with existing legislation, and amend existing waste management legislation to allow for the proper regulation of such waste (Duan, Miller, Gregory & Kirchain, 2013).

2.3.3 National e-waste management regulations for various countries

E-waste protocols regarding the management of WEEE have been established by various countries in order to regulate e-waste management practices and to ensure that this waste stream is correctly handled and disposed of. A summary of the e-waste legislation and policies of countries some countries is presented in Table: 2.4. The following countries were reviewed:

- Developed countries: USA, European Union, Japan, and Switzerland.
- Developing countries: China, India, Nigeria, Ghana, and South Africa

Table 2.4: Review of E-waste laws and regulations in developed and developing countries

Laws and Regulations	Major Content	Effective Date
European Union (EU) • Waste from Electrical and Electronic Equipment (WEEE): Directive (2002/96/EC)	Guidelines for producers and consumers to understand their duty to handle e-waste in an environmentally sound manner. It makes it incumbent on manufacturers and distributors in EU member states to take back their products from consumers and recycle them. Directive categories WEEE in to 10 categories.	Effective from August 2004

• Restrictions on the use of certain hazardous substances in electrical and electronic equipment Regulation (RoHS) (2002/95/EC)	Revised WEEE Directive 2012/19/EU Complements the scope of the WEEE directive. Also covers electric light bulbs and luminaries in households. It restricts the use of certain hazardous substances like lead, mercury, cadmium, chromium, polybrominated biphenyls and polybrominated biphenyl ethers in WEEE and promotes the use of alternative substances. Revised RoHS Directive 2011/65/EU (Shittu et al., 2021)	Effective from 14 February 2014 Effective from July 2006 Effective from 3 January 2013.
United States of America (USA) • National Strategy for electronics Stewardship (NSES	The Federal Government Interagency Task Force on Electronics Stewardship (ITFES) issued a National Strategy for electronics Stewardship (NSES). However, the US is a signatory of the Basel Convention on the Control of Transboundary Movement of Wastes and their disposal, but it has not ratified this Convention. Also, there is no federal legislation in place prohibiting or regulating e-waste generation, disposal, and export. Since 2003, many states in the USA have made the effort to collect and recycle e-waste from residential and commercial consumers in an environmentally friendly manner. Fifteen states have introduced producer responsibility bills in this regard (Andeobu et al., 2021).	Introduced in 2011 and updated in 2014
Switzerland • Ordinance for the Return, the Taking Back, and the Disposal of Electrical	It covers the collection, transportation, recycling/treatment, and disposal of e-waste (Chaudhary & Vrat, 2017).	Introduced in July 1998

and Electronic Appliances (ORDEA)		
Japan • Small Home Appliances Recycling Law	This law addresses the recycling of specified kinds of home appliances (Amemiya, 2018). E-waste laws in Japan require manufacturers and importers to take back electronics for recycling and waste management. It also ensures the separation of the e-waste stream from the municipal solid waste stream (Wath et al., 2010).	2013
• The Computer Recycling Law	Recycling operations are financed by fees collected from customers. A comprehensive e-waste take-back law covering all WEEE categories does not exist, although the law promoting their recycling and design for the environment does exist (Honda, 2016).	Implemented in 2003
Republic of China • Management Measure for the Prevention of Pollution from Electrical and Electronic Products' Recycling and Disposal.	Restrictions on the use of hazardous substance (RoHS); green product design; provision of information on the components, hazardous substances, and recycling.	Issued early 2006; enforced since March 1, 2007
• Regulation for the management of the recycling and disposal of waste electrical and electronic products (China WEEE).	Complements China's RoHS of 2006 and establishes the regulatory regime for the recovery, recycling, and disposal of electrical products. Covered products are listed in a catalogue. The disposal of discarded electronic and electrical products is formulated and adjusted from time to time under the leadership of the Ministry of Environmental Protection and Ministry of Industry and Information Technology (Wong, 2018)	Official document released on 4 March 2009. Entered into force on January 1, 2011.

India • E-waste (Management and Handling) Rules, 2011 • E-waste (Management) Rules, 2016	To enable the recovery and reuse of waste from electrical and electronic equipment; to reduce hazardous wastes destined for disposal; and to ensure the environmentally sound management of all types of electrical and electronic equipment waste. The rules aim to enable the recovery and/or reuse of useful material from e-waste, thereby reducing the hazardous wastes destined for disposal and ensuring the environmentally sound management of all types of waste from electrical and electronic equipment. 2018 Amendment (Chaudhary & Vrat, 2017)	Effective from 1 May 2012 1 October 2016
Nigeria • National Environmental Electrical/Electronic Sector Regulation	Requires importers of used electrical and electronic equipment to register with the National Environmental Standards and Regulations Enforcement Agency (NESREA) before commencing with importation (UNEP, 2019).	Effective from 2010
Ghana • Technical Guidelines on Environmentally Sound E-waste Management. • Hazardous and Electronic Waste control Management Bill	First country in Africa to officially launch guidelines for environmentally sound e-waste management. The two legal frameworks set the background for a new and innovative strategy towards sustainable management of e-waste in the country (Campen & Enders, 2016).	February 2018: official launch. August 2016
South Africa • The Constitution of the Republic of South Africa Act No. 108 of 1996	The South African Constitution is the most important legislative document and it acknowledges every citizen's basic human rights.	1996

	Section 24 of this Act states that everyone has the right to an environment that is not harmful to their health or well-being. It states that the environment must be protected for the benefit of present and future generations through reasonable legislative and other measures that should prevent pollution and ecological degradation, promote conservation, and secure ecological and sustainable development.	
• Hazardous Substances: Act 5 of 1973	To provide for the control of substances which may cause injury or ill-health to or death of human beings by reason of their toxic, corrosive, irritant, strongly sensitizing or flammable nature and for the control of certain electronic products and control of the importation, manufacture, sale, use, operation, application, modification, disposal or dumping of such substances and products.	Promulgated in 1973
• Environmental Conservation: Act 73 of 1989	To provide for the effective protection and controlled utilization of the environment and for matters incidental thereto.	Assented in 1989
• Occupational Health and Safety: Act No. 85 of 1993	To provide for the health and safety of persons at work and for the health and safety of persons in connection with the use of plant and machinery; the protection of persons other than persons at work against hazards to health and safety arising out of or in connection with the activities of persons at work.	Effective from 1993
• National Environmental Management: Waste Act No. 59 of 2008	The Act regulates waste management in order to protect health and the environment by providing reasonable measures for the prevention of pollution and ecological degradation. The Act	Enforced in 2009 and amended 2 June 2014

	provides for national norms and standards for regulating the management of waste by all spheres of government.	

Although fewer than half of all the countries in the world are currently implementing a policy/legislation to regulate e-waste, there has been some improvement in the number of countries that have implemented such legislation since 2014. In 2014, 61 countries had sets of legislation on the management of e-waste, and in 2017 the number of countries with such legislation increased to 67. In 2019, the number of countries with policies to regulate e-waste management was 78 (Forti et al., 2020). However, even in some countries where legally binding policies are enacted, enforcement is a key issue. Having the best policy or regulatory framework in the world means nothing unless it is setting reachable targets and is effectively enforced.

2.4 Volumes of Electrical and Electronic Waste

The handling methods of e-waste and the volumes that are generated are currently a major concern worldwide. Shah and Batool (2015) state that the issue was first noticed in developed nations, but it has expanded to all nations across the world. The volumes of e-waste that are generated are escalating due to consumer innovation and rapid developments in this technology which means that appliances become quickly outdated. More than necessary electronic and electrical devices are thus manufactured and sold to gadget-hungry consumers.

In 2016 the global volume of e-waste was about 44.7 million metric tons (Mt), or 6.1 kg per inhabitant (Baldé *et al.,* 2017). This volume increased to about 53.9 million metric tons (Mt) in 2019, or 7.3 kg per capita (Forti et al., 2020). Globally, the e-waste that was generated in 2019 was mainly comprised of small equipment (17.4 Mt), large equipment (13.1 Mt), temperature exchange equipment (10.8 Mt), screens and monitors (6.7 Mt), lamps (0.9 Mt), while information technology and telecommunication equipment (4.7 Mt) represented a small share of e-waste generated in this year.

Table 2.5: E-waste generation and collection per continent (2019 statistics)

Indicator	Africa	America	Asia	Europe	Oceania
Countries in region	53	35	49	40	13
E-waste generated	2.9 Mt	13.1 Mt	24.9 Mt	12 Mt	0.7 Mt
Per capita	2.5 kg	13.3 kg	5.6 kg	16.2 kg	16.1 kg
E-waste collected for recycling	0.03 Mt	1.2 Mt	2.9 Mt	5.1 Mt	1.06 t

Source: Forti et al., 2020

2.4.1 Developed countries

Developed countries generally have advanced technological infrastructures, a diverse service sector, and a mature and refined economy. Such countries are the USA, countries in the European Union, and Australia.

2.4.1.1 The United States of America (USA)

The USA is one of the largest producers of e-waste. It has the fastest growing e-waste stream in the world because of the high buying power of its residents who frequently upgrade and discard electronic equipment. Seeberger et al. (2016) argued that it is for these reasons that e-waste management practices and policies are not sufficient to meet the challenges. According to the United States Environmental Protection Agency (US EPA, 2015) in 2013 as much as 3.14 million tons of e-waste were generated in the USA, and of this volume only one million tons (or 40%) were recycled. The rest was disposed of at landfills or incinerators. In 2014, the USA produced 7 072 metric kilotons of e-waste which equates to 22.1 kg per inhabitant (United States Environmental Protection Agency, 2015).

The Global E-waste Monitor reported in 2020 that the waste produced by USA in 2019 was 6 918 Kt, which was 21 kg per capita (Forti et al., 2020). This was very similar to the volume produced in 2014. Various studies have indicated contradictory data of e-waste over the years, not only for the USA but for other countries as well.

The USA generally uses two methods of waste disposal, which are landfill or exportation. Between 2003 and 2005, about 85% of all e-waste generated in the USA was landfilled. The practice of exporting waste to developing countries is in contravention of the Basel Convention, but for a long time there were no laws in the USA that banned this practice (Ledwaba and Sosibo, 2017).

Baldé, Forti, Kuehr, and Stegmann (2017) estimate that e-waste represents about 3% of the entire municipal waste volume that is generated each year, whereas the United States Environmental Protection Agency (2015) states that e-waste in the USA accounts for only 10% of the total municipal solid waste that is generated. The estimations of these two institutions differ. Although the USA is one of the countries that generates the largest volume of e-waste globally, this type of waste is still below 10% of their municipal waste.

2.4.1.2 The European Union

According to Forti et al. (2020), in 2019 a large volume of e-waste was generated in Asia (24.9 Mt), but the region that generated the highest volume in kg per capita in that year was Europe (16.2 kg per capita). Europe was also the region with the highest documented formal e-waste collection and recycling rate at 12 million tonnes, or 42.5% of WEEE (Forti et al., 2020). The European Union introduced legislation to improve the waste collection and recycling infrastructure in its member states in an effort to drive environmental benefits in terms of sustainable use of resources and reduced carbon emissions.

Legislation introduced by the European Union was the WEEE Directive in 2002 (Directive 2002/96/EC), which was updated in 2012 (WEEE Directive 2012/19/EU). The European Union (EU) passed RoHS Directive 2002/95/EC (which was later revised to RoHS Directive 2011/65/EU) to limit the use of certain hazardous substances in electrical and electronic equipment. RoHS Directive 2002/95/EC came into effect in 2003 with the aim of regulating heavy metals such as lead, mercury, cadmium, and chromium as well as flame retardants such as polybrominated biphenyls (PBB) and polybrominated diphenyl ethers (PBDE). These now have to be substituted with safer options (Ledwaba & Sosibo, 2017).

2.4.1.3 Australia

In 2017, Australia ranked 28th amongst the countries in the world with an estimated GDP/capita of US$49 900 and a high per hour wage rate. The purchasing of EEE, especially television and IT equipment, has increased dramatically in this country over the years due to high income levels. E-waste is one of the fastest growing waste streams in Australia and, since 2016, 0.57 Mt of e-waste have been generated in the country (Baldé et al., 2017). In 2008, 17 million televisions and 37 million computers were sent to landfill sites (Australian Government, 2018). To divert increasing volumes of WEEE from these sites, the Australian government established a National Waste Policy in 2009, a waste regulatory framework in 2011, and the Product Stewardship Act in 2011 (Morris & Metternicht, 2016). In 2019, it was estimated that 975 000 tonnes of e-waste products had entered the Australian market. Around one third of this was solar PV and battery storage equipment at a volume of 333 000 tonnes. In the same year, about 8 215 000 tonnes of electrical and electronic equipment were in use, which was a volume that was 8.5 times that of product entering the market. Moreover, 521 000 tonnes of e-waste were generated that equated to 20.4 kg of e-waste per capita (Australian Government, 2021).

E-waste is the fastest-growing waste stream globally, yet the data that could be accessed on this waste stream for various countries indicate that WEEE is properly collected and treated in only a few. This poses a dire threat as it is argued that new and enhanced technologies will continue to accelerate the production and dissemination of products with undesirable components which will, in turn, exacerbate the risks associated with the e-waste stream.

2.4.2 Developing countries

Countries in this category have a relatively undeveloped industrial base and are still seeking to become more advanced economically and socially.

2.4.2.1 India

India is ranked among the top five generators of electronic waste in the world as an estimated 1.85 million tonnes are generated annually. The growth rate of the country's information and technology and electronics industry is increasing at an alarming rate. The increase in use and sales of electronic devices and IT hardware has led to high rates of WEEE. In 2014, it was reported that India had generated 1 641 metric kilotons of e-waste, which was 1.3 kg per inhabitant (UNU-IAS SCYCLE, 2015). Compared to a volume of 69 414 tonnes of e-waste generated in 2017-2018, India generated 1 014 961.2 tonnes of e-waste in 2019-2020, and thus ranked third after the USA and China. The collection and processing of e-waste in India have increased four-fold in recent years. However, it has been reported that only 11% of this waste is recycled in the country (Rana, 2021).

A study that was conducted on e-waste management in India identified computer equipment and mobile telephones as the principal e-waste generators in this country. Among many large Indian cities, Mumbai topped the list as it generated an estimated 1.2 tonnes of e-waste annually. Delhi and Bengaluru ranked second and third at 98 000 and 92 000 tonnes respectively (Garg & Adhana, 2019).

2.4.2.2 China

China is one of the largest manufacturers and consumers of electronic products and, as a result, this country generates large volumes of electrical and electronic waste (Lu et al., 2015). Rapidly developing economic advancement and urbanisation in China have resulted in ever-increasing volumes of e-waste being generated. This volume increased from 32.99 million units in 2001 to 229.66 million units in 2012 (Veenstra et al., 2010), and the volumes of a variety of e-waste are continuously increasing. For instance, in 2016 this country generated 7.2 million metric tons (Mt) of e-waste (Baldé et al., 2017). It is predicted that WEEE generation in China will grow to 27.2 Mt in 2030 and 51.6 Mt in 2050 (Zeng et al., 2020). Clearly, if control and effective disposal measures are not in place, the problem will intensify and even become completely unmanageable.

In China, e-waste is categorised into five types, namely cellular phones, personal computers, television sets, single-machine telephones, and printers. However, nine other categories of e-waste also flood the market, namely washing machines, refrigerators, air conditioners, cooker hoods, electric heaters, gas water heaters, copiers, fax machines, and monitors (China Household Electric Appliance Research Institute, 2017). The five main e-waste categories account for 62.4% of the e-waste stream, while the nine other types of e-waste account for approximately 37.6% of this waste stream (Li & Achal, 2020).

The overall weight of e-waste generated annually was estimated at around 4.06 million tons in 2015 and at 5.38 million tons in 2017, which is 21% and this demonstrates the escalation of this problem. Asia is home to over a third of the total global human population, with India and China accounting for more than half the population of the continent of Asia. WEEE activities in these two countries thus dominate the rest of this continent due to their large populations. China also influences the movement of electronics in Asia and beyond as it is a major EEE manufacturer (Shittu, 2021).

2.4.2.3 South Africa

In South Africa, WEEE is generated by three major sectors: the government (45%), the business sector (35%), and households (20%) (Lydall, Nyanjowa, & James, 2017), and these consumers make large volumes of EEE available for recycling when they become obsolete. Unfortunately, clear data regarding the types, rates, and volumes of WEEE that is generated, is in circulation, and is released for recycling are largely lacking in South Africa. A study by Finlay (2005) estimated that South Africa was generating between 1.12 Mt and 2.1 Mt of WEEE annually. In later years the Solving e-waste problem initiative program (2014) suggested a much lower figure of 300 000 tonnes, of which 18% was recycled. They estimated that electronic waste in South Africa increased by 10% each year with each person generating around 6.6 kg of WEEE. In 2011, the Department of Environmental Affairs (DEA) estimated that South Africa generated approximately 64 045 tonnes of WEEE (Lydall, Nyanjowa, & James, 2017). More recently, the Department of Environmental affairs believed that e-waste in South Africa made up 5% to 8% of municipal solid waste and that it was growing at three times the rate of any other waste types. According to the e-Waste Association of

South Africa (WASA), in the period 2017 – 2019 about 6.2 kg of e-waste was generated per inhabitant, of which only 12% was recycled (de Froberville, 2019). Unfortunately, no definitive data of a more recent date could be traced.

Globally, volumes of e-waste are increasing at an alarming rate which is almost 2 Mt per year. However, there is a lack of data on the exact volumes of e-waste that are generated and collected. Understanding the volumes and flow of e-waste will provide a basis for monitoring, controlling, and ultimately preventing illegal transportation, dumping, and improper treatment of e-waste. In 2019, the large volume of e-waste that had been generated (82.6%) was most likely not formally collected and not managed in an environmentally sound manner (Forti et al., 2020).

With the increase in internet connectivity, countries in Africa continue to increase the accessibility of mobile devices, while the usage of other consumer electronics is also escalating as more and more people have increased buying power. It thus seems inevitable that developing and emerging economies will continue to experience increased volumes of WEEE because of high production and import rates, particularly from developed economies such as the USA and countries in Europe (Bimir, 2020). Paradoxically, e-waste presents opportunities for the recovery of valuable minerals, but it is also associated with safety and health risks due to improper management. Therefore, although volumes of e-waste will continue to grow, developing countries are not capacitated to fully contain and manage the volumes of WEEE that is associated with risks to humans.

2.5 E-Waste Management Practices in Developed and Developing Countries

E-waste is usually managed in one of four ways, namely:

- formal collection;
- consumers deposit the item/s in special bins;
- collection facilities within formal systems in countries with a well-developed e-waste management infrastructure;

- collection facilities outside formal systems in countries with poorly-developed e-management infrastructure.

The two most common methods of e-waste disposal are landfilling and recycling (formal and informal), although re-use through recycling and the export market are other methods for e-waste disposal in most developed countries (Pucket & Smitt, 2002).

2.5.1 Landfill disposal

Although there has been a global move to zero waste over the years, the number of landfill sites has increased in both developed and developing countries. Organic waste and other materials deposited at landfill sites decompose and infiltrate through the soil as landfill leachate. Due to the composition of e-waste and its characteristic ability to pollute the environment, it poses a health risk to humans and the environment, and it has thus become illegal in many countries to dispose of e-waste with other municipal waste that is transported to landfill sites or incinerated.

2.5.2 Recycling of electrical and electronic equipment waste

E-waste is recycled throughout the world in formal and informal recycling processes. Formal e-waste recycling entails specially constructed facilities with proper equipment that facilitates the safe extraction of valuable materials. However, these facilities are expensive to construct and operate, and therefore there are not many found in developing countries (Schluep et al., 2009). Conversely, according to Chi et al. (2011), informal e-waste recycling is normally conducted beyond the reach of official governance, is unregulated, lacks structure, is unregistered, and is operated illegally.

Park et al. (2017) argues that, in developing countries, formal recycling is taken very seriously. In such countries there is e-waste management system that usually comprises three components: (1) A National Registry: This is a data base of producers of e-products with collection obligations attached. These stakeholders have the responsibility to ensure that their products are recycled in an environmentally sustainable way. (2) A collection system: This system usually consists of two primary

collection methods, namely a ‘collective system’ and a ‘clearing house system’. A collective system is usually founded by non-profit trade organisations and its purpose is to sort each waste type and to channel it to an appropriate division for re-use. The clearing house system is run like an auction. In this system businesses, manufacturers, and recyclers collaborate and offer their services for dissemination of devices/equipment and the disposal of e-waste. (3) Logistics: The logistics of e-waste disposal entail three main avenues: collection by municipal collection agents, retailer take-back schemes, and a direct producer take-back system.

The following sections present various countries’ approach to e-waste management in accordance with their respective legislation.

2.5.3 E-waste management practices in developed countries

Extended Producer Responsibility (EPR) and Advanced Recycling Fee (ARF) are the main e-waste management systems in Switzerland and other developed countries (Jadhav, 2013). Shamim et al. (2015) reveal that the first electronic recycling system was implemented in Switzerland in 1991. It began with the collection of used and obsolete refrigerators but, over the years, all other electrical and electronic devices have gradually been added to the system.

‘Extended producer responsibility’ entails the provision of incentives to encourage producers to design products “in a way that minimises waste management costs in as much as they are financially responsible for this process” (Gubanova, 2014).
There are five types of EPR that are categorised as financial, physical, compensational, informational, responsibility, and property rights. Responsibility, for instance, means that the manufacturer retains the right to own the product when it enters the waste stream. Consumers have a special role to play in the system as, in addition to being users, they are also e-waste holders who participate in the e-waste collection scheme (Gubanova, 2014).

2.5.3.1 Countries in the European Union

The Europe Union's approach to e-waste recycling and management is guided by two directives: The Directive 2002/96/EC for Waste from Electrical and Electronic Equipment (WEEE), updated in the year 2012 as 2012/19/EU, and the Restriction of Hazardous Substances (RoHS) Directive 2002/95/EC, which was later revised and made available as RoHS Directive 2011/65/EU. The goal of the WEEE Directive is to regulate the collection, recycling, and recovery of e-waste. It includes the provision of national e-waste collection points and processing systems and specifies treatment requirements for specific materials and components of e-waste. This legal framework uses the principle of 'extended producer responsibility', which requires producers to organise or finance the collection, treatment, and recycling of their products at the end-of-life point (Baldé et al*.,* 2017).

The European Union (EU) directive specifies minimum annual collection rates for WEEE by member states. In 2016, the minimum annual collection rate was 45% of the average volume of electrical and electronic equipment released into the market in the three preceding years. Most countries reportedly achieved this target, such as Sweden, Norway, Ireland, Slovakia, Portugal, Hungary, Luxemburg, and the Czech Republic. Of the EU member states, Liechtenstein and Bulgaria had the highest e-waste collection rates in 2016. Switzerland, Liechtenstein, and the Scandinavian countries are deemed the most advanced EU countries with regards to e-waste collection (Shevchenko, Laitala, & Danko, 2019). In 2019, the minimum collection rate was increased to 65% of the average EE put on the market, or 85% of annually generated WEEE (Shittu, 2021).

2.5.3.2 United States of America (USA)

In the USA, 25 states passed legislation requiring e-waste recycling even though there is no Federal mandate to recycle electronic waste. About 84% of the population is regulated by legislation on e-waste. There are 700 certified electronics recycling facilities in this country across all states (Baldé et al*.,* 2017). The states developed numerous methods to facilitate collection and proper disposal of obsolete electrical equipment and have various forms of incentives and penalties. One approach

employed in California is to charge an electronic waste recycling fee that is imposed on devices such as laptops, televisions, monitors, etc. (Ledwaba & Sosibo, 2017).

Many initiatives to manage e-waste were introduced by the USA Environmental Protection Agency (EPA). This is a United States Federal government agency that aims to protect human and environmental health. The EPA partners with the original manufacturers of electronics equipment as well as retailers to collect used electronics from the public. These partners are committed to using certified electronics recyclers to discard e-waste (Baldé et al., 2017). Various USA bills target several waste collection methods such as curb side collection, special drop-off events, permanent drop-off, take-back, and point purchase (European Commission, 2012).

The collection rate in the USA is estimated around 70%. It is suspected that some e-waste is exported to other countries as this country has not yet ratified the Basel Convention that restricts transboundary movement of hazardous waste. Duan et al. (2013) suspect that an estimated 8.5% of collected e-waste units such as computers, TVs, monitors, and mobile phones was exported as intact units in 2010. Also, landfill is still used to dispose of obsolete electronic equipment. In 2016 only about half of the US states had initiated a landfill ban for e-waste (Seeberger et al., 2016). Check lists exist for zero waste and e-waste restrictions in certain states in the USA.

2.5.3.3 Japan

Japan is one of the countries that first adopted e-waste legislative and regulatory frameworks. This was fostered by a general shift towards environmental policies in the country. E-waste policies in Japan require manufacturers and importers to take back electronics for end-of-life management. The Home Appliances Recycling law (Amemiya, 2018) mandates that four types of household e-waste have to be collected, namely televisions, refrigerators, washing machines, and air conditioners. Consumers are required to pay an end-of-life fee when such items are purchased to cover the costs of transportation and recycling. Once the equipment has become obsolete, consumers bring the e-waste to the retailer where it was bought. Retailers will transport the product to the designated collection sites and manufactures are required to ensure that the e-waste is recycled (Namias, 2013).

2.5.3.4 Australia

Australia regulates WEEE management through the National Waste Policy, the Product Stewardship Act, Product Stewardship regulations for TVs and computers, and the National Television and Computer Recycling Scheme (NTCRS) (Morris & Metternicht, 2016). These regulations led to the implementation of end-of-life management of WEEE. Privately funded schemes that are supported by the government provide services for the collection and recycling of computers and TVs and they aim to achieve 80% collection of this type of electronic equipment, even though other WEEE categories are not included. The Australia Mobile Telecommunications Association (AMTA) coordinates the collection and recycling of discarded mobile phones through the Mobile Muster programme (Australian Government, 2018).

2.5.4 E-waste management practices in developing countries

In many countries the cost of recycling exceeds the revenue recovered from the recycled materials, especially in countries with strict environmental regulations. This causes large e-waste volumes to be transported and dumped in countries where environmental standards are low and working conditions are poor. In the past, Asian countries were a common dumping ground for e-waste, but as regulations against dumping have been enforced in most of these countries over time, e-waste has been moved to other regions, predominantly in West Africa (Kuper & Hojsik, 2008).

Kristen et al. (2013) confirmed that although e-waste is informally processed in many countries, high volumes of informal recycling tend to end up China, Ghana, Nigeria, India, Thailand, the Philippines, and Vietnam. Demand for e-waste recycling began to grow when scrap yards in Asia discovered that they could extract valuable metals such as copper, iron, silicon, nickel, and gold from e-waste (Kuper and Hojsik, 2008).

The informal e-waste recycling sector uses sites valuable components contained in e-waste can be extracted without the use of safe equipment. The livelihoods of many workers and their families depend on the extraction of valuable materials from e-waste. These valuables are simply removed, and the remaining parts are burned, buried, or

conveniently dumped in waterways, which then become polluted (Sthiannopkao & Wong, 2013). Common operations in informal recycling are open pit burning to remove valuable metals and open acid bath procedures to strip metals from electrical components. These procedures lead to environmental contamination because toxic chemicals are emitted or released (Park et al., 2017).

2.5.4.1 India

E-waste management practices are a serious issue because informal recycling practices are employed. Ninety-five percent of e-waste is recycled through the informal sector (Borthakur & Govind, 2017). In India two small e-waste dismantling facilities operate in Chennai and Bangalore, and there is no large-scale organised e-waste recycling facility in this country where recycling occurs predominantly in an unorganised sector (Jadhav, 2013). Most activities such as collection, transportation, segregation, dismantling, recycling, and disposal are carried out by the informal sector.

The informal collectors, called 'kabadiwala', collect all kinds of waste like paper, plastic, cardboard, metal, and e-waste to earn a living. They sell e-waste to scrap metal dealers or to middlemen. This is a good source of income for informal collectors and scrap metal recyclers. However, recycling is not properly done because the appropriate technology is not in place. Moreover, few companies have implemented the take-back system voluntarily (Jadhav, 2013). Lakshmi, Raj, and Jarin (2017) estimate that about 80 000 people in India are working in the recycling sector. They state that some villages, such as Seelampur, have scrap markets where piles of e-waste are separated for recycling.

2.5.4.2 China

Electrical and electronic waste recycling in China occurs through three channels. The first is various second-hand markets where e-waste can be sold for a reasonable price (Ongondo et al., 2011). Some discarded e-waste items can still function and can be re-used after repair or upgrade. The second channel is where owners of electronic/electrical equipment donate items which they no longer use to the poorer communities or people living in rural areas (He, Li & Ding, 2008). Thirdly, obsolete e-

waste is sold to an e-waste informal collector who in turn sells it to e-waste dealers (Sepulveda et al., 2010). This channel is preferred as large volumes of e-waste can be collected in this manner. However, this channel causes the most problems as informal collectors and dealers do not have adequate skills and appropriate knowledge, equipment, or technology to treat e-waste. After e-waste has been collected, they use simple techniques such as dismantling the equipment, burning parts, and cutting cables and wires to recover precious metals. Informal recycling appears to be a prevailing activity at e-waste dumps. These methods are environmentally unsound and lead to degradation of the environment.

Guiyu, a small town in south-east China, is well known all over the world for environmental pollution due to its illegal e-waste recycling activities. These activities in Guiyu reportedly started in the late 1980s and, since the middle of 1990s, many local farmers have been involved in e-waste recycling to earn a living (Wang et al., 2020). These e-waste recycling activities thus mainly occur in the informal economy and constitute a substantial portion of the gross national product (GNP) (Schluep et al., 2009).

In recent years, the Chinese government has implemented a mechanism for e-waste management which streamlines every part of the e-waste processing sector. The stages of this development have included the following:

- A specific number of informal and formal disassembly and disposal sites were established before 2005.
- The construction of a demonstration enterprise was initiated to manage the treatment of household e-waste between 2005-2009.
- More than 100 designated and formal disassembly plants of household e-waste were created through the Old for New Program from 2009-2011.
- In 2015, about 109 qualified enterprises received disassembly and disposal qualifications to formally treat 133 million units of WEEE (Zeng et al., 2020).

As a result of these initiatives, extensive growth, and comprehensive coverage obtained by qualified e-waste recyclers, a formal sector of e-waste treatment developed. This accomplishment by the Chinese government to change the problem

created by illegal e-waste activities and formally manage e-waste is a good lesson for other developing countries, including South Africa.

2.5.4.3 South Africa

The National Environmental Management Act (NEMA) 1998, is designed within the framework South African Constitution. NEMA is aimed at the promotion of sustainable development. In addition to sustainable development NEMA also promotes the polluter pay principle. The main aim of this principle is the preservation and protection of the environment. Section 2 (4) of NEMA provides that: the cost of remedying pollution, environmental degradation and consequent health effects must be paid for by those responsible for harming the environment.

The Department of Environmental Affairs published a National Environment Management Waste Act Section 28 Notice (Government Notice 1353) on 06 December 2017. This notice requires the paper and packaging industry, the lighting equipment industry, and the electrical and electronic industry to develop and submit an Industry Waste Management Plan (IndWMP) on how they will manage their waste. The objective of the Act and this Notice is to hold the generators of waste responsible for the waste streams they create (South Africa, 2014).

The aim of the Industry Waste Management Plan is also to create public awareness and divert waste from landfill sites towards reduction, re-use, and recovery. However, the Minster of Environment Forestry and Fisheries, Minister Creecy, made the decision to withdraw Section 28 (GreenCape, 2020). This was done as a public announcement in 2020 in which she stated that she would be starting an entirely new process under Section 18 to allow for an industry-managed plan rather than a government-managed plan.

Three years ago, GreenCape (2019) reported that, of the 425 000 tonnes of electrical and electronic equipment entering South Africa annually, 360 000 tonnes were discarded as e-waste. Of this volume, only 25 100 tonnes (7%) had been intercepted before landfill. This left 334 900 tonnes of e-waste (at a value of R438 million to R548 million) that could have been collected and processed. According to Lydall et al. (2017),

the rate of e-waste recycled in South Africa was only 11% at the time. Even earlier, proposals had been put forward to increase the recycling of e-waste to 20% within five years (e-Waste Association of South Africa [eWASA], 2013), but this clearly did not happen.

South Africa has more than 100 formally registered e-waste businesses and service providers involved in the early stages of the e-waste supply chain (Lydall et al., 2017). It is estimated that there are 10 000 informal collectors of e-waste and 25 formal small- to medium-size businesses involved in the collection of e-waste for recycling purposes (GreenCape, 2020). The e-waste industry in South Africa is still developing and there are many existing challenges that the country needs to overcome. One obstacle is the lack of available data on the volume of e-waste that is produced annually. Ledwaba and Sosibo (2017) argue that, although there are existing barriers, the country is shifting in a positive direction as e-waste is now recognised as one of the six priority waste streams.

The problems that are created by improper disposal and management of e-waste and opportunities for the recovery of valuable materials through recycling have compelled countries to consider efficient e-waste management solutions. The improper management of e-waste also contributes to global warming. If the materials in e-waste are not recycled, they cannot provide alternatives for primary raw materials and reduce greenhouse gas emissions from extraction and refinement of primary raw materials (Ahiwar & Tripathi, 2021).

2.6 Sustainable Development Goals

At the United Nations General Assembly Summit in September 2015, the UN's 193 Member States adopted the 2030 Agenda for Sustainable Development. This new agenda identified 17 Sustainable Development Goals (SDGs) and 169 targets to end poverty, protect the planet, and ensure prosperity for all. The SDGs were developed through an exceptional consultative process that brought together national governments and millions of citizens from the world to negotiate and adopt this bold agenda (Forti et al., 2020). The 17 sustainable goals that were identified are listed in Table 2.6.

Table 2.6: Sustainable Development Goals

1	End poverty in all its forms everywhere.
2	End hunger, achieve food security and improved nutrition, and promote sustainable agriculture.
3	Ensure healthy lives and promote the well-being of all at all ages.
4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.
5	Achieve gender equality and empower all women and girls.
6	Ensure the availability and sustainable management of water and sanitation for all.
7	Ensure access to affordable, reliable, sustainable, and modern energy for all.
8	Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all.
9	Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation.
10	Reduce inequality with and among countries.
11	Make cities and human settlements inclusive, safe, resilient, and sustainable.
13	Take urgent action to combat climate change and its impacts.
14	Conserve and sustainably use the oceans, seas, and marine resources for sustainable development.
15	Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.
16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all, and build effective, accountable, and inclusive institutions at all levels.
17	Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development.

Source: United Nations, 2015.

2.6.1 E-waste and its relation to the Sustainable Development Goals

Proper e-waste handling and disposal practices will contribute to the achievement of several goals of the 2030 Agenda for Sustainable Development. For instance, the goals related to environmental protection and health and employment and economic growth will be addressed as sound management of e-waste will create new areas of employment and promote entrepreneurship development (Forti et al., 2020).

Conversely, e-waste that is treated incorrectly poses a serious threat to the environment and people's health as such waste contains various hazardous components. The improved management of e-waste is closely linked to Goal 3 (good health and well-being), Goal 6 (clean water and sanitation), Goal 12 (responsible consumption and production), Goal 14 (life below water), and goal 8 (decent work and economic growth) (Forti et al., 2020).

The principles of the South African National Waste Management Strategy of 2020 (NWMS) are closely aligned with the Sustainable Development Goals. The NMWS provides a framework and strategy for the implementation of the Waste Act and outlines government's policy and strategic approach to waste management within the South African context. The contribution of the NWMS aims to ensure that the SDGs related to waste management are achieved (South Africa, 2020).

2.7 Summary

E-waste is the fastest growing category of waste. Innovative technologies in the development of electrical and electronic equipment result in fast obsolescence and generate large quantities of e-waste. Developed countries often shift their responsibility to manage this waste in an environmentally friendly manner by legally or illegally transporting it to developing countries.

Electrical and electronic equipment has many components that contain hazardous and non-biodegradable material. Environmental problems associated with e-waste management have a direct impact on human health, therefore it is important that e-waste management programmes and processes have the technological capacity for

proper waste management to ensure health protection and environmental sustainability. Such processes include the collection, transportation, treatment, and disposal of e-waste.

Recycling is very important for the reduction of e-waste. Moreover, it has environmental benefits. Other than the reduction of greenhouse gas emissions, recycling also reduces air and water pollution associated with the production of new products from raw materials. It also reduces air pollution and the negative impact caused by illegally dumped electrical and electronic equipment. Recycling should be conducted in a safe and standardised manner. Where possible, e-waste should be refurbished and reused as a complete product instead of merely dismantling it.

A large percentage of the world's population is regulated by national e-waste legislation. This is because 78 countries have policies, legislation, or regulations that govern e-waste. The challenge that still exists is that many countries' policies on e-waste management are not legally binding. Moreover, even where legally binding policies were passed, implementation and enforcement are key issues.

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CHAPTER 3
RESEARCH METHODOLOGY AND DATA ANALYSIS

3.1 INTRODUCTION

Research is a logical and systematic search for new and useful information on a particular topic. It is an investigation to find solutions to scientific and social problems through objective and systematic analysis; it is therefore a search for knowledge and a discovery of hidden truths (Rajasekar et al., 2006).

This chapter provides a description of the study area and the research methodology that was employed. The latter is discussed in detail with emphasis on the research design, data gathering tools and processes, and data analysis procedures.

3.2 RESEARCH DESIGN

The study utilised a qualitative research methodological approach. Wiid and Diggins (2015) explain that qualitative research is about exploring issues to understand underlying reasons for their prevalence. The aim of a qualitative research study is to describe and explain a current situation so that the findings can be generalised (Aspers & Corte, 2019).

To achieve this, an exploratory study design was adopted to understand the nature of the problem. This design was appropriate as a literature review revealed that only a few studies on e-waste management and recycling had been undertaken in the eThekwini Metropolitan area, KZN. The exploratory strategy assisted the researcher to understand the e-waste disposal methods that were employed by various

organisations under study. This understanding in turn assisted in the development of proposed guidelines that can be used in the future to better manage and dispose of e-waste.

3.3 AIMS AND OBJECTIVES

The aim of the study was to assess current handling and disposal methods of e-waste in the eThekwini Metropolitan area in KZN.

The objectives of the study were to:

- Explore and record key components of relevant legislation, by-laws, and guidelines that currently guide e-waste handling and disposal in the study area;
- Evaluate the extent of recycling of e-waste in the area under study in order to establish the volumes of e-waste being generated and the range of disposal opportunities and practices being employed;
- Assess current e-waste handling and disposal practices in order to identify gaps that should be addressed;
- Compile guidelines regarding e-waste handling in the form of a brochure/leaflet for distribution by the Waste Management Education Section of eThekwini Municipality.

3.4 STUDY AREA AND SAMPLE SELECTION

The study was conducted in the eThekwini Metropolitan area in KwaZulu-Natal Province in South Africa. South Africa is the most southern country in Africa. With a population exceeding 59 million, it is the world's 24th most populous nation and covers an area of 1 221 037 square kilometres. South Africa is a developing country and ranks 113th on the Human Development Index, which is the seventh highest in Africa (Congregational Research Service, 2020).

South Africa is divided into nine provinces, namely Gauteng, Eastern Cape, Western Cape, Limpopo, Mpumalanga, North-West, Free State, Northern Cape, and KwaZulu-Natal. The KwaZulu-Natal Province, generally referred to as KZN, is in the south-eastern part of the country.

3.4.1 Study area

The study was undertaken in the eThekwini Municipality area in the province of KwaZulu-Natal. eThekwini is one of eleven districts in this province. It includes the city of Durban which is the largest city in this province and the third largest city in the country. It has a population of 3 344 398 people and comprises 2 297 km^2 land area. It is located on the east coast of South Africa.

Figure 3.1: Map of South Africa indicating the eThekwini Metropolitan area in KZN [Source: SA Coastal Information centre (2014)]

3.4.2 Sample selection

Electrical waste and electronic waste are terms used to describe equipment that relies on power to function and that has reached its lifespan. These types of equipment are used on a daily basis at schools, the work environment, and in homes where they generally make life and connectivity easier for humans. E-waste is generated when

such equipment and devices are broken or become obsolete. This study was designed to explore the manner in which selected organisations handled and disposed of their e-waste. These organisations varied in the type of functions and services they offered and include:

- educational institutions;
- government departments;
- health facilities;
- the hospitality industry; and
- manufacturing companies.

The convenience sampling method was used. Convenience sampling is when the sample is drawn from a section of the population that is readily accessible to the researcher (Wiid & Diggins, 2015). This type of non-probability sampling is used when members of the target population who meet certain criteria are included in the study. They are, for example, convenient due to their geographical proximity, availability, and/or willingness to participate.

3.5 DATA COLLECTION

To formulate the research questions and design the questionnaires, relevant literature was reviewed. This literature study utilised relevant secondary sources of information such as academic journals, books, magazine reports, as well as government and non-government organisations' reports and publications. The latter sources were reviewed to obtain a better understanding of the framework that guides the management of e-waste, recycling activities, and legislation regarding the handling and disposal of such waste in various countries and on different continents. Moreover, to be able to address the objectives of the study, data were obtained from these secondary sources as well as from selected primary sources.

Primary data were collected by means of two self-administered questionnaires that targeted different organisations identified within the eThekwini Metropolitan area. Sekaran (2003) states that the main advantage of personally administered questionnaires is that the researcher is able to collect information within a short period

of time. Any doubt that the respondent might have on any question could be clarified easily by the researcher or person administering the questionnaire. The collection of such primary data was an integral part of the research.

3.5.1 Questionnaire design and pilot study

The administration of two questionnaires was the data collection tool of preference for this study. The questions were posed in English as it was understood that all the participants would be proficient in this language due to the nature of the organisations/institutions that would be involved. No translation – either of the questionnaire or the responses – was required. The questionnaires were designed to ensure that the required data would be collected in order to achieve the objectives of the study.

A pilot study was conducted when a draft questionnaire was tested on a small sample of people representing the research population. The pilot study was conducted at five randomly selected organisations that were known to handle electronic devices and/or electrical equipment. The participants in the pilot study were not included in the actual study. The pilot study enabled the researcher to determine how long the respondents would take on average, to complete the questionnaires, and to assess and eliminate any problems encountered in completing these questionnaires or understanding the questions. This helped to identify and resolve any ambiguous or repetitive questions. Based on the feedback received, a few questions were rephrased.

Two questionnaires were administered: One was aimed at e-waste generators (Annexure A) and one was aimed at waste recyclers/companies (Annexure B).
To achieve the study objectives, both independent (predicted) and dependent variables were included. Dependent variables can be viewed in terms of their effect. Changing the independent variable (predictor) will affect the dependent variable as it only changes in response to the independent variable.

3.5.2 Variables

3.5.2.1 Independent variables (zero control variables)

These values can be controlled and do not depend on the state of another variable as they are stable. The following independent variables were included in the study to elicit demographic information from the respondents:

- gender
- age
- educational level
- waste management training.

3.5.2.2 Dependent variables

Dependent variables depend on factors that are measured and that are expected to change (or vary). Thus, the e-waste generators' responses in terms of types of e-waste generated, the transportation or collection of e-waste by recycling companies, and the disposal methods used were dependent variables as they related to:

- what items were considered as e-waste
- generation rates and types of e-waste
- procedures and guidelines for handling of e-waste
- removal/collection strategies to dispose of e-waste.

Data were collected by analysing the responses of e-waste generators and recycling companies. These responses contributed to the identification of e-waste types and current e-waste handling procedures.

3.5.3 Application of the findings of the study

Based on the findings, general information regarding e-waste practices in the eThekwini area will be disseminated to the Education section of the Cleansing and Solid Waste Unit of the eThekwini Metropolitan Municipality in the form of a brochure/memorandum. This information will focus on e-waste handling and appropriate disposal strategies. Various aspects covered in the recommendations section of this dissertation will be applicable to educational programs that

environmental health practitioners (EHPs) conduct. This information may be further disseminated to enhance the knowledge of community members and motivate them to correctly handle e-waste and maximise its recovery.

3.5.4 Breakdown of questions

The questionnaires contained the following categories:

Questionnaire 1: E-waste generators

Section A: Information elicited from e-waste generators: Q1 to Q5

The information that was obtained from e-waste generators (government departments, educational institutions, health facilities, and the hospitality industry) included socio-demographic characteristics (gender, age, educational level, and training in e-waste handling). As a specific audience was targeted, it was important to know who was completing the questionnaire (Barnard, 2013). Some responses, such as education level and age, enabled the researcher to compare the opinions of the respondents according to their ages and levels of education.

Section B: Q1 to Q5

This section included questions that assessed respondents' understanding of what e-waste is, their ability to identify e-waste items and their use in their respective companies, the potential of hazards associated with e-waste, and their understanding of increased volumes of e-waste.

Section C: Q6 to Q14

This section focused on the aspects relating to the current procedures, guidelines and protocols of handling e-waste, dealing with broken down, unusable electrical and obsolete equipment, removal process from premises, financial implications of recycling, knowledge of final destination and legislation regarding e-waste.

Questionnaire 2: E-waste Recyclers

This questionnaire was designed for companies that provide e-waste management services as well as recyclers of e-waste.

Section A: Q1 to Q6

The first section covered the demographics of each respondent representing a particular company. Information was gathered regarding age, educational level, waste management training, and experience in the field of waste management.

Section B: Q6 to Q11

The questions in this section related to the geographic footprint of the recycling companies and their activities. The researcher wanted to determine which areas were covered in terms of e-waste recycling and which were not. Other questions in this section elicited information regarding the respondents' levels of awareness of the proper disposal of e-waste.

Section C: Q11 to Q20

Responses to questions in this section helped the researcher to understand what equipment/devices were generally recycled in the study area. It also helped to determine the (average) value of the items used, the quantities of items that needed to be recycled/disposed of, and the challenges the e-waste recyclers faced during these operations.

3.6 Ethical Considerations

All the ethical requirements associated with a study of this nature were strictly adhered to during the survey. Permission to conduct the study was granted by the institution where the researcher was enrolled as well as the management of each participating organisation/institution. The respondents were assured of their anonymity and that the information they provided would be used for this specific study only. All the respondents who completed the respective questionnaires signed a permission

declaration which also indicated that they could discontinue participation at any time during the survey should they wish to do so. The raw data are secured in a safe location and no persons, except the researcher, the supervisor, and the statistical analyser, were and will be able to access the original data.

3.6.1 Questionnaire administration

At the time the study, the researcher was employed as an Education Officer in the Cleansing and Solid Waste Department of the eThekwini Municipality. The results of the study will assist this department in conducting awareness campaigns on e-waste management. To collect the data, various relevant businesses and organisations that use electrical and electronic equipment in the study area were identified. To create an inclusive list, different types of industries were incorporated. A letter requesting permission to collect data for the study was emailed to the management of each organisation/institution. Personal appointments were made with 90% of the respondents after permission had been granted by the relevant gatekeepers. The researcher administered the questionnaires while 10% was emailed to and returned by the respondents after completion.

3.6.2 Companies/recyclers

All recycling companies operating within the study area were identified and listed. The management of each organisation was approached by sending them emails requesting permission to conduct the study. The emails sent outlined the study and sought their informed consent. The companies that responded positively provided the researcher with the names and contact details of persons who would be prepared to participate in the survey.

3.7 Data Analysis

The data that were provided by the respondents for both questionnaires were coded and captured in Microsoft Excel by the researcher. Frequencies and percentages were

calculated for categorical data. Means, standard deviations, and percentiles were calculated for numerical data. The data are presented and discussed by using tables and graphs. The data was analysed by a statistician using SAS version 9.4. The results are discussed in chapter four and chapter five.

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CHAPTER 4

AN EVALUATION OF E-WASTE MANAGEMENT IN THE ETHEKWINI, REGION, KWAZULU-NATAL

4.1 Introduction

Technological advancements in the modern age have made people's lives easier, simpler, and faster, particularly because of the continued innovations in electrical and electronic equipment (Zeng et al., 2015). However, most of these items have a limited lifespan and, when discarded, they become a complex waste issue. Currently, electrical and electronic waste is considered one of the fastest growing waste streams globally, with a growth rate of between 3-5% per year (Cucchiella et al., 2015).

Electronic waste, or e-waste, refers to all discarded electrical and electronic equipment (EEE) and their parts (Step Initiative, 2014). E-waste is also referred to as 'waste from electrical and electronic equipment' (WEEE), electronic waste, or e-scrap that is globally discarded in different regions and under different circumstances. Such waste includes a wide range of household and business items with circuit or electrical components that are fitted with a power or battery supply (Baldé et al., 2017).

According to Schwarzer et al. (2005), e-waste is classified into two types based on its physical composition, namely electrical and electronic waste. Electrical e-waste includes refrigerators and household appliances such as cables, bulbs, washing machines, dryers, air conditioning units, vacuum cleaners, coffee machines, water heaters, toasters, and irons. Electronic waste includes TVs, computer monitors, and other small consumer electronics such as DVDs, VCRs, CD players, radios, cameras, and information and communication products such as PCs, mobile phones, printers, fax machines, and photocopiers.

Widmer et al. (2005) state that the constituents of e-waste differ according to their manufacturing process. Some of these products contain more than 1 000 diverse substances that are either hazardous or non-hazardous. About 50% of such waste contains iron and steel, about 21% contains plastics, and about 13% contains non-ferrous metals or other elements. Non-ferrous metals may be copper, aluminium, and

precious metals such as silver, gold, platinum, and palladium. If e-waste is effectively recycled, it could reduce the use of virgin resources in manufacturing processes and contribute to the reduction of greenhouse gas emissions.

Although e-waste is generated everywhere, first-world countries such as the US, the UK, members of the European Union, Australia, and Japan are considered the main sources of waste as such waste constitutes about 8% of the total solid waste stream that is generated in these countries (Robinson, 2009). According to Hossain et al. (2015), rapidly increasing trends of e-waste production have been noted in growing economies such as China and India. For instance, China generated 2.3 million tonnes of e-waste in 2010.

4.2 Results and Discussion

4.2.1 Respondents' demographic data

The purpose of this section is to illuminate the background of the participants who were responsible for electronic waste in the various organisations/companies that participated in the study. Data were collected, among others, of their ages, qualifications, and levels of training in the management of electronic waste.

4.2.1.1 Gender

Most of the respondents (70.59%) were male, while fewer (5 or 29.41%) were female. The highest positions in the companies/organisations under study were held by males. According to Statistics South Africa (2018), female representation in top influential positions in South Africa is still less than 50%, regardless of the fact that some strides have been taken to rectify this situation. In fact, in 2018 only 32% of the managers of large and influential companies in South Africa were women, but this gender dominated the domestic worker and clerk or technician occupations. Only 3.0% of the domestic work force were men, while 10.9% of art and trade jobs were occupied by women (Statistics SA, 2018).

4.2.1.2 Respondents' age profile

Four years ago, Statistics South Africa (2018) estimated that the population of people younger than 15 years was about 28.8%. The survey found that approximately 5.3 million people (9% of the population) were 60 years or older at the time. The majority

of those younger than 15 years of age resided in Gauteng (21.5%) and KwaZulu-Natal (21.1%). The highest percentage (23.9 % or 1.27 million people) who were aged 60 years and older resided in Gauteng (Statistics SA, 2018).

Eight (47.06%) of the respondents were between 18 and 25 years of age. None of the participants were older than 55 years (Figure 4.1).

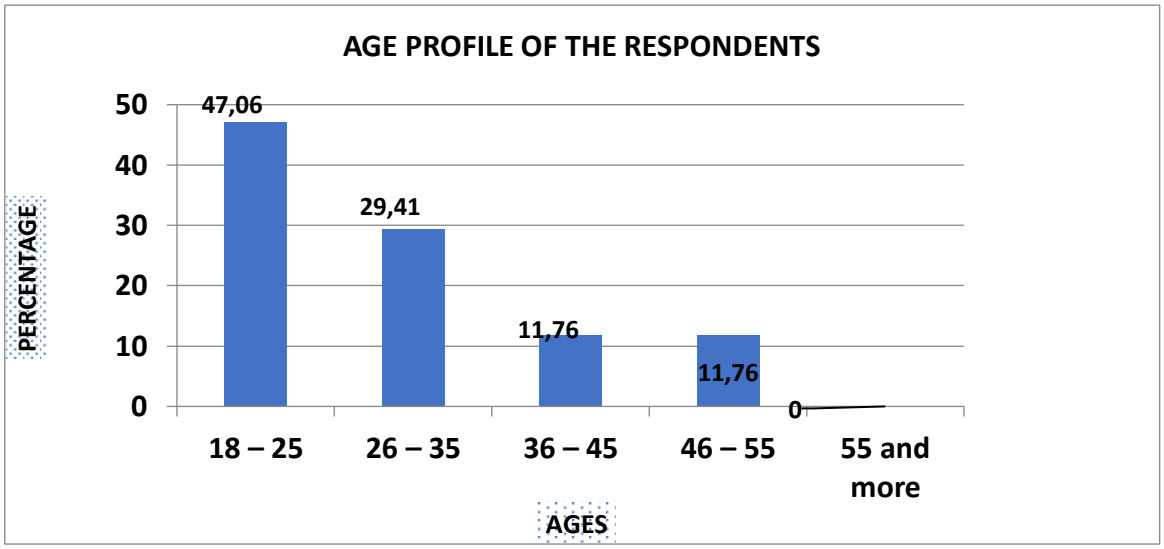

Figure 4.1: Age profile of the respondents

4.2.1.3 Educational level and waste management training

According to 2019 statistics issued by the Organisation for Economic Co-operation and Development (South Africa, 2019), more South African adults had attained an upper secondary school education in the survey period than a decade before. This survey found that the portion of young adults without upper secondary school education had dropped from 27% in 2008 to 18% in 2018. Although the report admits that educational accomplishment was still low in South Africa at the time, there was some improvement as, in 2018, more than half (59%) of those aged 25 to 64 years had attained an upper secondary school education (Grade 10 to 12) as their highest education level. This figure was well above the average of 32% of G20 countries and the OECD average of 38%. Although 26% had not attained an upper secondary education, there had been an increase in the number of people obtaining a secondary school qualification. This increase was deemed the result of the implementation of the South African Schools Act of 1996, which makes education compulsory for children aged 7 to 15 years (South Africa, 2019).

Figure 4.2 indicates that all the participants had received some formal education at a higher level than primary school. In terms of the highest level of qualifications, thirteen of the respondents (76.47%) held a tertiary qualification while four (23.53%) had a high school or National Senior Certificate qualification.

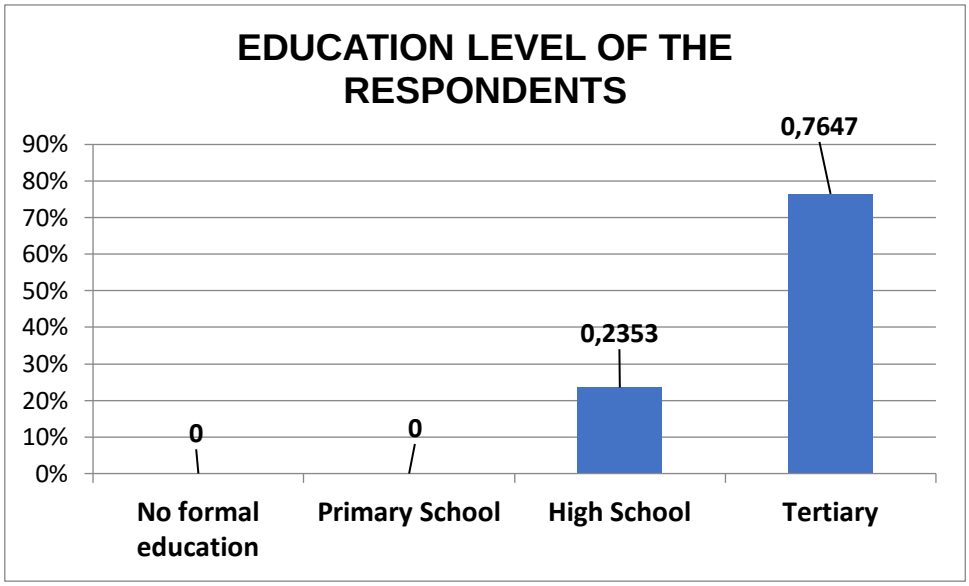

Figure 4.2: Educational level of the respondents

Nine of the participants (52.94%) received internal waste management training, while eight (47.06%) received no training on waste management. Waste management training varied between 3 to 4 years for those who held an environmental health qualification, while those who did not have such a qualification generally received one day of training per year.

4.2.2 Waste from electrical and electronic equipment

This section evaluates the respondents' understanding of e-waste. The questions also elicited information regarding the types of equipment they regarded as electronic waste and the related items each organisation used and discarded.

4.2.2.1 Electronic and electrical waste

The respondents were asked to define their understanding of e-waste. All the respondents had a broad understanding of the concept and were able to distinguish between electrical and electronic waste (e-waste), but their explanations differed. Four

(23.52%) did not correctly describe e-waste but provided correct examples. The following is a summary of the descriptions of e-waste the participants provided:

- This waste comprises assets that require electricity to function and that have reached the end of their life span/usefulness (4 or 23.52%).
- It is electronic equipment that is no longer in use and must be disposed of in a manner that ensures safe health and a safe environment (3 or 17.64%).
- It is all types of office equipment that need to be discarded because they have reached the end of their lifespan or have become non-functional (1 or 5.88%).
- Anything that uses electricity or has a circuit board (4 or 23.54%).
- Old computers and items such as TVs, globes, and discarded cellular phones (4 or 23.54%).
- Discarded electronic and electrical devices (1 or 5.88%).

It was concluded that all the respondents had a basic understanding of what e-waste is.

4.2.2.2 Items considered as e-waste

The respondents were provided with a list of items and were asked to indicate which they considered to be e-waste. The results are presented in Figure 4.3. The participants selected most of the options, but nine participants (52.94%, which was more than half) did not consider fluorescent light tubes/bulbs as e-waste.

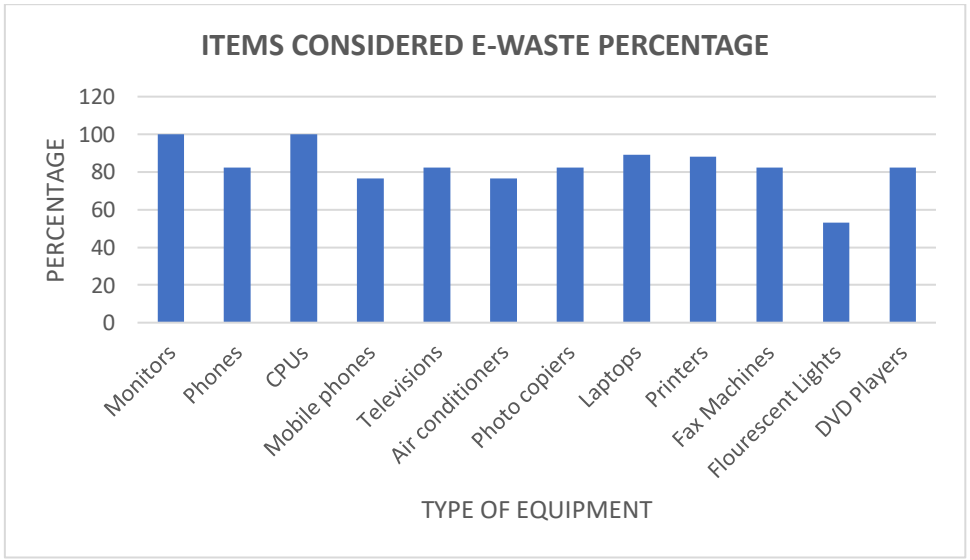

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Figure 4.3: Equipment considered as e-waste

All the participants identified discarded computers and monitors as e-waste, but the various other items that were listed varied in selection frequency (Figure 4.3). Generally, e-waste is defined as “electrical and electronic equipment and devices that use electric power but have reached their end-of-life” (Adanu, Gbedemah & Attah, 2020).

4.2.2.3 Types of equipment currently in use in the companies/organisations under study

As was mentioned earlier, the term e-waste, or WEEE, includes all components, sub-assemblies, and consumables such as large and small household appliances, IT and telecommunications equipment, lighting equipment, and automatic dispensers that are regarded as obsolete and have thus been discarded by their users (Qu et al., 2013). Step Initiative (2014) indicates that WEEE includes a wide range of products with circuit or electrical components that are powered by electricity and/or a battery.

The types of electrical and electronic equipment used by the companies/organisations under study varied (Figure 4.4) depending on the nature of the work they did. The respondents were asked to tick items from a list to indicate the equipment they currently used. The results are summarised in Figure 4.4.

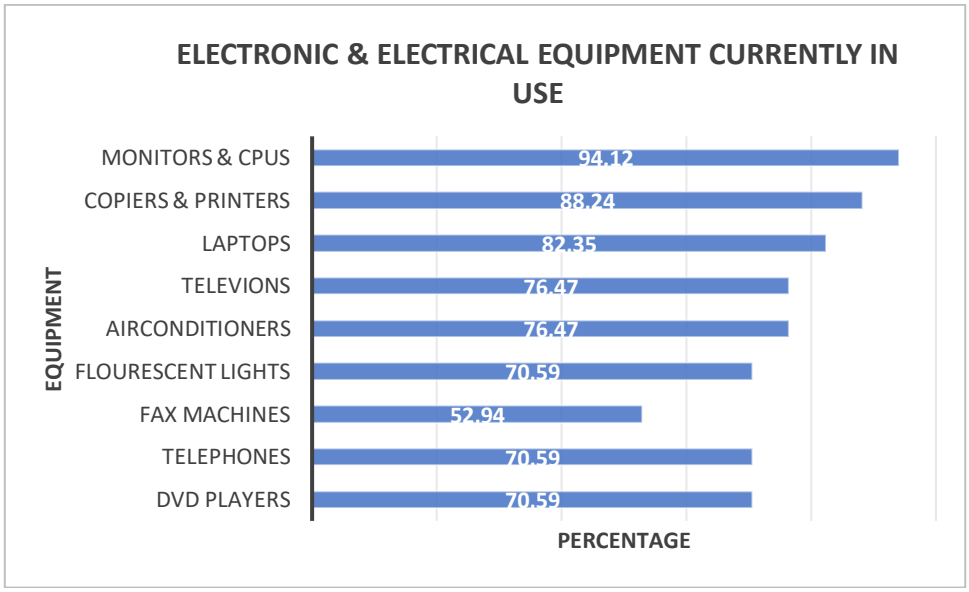

Figure 4.4: Electronic and electrical equipment mostly in use

The participants were also asked to mention other electrical/electronic equipment they used that was not included in the list. The items that were mentioned by participants

over and above this were industry specific for example accommodation establishments included kitchen appliances and educational institutions talked about equipment mostly used in lecture halls such as overhead projectors.

4.2.3 Hazardous e-waste

Studies conducted over several years have shown that some components in e-waste contain toxic substances that will have an adverse impact on human health and the environment if not handled properly (Verma & Prakash, 2020). Various researchers caution that, if e-waste is improperly handling and processed, it releases different types of chemicals and pollutants into the environment. It has been argued that such toxic substances can accumulate in the human body through various pathways. Inhalation of contaminated air and dust is considered the most important pathway (Wong et al., 2007; Fu et al., 2008).

In the current study the respondents were asked if they considered e-waste as hazardous or not. Two (11.76%) did not while fifteen (or 88.24%) understood that e-waste could be hazardous. One respondent argued that if any such equipment was still intact, it did not pose a danger to humans or the environment. Grant et al. (2013) points out that there is a relationship between e-waste exposure and health-related consequences. Such health consequences are mainly outcomes such as poor reproductive, lung, and thyroid functions as well as diminished growth and changes in cell function. Examples of two components found in e-waste that may have adverse effects on human health are the following:

- The brominated flame retardants present in plastic material interfere with fertility and have a negative effect on the nervous system.
- Lead, which is mostly present in the cathode ray tube (CRT) of old television sets and lead-acid batteries, may cause vomiting, diarrhoea, convulsions, coma, and even death when induced into the human body.

4.2.4 E-waste generated by the companies under study

The respondents were asked to agree or disagree with the statement: "*Our company generates large volumes of e-waste".* The results (Table 4.1) indicate that seven (41.18%) disagreed with the statement. These respondents explained that the life span

of most electronic equipment was longer than five years, and thus these items were only discarded after five or more years. Eight (47.06%) agreed that their companies/institutions generated large quantities of e-waste, while two (11.76%) strongly agreed that their companies produced large volumes of e-waste.

Table 4.1: High volumes of e-waste generated by the participating companies

Response	Percentage %	Frequency
Strongly disagree	0	0
Disagree	41.18	7
Neither disagree nor agree	0	0
Agree	47.06	8
Strongly agree	11.76	2

Consistently improved designs and smart functions resulting in ever-changing and improved technological developments over the last 20 years have caused the rapid obsolescence of many electronic items. The lifespan of many of these items has been considerably shortened due to advancements in electronics, their attractive designs, and marketing and compatibility issues. The average lifespan of a new computer has decreased from 4.5 years in 1992 to an estimated 2 years in 2013, and this has resulted in increasingly higher volumes being discarded at an increasingly rapid rate (Kidde, Naidu & Wong, 2013). The estimated lifespan of various EEE and their weights are presented in Table 4.2 (Kidde, Naidu & Wong, 2013).

Table 4.2: E-waste types and their estimated lifespan

Item	Mass of Item (kg)	Estimated Life Span (years)
Personal computer (PC)	25	3
Fax machine	3	5
Cellular phone	0.1	2
Electronic games	3	5
Photocopier	60	8
Television set	30	5
DVD Player/Video recorder	5	5
Air conditioner	55	12
Dish washer	50	10
Electronic cooker	60	10
Freezer	35	10
Hairdryer	1	10
Iron	1	10
Kettle	1	3
Microwave	15	7
Refrigerator	35	10
Toaster	1	5
Tumble dryer	35	10
Vacuum cleaner	10	10
Washing machine	65	8

Source: Kidde, Naidu & Wong, 2013

The study noted that the entities that produced the largest volumes of e-waste were mainly government departments and tertiary institutions. It is argued that this is due to the large number of electrical and electronic equipment they acquire for the use of the

extensive number of people they employ. All such equipment become e-waste once they have reached their end-of-life.

4.2.5 Management and disposal of e-waste

The volume of e-waste that is generated is determined by the frequency of the use of electrical and electronic equipment in an organisation or institution. It came as no surprise that all the respondents reported the use of electronic equipment to varying degrees. Questions were posed to ascertain the measures each organisation employed to appropriately handle and dispose of their e-waste.

4.2.5.1 Procedures and guidelines regarding e-waste

The procedures and guidelines employed by the organisations to dispose of e-waste varied, but all commonly endeavoured to ensure that structure was maintained and protocol was followed. Twelve participants (70.59%) indicated that their organisations had a policy to manage e-waste.

Table 4.3: Procedures and guidelines to manage e-waste

E-waste Management Protocol in Place	Percentage %	Frequency
Yes	70.59	12
No	29.41	5

The following guidelines were commonly in place Table 4.4:

- In five (29.4%) of the organisations, all their information and communications technology devices and other electrical equipment were managed by their respective finance departments (also referred to as the Asset Management Section). This department was reportedly responsible for the maintenance, repair, and disposal of electronic and electrical equipment. If any such equipment could not be repaired, the finance department was responsible for declaring it obsolete and replacing it with a new one. Generally, an asset register

form was completed to report defunct ICT equipment such as computers, laptops, or printers when they broke down or became obsolete.

- Two (11.76%) of the respondents mentioned that the obsolete electrical items in their organisations were taken back to their head offices (Table 4.3). Members of the head office staff were then responsible for appointing contractors to dispose of or recycle these items.
- A tender process was followed by three (17.64%) of the organisations for the safe disposal of e-waste. Advertisements were placed in the public domain and the successful contractor would then provide a disposal certificate to authenticate its disposal practices.
- Two (11.76%) of the companies/organisations had clear guidelines regarding the appointment of a registered e-waste recycler who would be responsible for the removal, recycling, or disposal of their e-waste. In these cases, a certificate had to be submitted after each collection to authenticate the manner of disposal/recycling.
- In four instances (23.52%), the companies did not have procedures or guidelines in place for the disposal of e-waste. The e-waste was stored on site for long periods of time. It was reported that the stored equipment was sometimes stolen. Some organisations sold old equipment to staff members at much reduced prices.
- One participant's organisation (5.88%) disposed of old/dysfunctional electrical and electronic equipment by crushing it and then disposing of the waste at a general waste landfill site. The respondent explained that this organisation's earlier policy had been to sell obsolete equipment to staff, but this had been reviewed because some members tended to mishandle equipment on purpose so that broken devices could be sold cheaply, only to be fixed and used by them. Some workers even removed parts to render devices dysfunctional, only to buy these items cheaply and then having them fixed at low cost.

Not having clear guidelines seemed to create confusion in some organisations. For instance, in one organisation two separate departments were responsible for the procurement and maintenance of devices and equipment, and e-waste was then managed differently in various sections of the organisation. In one section e-waste was

disposed of in municipal bins, while in another section such waste was stored and later handed to an appointed service provider for proper disposal or for recycling.

Table 4.4 Policy on e-waste handling procedures

Handling Procedure	Percentage	Frequency
Finance Dept	29.4%	5
Head office	11.76%	2
Tender process	17.64%	3
Registered e-waste recycler jk	11.76%	2
E-waste material stored	23.52%	4
Crushed and disposed at general waste landfill	5.88%	1

A concern raised by the member of one organisation was that sensitive information could be leaked; therefore, it was prudent to crush the equipment on site. Another participant mentioned that his company made use of e-waste drop- off points, for example at Makro or at other shopping centres.

4.2.5.1 Disposal of e-waste

Different methods of e-waste disposal are employed in different countries. The six most common disposal methods are: second use, storage, discarding, disassembly, formal recycling, and informal recycling. To achieve the environmentally sound recycling of e-waste, particular skill and the training of disposal operators are required. To screen waste for toxic and valuable materials, the appointment of expert personnel is a prerequisite. If e-waste is not handled properly, the environment and people's health may be adversely affected (Garlapati, 2016).

The participants were asked to indicate the process that was followed when electrical equipment had broken down. Figure 4.5 shows that six companies/organisations

(35.29%) stored their e-waste for some time before any decisions to recycle, repair, or donate were taken.

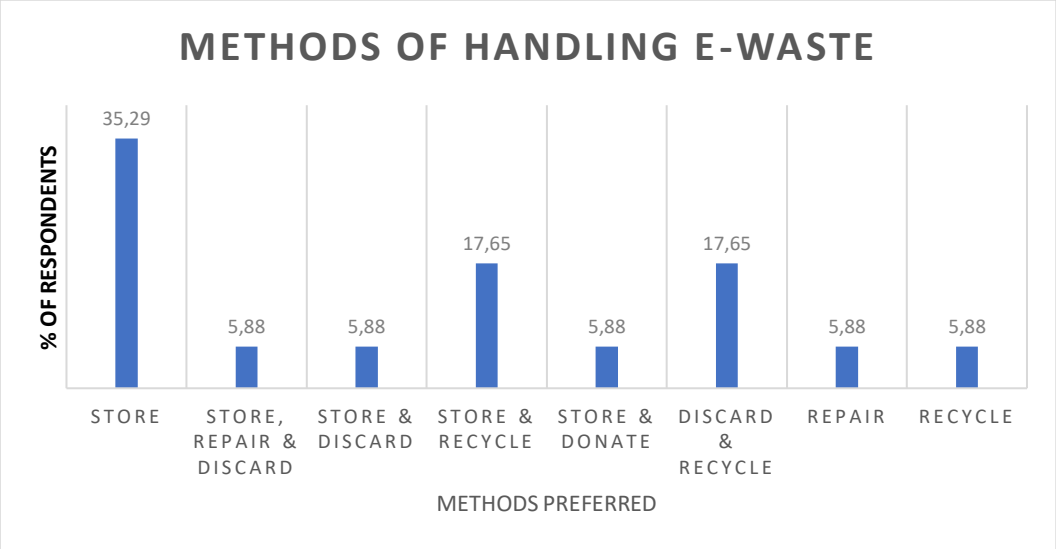

Figure 4.5: Methods used to handle e-waste

4.2.5.3 E-waste collection services

Seven (41.18%) of the respondents indicated that their e-waste was collected by an authorised e-waste management and disposal company. Nine (52.94%) stated that they were not using the services of an authorised company/contractor, while one (5.88%) said that he did not know how e-waste was handled (Table 4.5). All the respondents (41.18%) who said they were using the services of a registered waste company for waste disposal revealed the name of the recycling company. It was confirmed that all these companies were based in the study area, thus confirming this claim.

Table 4.5 E-waste collection services

Collector	Percentage	Frequency
Registered company	41.18%	7
Non-registered company	52.94%	9
Do not know	5.88%	1

According to Lydall et al. (2017), there are 100 formally registered e-waste businesses and service providers in South Africa. These companies are generally involved in the early stages of the supply chain, with a few companies acting as points for consolidation (refurbishing or dismantling of waste) or processing waste for export. The typical e-waste value chain in South Africa is presented graphically in Figure 4.6.

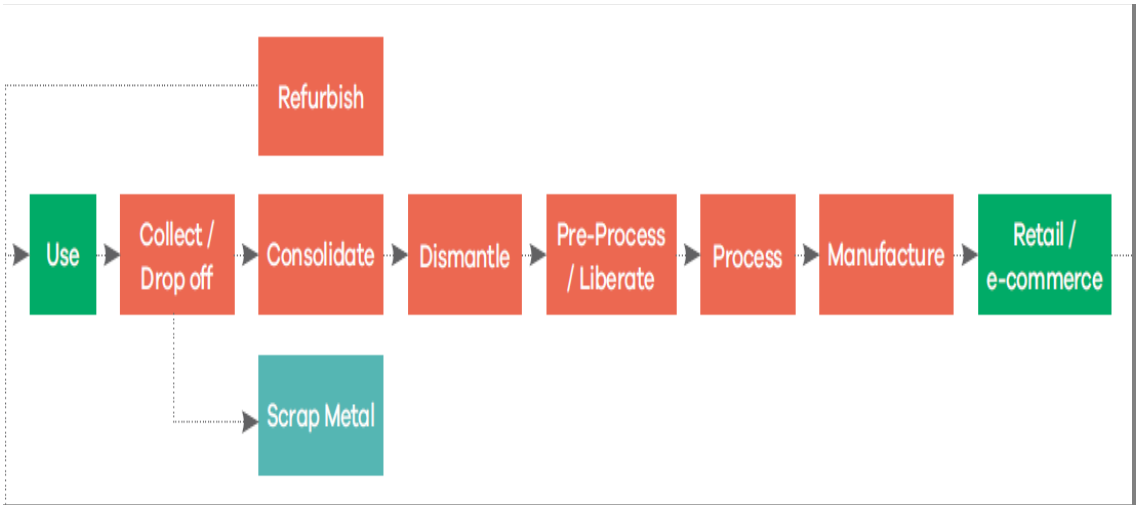

Figure 4.6: Typical e-waste value chain (Source: Market Intelligence Report, 2019)

4.2.5.4 Methods used for e-waste disposal

Nine of the participants (52.94%) (Table 4.6) indicated that they did not know what happened to discarded equipment once it was removed, but they assumed it was recycled. This lack of knowledge was confirmed as no proof of disposal (such as a disposal certificate) was required in these cases, and there was thus no verification that contractors had removed old and unused equipment to discard it in an appropriate or sustainable manner. This figure includes the companies that were not using the services of registered recycling companies. However, eight (47.06%) of the respondents indicated that they received regular confirmation of e-waste disposal by their appointed recycling companies in the form of a waste disposal certificate. The results are shown in Table 4.6.

Table 4.6: E-waste disposal method by service providers

Method used	Percentage	Frequency
No confirmation or verification	52.94	9
Verification in form of waste disposal certificate	47.06%	8

4.2.5.5 Cost of e-waste disposal services

Eleven (64.71%) of the respondents indicated that their organisations/companies were able to pay service providers for the collection and recycling of e-waste. Six (35.29%) stated that they were not able to pay for such services and that selling the recyclable parts of this type of waste was more profitable. The responses are recorded in Table 4.7.

Table 4.7: Organisations willing/able to pay for e-waste collection services

Willing/Able to Pay for E-waste Disposal	Percentage %	Frequency
Yes	64.71	11
No	35.29	6

4.2.5.6 Lighting equipment

Commonly used fluorescent lights are energy saving but, because they contain mercury even in relatively small quantities, they must be disposed of as hazardous waste. According to Baldé et al. (2018), mercury is used in fluorescent light sources such as background lights in older flat panel displays and TVs, in compact fluorescent lamps (energy-saving lamps), fluorescent lamps, measuring and control equipment, and in old switches. If these appliances are not properly recycled or disposed of and are abandoned on open dumpsites, mercury can enter the food chain and accumulate in living organisms where it will damage the central nervous system as well as the thyroid, kidneys, lungs, and the immune system (Baldé et al., 2018).

Most organisations that were represented in the study still used fluorescent lights in their buildings. Only a few participants stated that they used LED lights instead. When asked how these former items were discarded, 52.94% stated that they had special bins for fluorescent lights and that these were collected by a designated service provider for recycling. Two companies in KZN are known to recycle lighting material, namely Reclite and E-waste Africa. Table 4.8 shows the responses from participants who were still using the fluorescent light bulbs.

Table 4.8: Disposal of fluorescent lights

Disposal Method	Percentage %	Frequency
Discard it in a bin	23.53	4
Cover with plastic and discard it in a bin	11.76	2
Discard it in a special bin	52.94	9

Following the introduction of norms and standards (GN R636) for the disposal of waste at landfill sites (South Africa, 2013), lighting e-waste was abolished from disposal at these sites in 2016. However, regardless of this ban, large volumes of lighting equipment are still discarded at these sites.

4.2.5.7 Most frequently discarded electrical and electronic equipment

The rate at which electrical and electronic products have been manufactured, purchased, and discarded in recent years has led to the generation of substantial quantities of e-waste (Baldé et al., 2014). Forti et al. (2020) report that the world generated 53.6 Mt of e-waste in 2019, and that this volume is projected to grow to 74.4 Mt by 2030. This growth is mainly influenced by higher consumption rates of EEE, its short lifespan, and few repair and reuse options.

Figure 4.7 shows that eight (47.06%) of the respondents indicated that the items their respective organisations discarded most frequently were information and communications technology (ICT) equipment. Broken or obsolete mobile phones are critical electronic e-waste items as their use becomes quickly obsolete due to their fast

release, new features, and short life span (Islam & Huda, 2019). A study conducted in China in 2019 found that the average age of mobile phones was 1.6 years, which was shorter than the lifespan of tablets (1.7 years), desktops (3.5 years), laptops (2.0 years), and digital cameras (2.5 years) (Zhang et al., 2019).

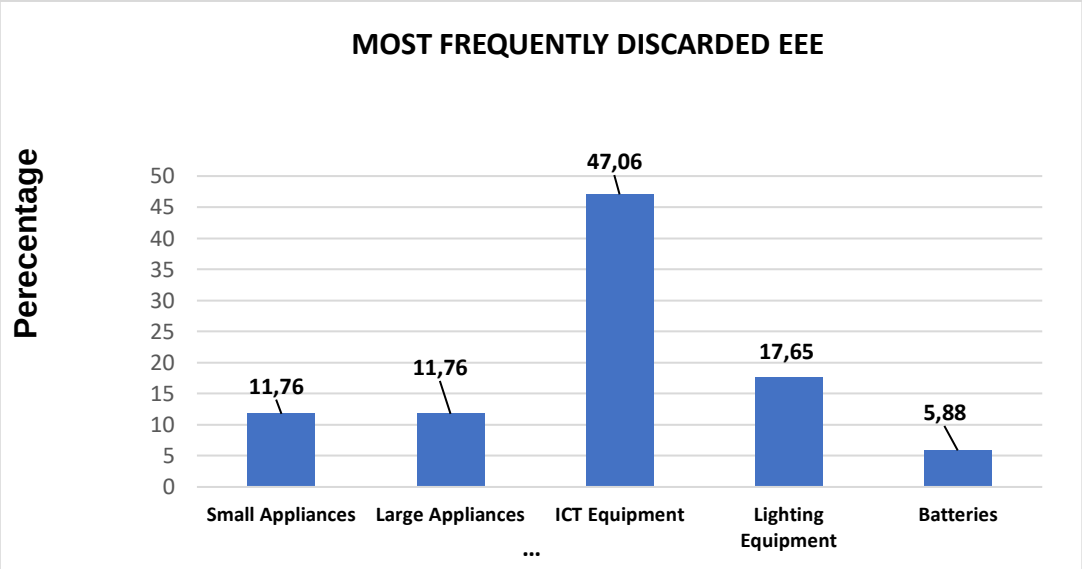

Figure 4.7: Most frequently discarded EEE

4.2.6 Regulations on e-waste handling

The respondents were asked if they were aware of any legislation that regulates the handling of e-waste in South Africa. Eleven (64.71%) were not aware of such a regulation while six (35.29%) were aware. The results are shown in Table 4.9. In South Africa the National Environmental Management Waste Act No. 59 of 2008 and the National Environmental Management Act of 1998 both provide guidelines for the management of e-waste. According to Keith Anderson, Chairman of eWASA, the implementation of these laws is not monitored and therefore poor, and the application of the guidelines is treated as voluntary (South African are drowning in e-waste, 2018).

Table 4.9 E-waste regulation in South African

SA Regulation on e-waste	Percentage	Frequency
Aware	35.29%	6
Not aware	64.71%	11

4.2.7 Participants' general comments

At the end of the questionnaire, the respondents were asked to offer some general comments about e-waste handling. Their responses are summarised below:

- Some felt that their organisations needed to improve their e-waste management strategies.
- They argued that more recycling collection points should be established to allow the public to safely drop off broken electrical appliances. This could be done at a reasonable fee.
- They also argued that many government departments fail to implement proper e-waste management strategies.
- They highlighted that storing obsolete equipment while waiting for the disposal process to be approved was a problem. They argued that some companies did not have enough storage space.
- Some felt that South Africa's e-waste disposal practices were not up to standard. They argued that although regulations and laws were in place, enforcement was lacking.

To manage the growing end-of-life volumes of electrical and electronic products, policies and legislation have been developed by the governments of various countries. These policies are the forerunners of plans and courses of action that society, industries, governmental departments, and private institutions need to implement to manage e-waste effectively. South African legislation regarding the management of e-waste is reviewed in the next section.

4.2 Review of South African Legislation on E-Waste

South Africa has a three-tier governing system; thus, governance is scaffolded to national, provincial, and municipal levels (Finlay & Liechti, 2008). Waste management policies and legislation are established by the national government, which means that limited specific waste legislation is established at provincial or municipal level. However, at municipal level specific waste legislation, in the form of bylaws, must be established.

4.3.1 The Constitution of the Republic of South Africa

The Constitution of the Republic of South Africa Act No. 108 of 1996 (South Africa, 1996) is the most important legislative document of this country as it acknowledges the basic human rights of every South African citizen and provides the foundation for environmental regulations and policies. For instance, Section 24 of this Act states that everyone has the right to an environment that is not harmful to their health or well-being. Each citizen has the right to live in an environment that is protected for the benefit of present and future generations through reasonable legislative and other measures that should prevent pollution and ecological degradation, promote conservation, and ensure sustainable development.

4.3.2 The National Environmental Management Act No. 107 of 1998

The National Environmental Management Act No. 107 of 1998 (NEMA) is a statutory framework that enforces Section 24 of the Constitution (South Africa, 1998). NEMA is intended to provide for co-operative environmental governance by establishing principles for decision making on matters affecting the environment.

4.3.3 National Environmental Management: Waste Act No. 59 of 2008

The year 2008 was a significant milestone for the waste management sector in South Africa, as it was in this year that the first piece of waste legislation was promulgated, namely the National Environmental Management: Waste Act 59 of 2008 (South Africa, 2008). This Act applies to different stakeholders in the waste industry such as collectors, producers, recyclers, and re-furbishers. This Act is underpinned by sustainable resource management principles that drive the waste hierarchy and promote reuse, recycling, and recovery as opposed to landfill disposal only (Sadan, 2019). The main aim of NEMWA is to protect health and the environment. It provides reasonable measures for the prevention of pollution and ecological degradation and for securing ecologically sustainable development.

The Act makes provision for measures to improve waste management practices, including the following:

- minimizing the consumption of natural resources;
- preventing the generation of waste;
- reducing, recycling, and recovering waste;
- treating and safely disposing of waste as a last resort;
- promoting and ensuring effective waste service delivery; and
- rehabilitating land where contamination has occurred.

4.3.4 Research development and innovation (RDI)

The Waste Research, Development, and Innovation (RDI) Roadmap is an initiative of the Department of Science and Innovation (DSI). This 'map' (or plan) guides South Africa's public and private sectors' investment in waste research, development, and innovation over the period 2015 to 2025. The Roadmap aims to address issues relating to the following five priority waste streams:

- municipal solid waste;
- waste from electrical and electronic equipment (WEEE);
- plastic waste;
- organic waste; and
- waste tyres.

The successful implementation of the Roadmap is expected to assist government and industry to significantly increase the diversion of waste away from landfill towards value adding alternatives through more effective decision making, faster introduction of context-appropriate technologies, the export of knowhow and technology, and the strengthening of RDI capability and capacity (Department of Science and Innovation, 2012).

4.3.5 Waste Removal By-Law 2016 of the eThekwini Municipality

In South Africa, municipalities are the main bodies in the governmental sphere that are mandated to deliver waste management services to citizens. These services include waste removal, waste storage, and waste disposal. NEMWA (South Africa, 2008) stipulates that all these activities must be carried out in a manner that does not conflict

with waste service standards as specified in the Act. In performing these services, municipalities must adhere to all national and provincial standards. They are also required to integrate their waste management plans with national integrated development plans (IDPs) and they must pass solid waste by-laws.

In compliance with the Act, the eThekwini municipality has established local standards for waste collection, separation, storage, and disposal. These standards focus on the effective and efficient management of domestic waste. However, Chapter 5 of the eThekwini Municipality Waste Removal By-Law of 2016 (eThekwini, 2016) states that the municipality is not obliged to collect and remove special industrial waste, hazardous waste, or health care waste. Each industrial or hazardous waste generator must therefore liaise with an authorised waste removal contractor for the removal and disposal of its waste at a suitable waste disposal site at a specified tariff. Therefore, as e-waste is categorised as hazardous waste, the municipality is not responsible for its collection and disposal.

4.4 Summary

- The data that were collected by means of questionnaires revealed that most of the companies/organisations under study were not handling and disposing of their e-waste properly, and it could thus be concluded that large volumes of this waste would end up at landfill sites.
- Several organisations showed interest in managing their e-waste in an environmentally responsible manner. Some even requested more information on companies that collect and recycle e-waste.
- Some companies/organisations were willing to use suitable information to formulate their own guidelines on e-waste handling. However, in some organisations effective e-waste management will remain a problem as waste in general is not deemed a matter of high priority by their respective top management structures. This is unfortunate, as poor e-waste management decisions will eventually have a negative impact on the health of people and the environment, as such waste will end up in increasing volumes at landfill sites.
- The Solid Waste Department of the eThekwini Municipality is responsible for removing and disposing of general waste from households as well as various

businesses and industries. It is also responsible for operating three landfill sites. Because e-waste is categorized as hazardous waste, this Department should not accept this waste for landfilling. However, the data revealed that some organisations mix their general waste with e-waste that is then collected and taken to landfill sites for disposal. This means that, even though the municipality is not responsible for the collection and disposal of e-waste, unspecified volumes of this waste end up at general waste landfill sites. Measures thus need to put in place to ensure that such waste disposal practices do not occur and that companies that are guilty of this transgression are taken to task.

- Most of the respondents were not aware that e-waste is hazardous. Awareness of this fact should thus be created by disseminating e-waste disposal facts to all organisations/companies/institutions, large and small. This should reduce the negative impact that the mismanagement of e-waste has on the environment. Educating people and making pertinent information regarding e-waste available on a broad front will enable managers to make informed decisions and to formulate appropriate strategies to manage their companies' e-waste. Such information should include proper disposal methods and the names of reputable companies that provide e-waste removal and recycling services.
- South African legislation on e-waste management is ample, but many organisations are not aware of it or turn a blind eye to its requirements. There is also poor law enforcement as many companies and organisations persist in poor handling and disposal of e-waste. Programmes to create awareness of the need for proper e-waste management among all role-players in the e-waste industry, whether they operated formally or informally, should be undertaken to ensure compliance.

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CHAPTER 5

RECYCLING WASTE FROM ELECTRICAL AND ELECTRONIC EQUIPMENT

5.1 Introduction

E-waste is generated when used (broken or obsolete) electronic devices such as computers, cellular phones, and household appliances that are not fit for their original use are discarded. Such items are destined for recovery, recycling, or disposal. In South Africa, waste from electrical and electronic equipment (WEEE) is defined as an item “that uses an electric power supply to perform its functions and that has been discarded by its original owner” (Lydall et al., 2017).

Park et al. (2017) reported that the production of e-waste is increasing at an alarming rate due to advancing technology that creates faster, smaller, more advanced, and more convenient devices. It is thus a given that in this modern technological age we live in a consumer-driven society that is constantly buying, upgrading, and replacing devices and equipment of convenience. When these products reach the end of their usefulness, they are discarded and become e-waste. Proper disposal of this waste is essential due to the harmful materials many of these devices contain.

Baldé et al. (2015) stated that directing WEEE away from landfill through recovery and processing has enormous environmental benefits. This is because many of these items contain hazardous materials that may be harmful to health and the environment if inappropriately discarded or dismantled. The recovery of the useful components of these items creates an important source of secondary metal supply, particularly when metals of high value that are difficult to access are recycled. Moreover, the value of recyclable components and the rate at which WEEE is generated also present significant opportunities to expand the small- and medium-sized business sector, particularly in developing countries. United Nations University recently estimates the value of minerals in e-waste at 55 billion Euros (Baldé et al., 2017). Another important function of recovery and recycling is to remove and properly dispose of all the toxic substances that are present in e-waste.

According to Binnemans et al. (2013), there are many advantages of e-waste recycling, but the volumes that are currently being recycled globally are still relatively limited. Lydall et al. (2017) argued that, due to the non-availability of technology to process certain e-waste items and the lack of investment in the e-waste recycling industry, only about 11% of e-waste is currently recovered in South Africa. In this country, recycling activities have concentrated mainly on the recovery of ferrous and non-ferrous metals because of an established market for these commodities in South Africa. It is therefore not surprising that South Africa has more than a hundred formally registered e-waste businesses and service providers. The Waste Research Development and Innovation Roadmap Research Report (Lydall et al., 2017) stated that these companies are involved in the early stages of the waste value chain, but that only a few companies dismantle, refurbish, and process e-waste for export purposes.

5.2 Methodology

A second survey (the results of the first survey were discussed in Chapter 4) was conducted among companies that collected e-waste for disposal and recycling and that operated within the study area. They were purposively selected as they provided waste collection services to various companies and organisations at the time of the study. Upon close scrutiny, it was found that there were very few formal electronic waste recycling companies in the eThekwini municipal area. Eventually eight were identified and contacted with the request to participate in the study. However, four declined, with the result that a questionnaire was sent to each of four companies whose management identified a respondent to complete the questionnaire.

Convenience sampling was used for this part of the study and a questionnaire was used to collect data from each of the four companies responsible for e-waste collection. One respondent from each company completed the questionnaire. Although the questionnaire was distributed to four formal e-waste recycling companies, it is acknowledged that informal e-waste recycling activities take place in the city of Durban and its surroundings. These activities are mainly executed by informal collectors who dismantle various electronic appliances and then sell the valuable material they collect to scrap metal buyers. The South African State of Waste Report (2018) indicated that

there are over 10 000 informal pickers engaged in e-waste collection in South Africa, whereas about 2 000 regular collectors operate formally in this industry.

5.3 Results and Discussion

This study focused on formal e-waste collection and recycling companies and thus no informal collectors/recyclers were surveyed. Formal e-waste recycling is an important industry in many countries (International Labour Organisation, 2019) When e-waste is collected and treated formally, the process usually includes the following steps:

- Collection: products are collected from public recycling centres, various organisations, workplaces, public institutions, or private companies.
- Sorting and disassembly: a product is dismantled, and valuable or hazardous components are removed manually.
- Size reduction: products are broken down into relatively homogenous streams by mechanical and physical processes and reusable and recyclable components are salvaged.
- Separation: streams from the previous step are again separated and detoxified by thermal, chemical, and metallurgical methods to recover valuable materials. Toxic materials are separated and appropriately discarded.

5.3.1 The recycling companies' years of operation

GreenCape (2018) states that South Africa has a well-developed network of e-waste collectors and dismantlers, with much of the e-waste stream being processed in Gauteng. To understand the services that the four recycling companies offered, the respondents were asked how long their companies had been in operation. They were also asked to comment on the areas they covered and the type of service they rendered. The following is a summary of their responses:

- Company A had been in operation for more than thirty years (Table 5.1). It provided total waste management and recycling and its staff serviced customers across KwaZulu-Natal (KZN) province.
- Company B started operating in 2013. It serviced different regions in KZN, but most of its customers were in the eThekwini Metro area.

- Company C had been in operation for 17 years. It serviced companies within an 80 to 100 km radius from its location in Durban. It also provided a total waste management service to the customers they contracted.
- Company D had been in operation since 1999. It operated nationally but its head office was in Durban.

Table 5.1: Years the recycling companies have been in operation

Company's Code	Years in Operation	Percentage of Sample %	Frequency
A	5	25	1
B	17	25	1
C	20	25	1
D	30	25	1

5.3.2 Type of service rendered

The respondents were asked what type of service they rendered. The following summarises the responses:

- Company A sorted and sold different types of e-waste which were collected from their customers.
- Company B provided a service to businesses who contacted them by telephone or email. They then scheduled a collection date.
- Company C collected electronic waste from customers' premises and brought the items on site for separation.
- Company D offered a collection service but also allowed companies and the public to bring old equipment to their site for disposal or recycling.

Table 5.2: Services rendered by the four waste management companies

Service	Percentage %	Frequency
Items delivered to the site by customers for recycling and disposal	25	1
Collection service for recycling and disposal	75	3

5.3.3 Business activities and growth

To better understand developments in the e-waste recycling industry, the respondents representing the four companies were asked if they had witnessed an increase in the number of customers they had serviced over the years. The responses indicated that there was no increase in their clientele before 2012 (Figure 5.1), whereas a limited increase occurred between 2012 and 2014. A significant increase occurred between 2014 and 2016.

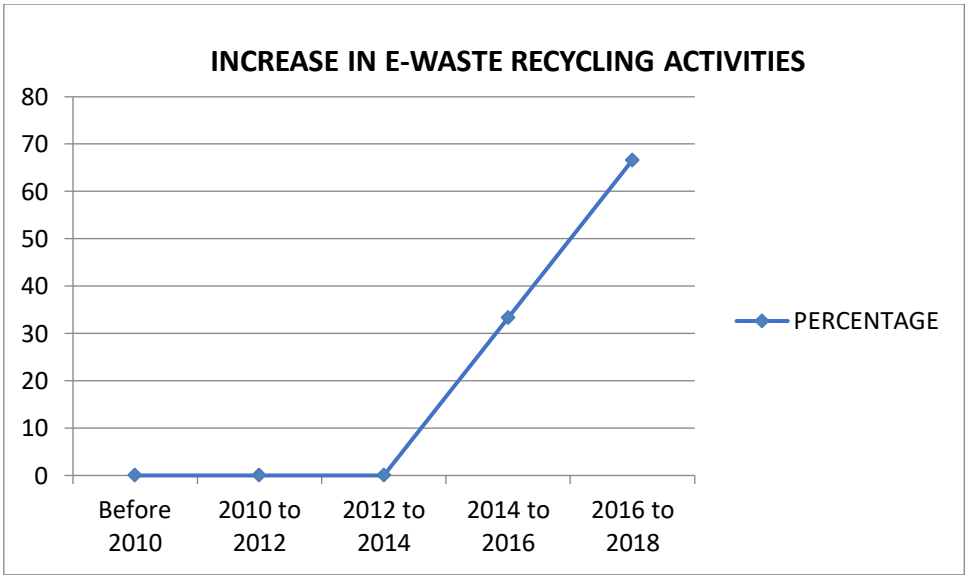

Figure 5.1: Increase in clientele requiring e-waste disposal

One company reported a decline in their number of customers. They attributed this to a global drive that resulted in more people printing less and more people going digital. They also witnessed an increase in the production of materials that were not recyclable. Participants argued that many people bought items that contained these

materials because they were cheap, but these items and their components were not recyclable and thus tended to be discarded at general waste landfill sites.

According to GreenCape (2018), there is a viable e-waste collection network in South Africa and the country also has the technological means to generate income from e-waste. However, many e-waste processing facilities are not running at full capacity and there is thus an unmet demand for e-waste recycling. Gaining access to e-waste seems to present the greatest challenge. This can be attributed to factors such as insufficient drop-off points, the inaccessibility of collection points, no separation of e-waste from other solid waste streams at source, and low public awareness of the need to discard e-waste responsibly (GreenCape, 2018).

5.3.1 Factors that influence increased demands for e-waste recycling

Three of the respondents reported that there had been in increase in the number of customers they were servicing. They were asked what they thought the contributing factors were for this increase, and the responses were as follows:

- **Fast-paced technological advancement:** When the manufacturers of electronic equipment introduce newly developed products into the market, many people discard the old and buy the newer version. This causes many old/obsolete devices to be discarded, often in waste bins that are emptied by the municipality.
- **An increase in marketing and awareness**: Many new initiatives are driven by waste management companies to encourage the public to bring unused electronic equipment to certain collection points for proper disposal. This seemed to have a positive impact on proper disposal practices.
- **Legislation on e-waste management:** Legislation has been introduced to prohibit the disposal of some electrical and electronic equipment at general waste landfill sites. This has had some positive impact, but unfortunately not nearly enough.

5.3.2 Awareness of proper e-waste disposal practices

The respondents were asked if they thought the public was aware that e-waste is hazardous and should be disposed of properly. All the respondents (100%) indicated that they thought that many people were not aware that electronic equipment contains toxic chemicals and that it should be handled and disposed of in a way that will ensure that the environment is protected. They observed that the number of private people who contacted them for e-waste collection services was very low compared to the number of organisations in the area. They argued that the unspecified volumes of e-waste mixed with general waste that was disposed of at landfill sites was also an indication that awareness still needed to be enhanced.

The researcher visited various companies/institutions that are known to generate e-waste (such as old computers and fridges) and observed that many such items were simply dumped as trash into municipal skips. One of the recyclers stated that businesses in general were more concerned about making a profit than paying for waste management services. It was strongly argued that this attitude resulted in the improper management of e-waste. Colesca, Ciocoiu and Popescu (2014) argued that, for high recycling rates to be achieved, it is important that consumer behaviour changes to ensure that they participate in proper waste disposal. Various factors affect consumers' recycling behaviour, such as demographic and socio-economic factors, environmental knowledge, entrenched habits, convenience, and motivation.

5.3.6 Proposed initiatives to create awareness

To create public awareness (Table 5.2), the respondents suggested the implementation of the following strategies (also see Table 5.5):

- **Advertising on television:** To reach larger numbers of the population, three (75%) of the respondents proposed that more educational programmes and advertising initiatives appear on television. Such initiatives should be used to educated citizens on the importance of correct waste disposal, particularly when they discard e-waste. Such campaigns should raise awareness of both health and environmental issues associated with poor e-waste disposal.

- **Newspapers:** Two (50%) of the respondents stated that advertisements should be printed in newspapers to inform the public where they can take their e-waste for disposal, such as the whereabouts of public drop-off points.
- **Governmental intervention**: All spheres of government should work together to create awareness of proper e-waste disposal. All four the respondents reported that most awareness programmes were aimed at schools and not at the larger public. All spheres of government thus need to conduct education and awareness initiatives.
- **Awareness initiatives by industries and companies**: Industries and companies that manufacture or trade in equipment and devices that can be recycled as e-waste should also play a role in awareness creation by providing funding for awareness programmers and working in collaboration with the government to curb the impact of e-waste.
- **Awareness creation**: Two (50%) of the participants proposed the following awareness initiatives: Cohesion and collaboration (government working together with the e-waste industry), roadshows, and enhanced communication (such as using municipal service bills and various social media platforms to create e-waste disposal awareness).

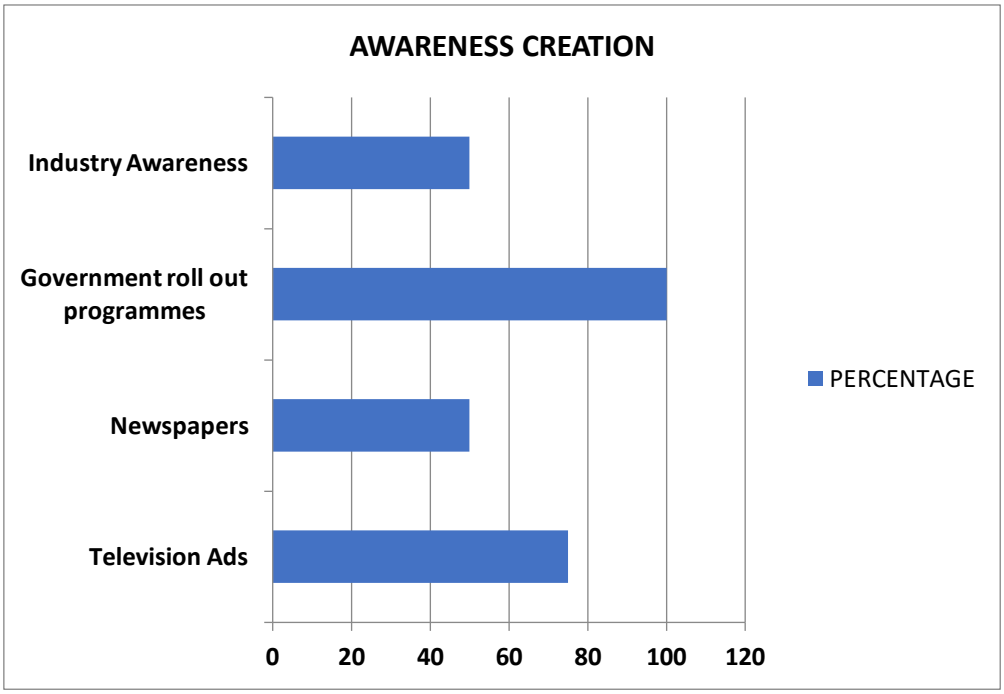

Figure 5.2: Awareness creation on e-waste recycling

5.3.7 Monthly volumes of recycled e-waste

The actual volume of e-waste that is produced in South Africa is unknown, and methods used to provide estimates vary. According to the e-Waste Association of South Africa (eWASA), this country produces an estimated 322 000 tonnes of e-waste per year, while a per capita estimate supplied by Lydall et al. (2017) indicated that the annual e-waste produced was approximately 367 314 tonnes in 2016.

Respondents from the four recycling companies were asked to indicate the average volume of electronic waste they received monthly. The smallest recycling company reportedly received 500 kg, and even less. This can be attributed to legislation that requires companies processing more than 500 kg of waste monthly to apply for a waste license at a fee. However, although this company had space, it operated on budgetary constraints and thus remained within the set limit. The three larger companies were able to receive and process approximately seven tonnes of e-waste a month. The findings are summarised in Table 5.3.

Table 5.3: Average volumes of e-waste recycled per month

Volume	Percentage %	Frequency
Less than 500 kg	25	1
Between 501 - 1 000 kg	0	0
1 001 to 1 500 kg	0	0
More than 1500kg	75	3

5.3.8 Type of equipment recycled

The equipment that the participating companies generally recycled comprised ICT units (computers, printers, and mobile phones) as well as televisions and electrical appliances such as fridges, microwaves, air conditioners, and washing machines. Other recycling companies that only dealt with one specific type of e-waste indicated that they only collect those.

Table 5.4: Types of WEEE collected for recycling

Equipment	Percentage %	Frequency
Monitors	75	3
Computer keyboards	75	3
CPUs	75	3
Laptops	75	3
Printers	50	2
Mobile phones	50	2
Televisions	75	3
Air conditioners	50	2
Fluorescent light tubes/bulbs	25	1
CD & DVD players	50	2
Household appliances (e.g., kettles, fridges, washing machines, microwaves)	75	3
Others (e.g., ink cartridges)	25	1

5.3.9 Valuable materials recovered from of e-waste

It was found in Table 5.5 that prices for recovered recyclables fluctuated depending on the market over a specific period. The respondents listed the types of commodities extracted from e-waste and the value of each. Valuable materials that could be recovered were sold locally and nationally to manufactures focusing on different industries. Four of the respondents reported that they were not exporting any materials at the time the study was conducted. This was attributed to high export costs and strict government regulations regarding the exportation of such material. One respondent reported that his company refurbished about 20% of the equipment they collected, particularly computers and laptops.

Table 5.5: Commodities extracted from e- waste and their estimated value

Commodity	Value/kg
Subgrade	R2.00
Steel	R2.60
Aluminium	R11.00
Copper	R60.00
Printer circuit board (gold)	R8.00
Stainless steel	R12.00 to R15.00
ABS plastic	R1.00

One respondent reported that his company did not dismantle any equipment but sold it to recyclers that could process it. This equipment was collected, stored, and sold without dismantling any components. The prices at which such items were sold at the time of the study are presented in Table 5.6.

Table 5.6: Prices of intact equipment

Equipment	Value per Item
Telephones	R0.50
Batteries	R2.00
Mother boards	R15.00
Printers	R0.50
Computer monitors	R0.50

The South African State of Waste report (South Africa, 2018) estimated that about 17 773 items of WEEE were handled in 2015 by 27 firms. The bulk of the waste streams they handled (79%) comprised ICT and consumer electronic equipment. The surveyed firms recovered mainly ferrous metals (47%), non- ferrous metals (16%), and unquantified amount of printed circuit boards. The report further explains that, although local recycling companies are committed to processing such recovered materials locally, the complex parts are exported mainly to Europe and Asia. According to Forti et al. (2020) in 2019, the formal documented volume of collected and recycled e-waste in South Africa comprised 9.3 Mt, which was 17.4% of to the e-waste that had been generated (Forti et al., 2020).

5.3.10 E-waste not recycled

According to the participants, of the total volume of e-waste collected per month, about 5% is not recyclable. They dispose of this latter waste at a class I landfill that accepts hazardous and non-hazardous waste. One company reportedly recycled everything.

5.3.11 Obstacles impeding the proper recycling of e-waste

Although an increase has been noticed in the number of businesses and government institutions that are recycling their electrical and electronic waste, the e-waste recycling industry is still facing various challenges (Table 5.7). These challenges are summarised as follows:

- **Costs:** Recycling WEEE presents a challenge due to the hazardous components most contain, their highly technical recycling requirements, and the high overhead costs of environmentally sound waste management (Hossain et al., 2015). To operate a formal e-waste recycling company in South Africa, one needs to set it up a proper recycling facility with appropriate infrastructure. Yose (2014) observed that operating an e-waste recycling business requires suitable premises, protective wear for all employees (safety boots, work suits, gloves, glasses), tools and machines to dismantle equipment, security, and insurance.
- **Impact assessment:** An environmental impact assessment also needs to be conducted to acquire an official waste management license.

Table 5.7 Challenges associated with the recycling of WEEE

Obstacles	Percentage %	Frequency
Costs	25	1
Company policies	0	0
Lack of knowledge	0	0
Absence of recycling opportunities	50	2
Lack of legislation	25	1
Non-compliance with legal framework	100	4
Limited infrastructure	25	1
Poor logistics and lack of support from the government	25	1

E-waste is defined as hazardous waste and it is thus regulated accordingly by South African legislation (South Africa, 2014). Regulations limit the recycling and recovery of e-waste to less than 500 kg per day, otherwise a waste license is required. However, the financial implications of this process make it impossible for many small businesses to obtain this license even though they want to grow their operation and process more e-waste (GreenCape, 2019).

According to Yose (2014), small business that recycle e-waste are listed under Category A in the waste management activity list. For authorization to operate a basic

recycling business, application and assessment by an environmental assessment practitioner are required. The cost of the assessment ranges from R40 000 to R50 000, but if the business grows it may be listed under Category B, which means that an environmental impact assessment needs to be conducted, which is also costly (Yose, 2014).

- **Logistics**: Anderson et al. (2014) state that the overall value of e-waste is determined by costs associated with the collection, transportation, storage, and the appropriate treatment of all components. These costs are sometimes not in balance with the value of the recovered materials, which means that some recycling companies are not financially viable unless they resort to other means.
- **Lack of knowledge:** The expertise of personnel is a prerequisite in the waste recycling industry as they must screen products for any toxic and valuable components. Moreover, environmentally friendly processes must be adopted to separate toxic from desirable parts (Garlapati, 2016).
- **Non-compliance with legislation**: The implementation and enforcement of legislation is often side-lined in the e-waste recycling industry. Large volumes of e-waste still end up at landfill sites and some are illegally dumped on vacant lots, which results in environmental pollution.
- **Limited support:** The government and e-waste institutions such as eWASA often do not provide sufficient support. Cucchiella et al. (2015) argue that the environmentally sound management of e-waste requires the establishment of collection centres, transportation, treatment, storage, recovery, and the safe disposal of e-waste at national and regional levels. Regulatory authorities must provide these facilities and there should be incentives for better performance. However, both the latter are lacking to a large extent in this industry.

5.3.12 Skills development and training in e-waste management

The respondents who participated on behalf of their companies had different backgrounds and qualifications. Some had degrees and others had a Grade 12 National Senior Certificate. Most thought that training would benefit their personnel. One recommendation was that staff should improve their qualifications by obtaining, for instance:

- a qualification in Environmental Science as this would enhance knowledge about legislation and waste classification strategies, and
- a qualification in Electrical Engineering.

Ongoing training was also highlighted as they suggested:

- training on dismantling and how to handle equipment such as grinders and a blow torch; and
- training in accounting or bookkeeping.

Moreover, workers in the e-waste recycling industry need to be well informed about occupation-related health hazards. Personal protective gear and appropriate equipment must be provided to ensure the health of all workers. Regular health assessments also need to be conducted to maintain the safety and sustain the health of all personnel.

5.4 A Circular Economy

Over the years, many principles associated with sustainability and waste reduction have been developed and applied. These include the ‘cradle to cradle’ policy, the ‘zero waste’ policy, and the ‘closed-loop supply chain’ policy. Recently, the term ‘circular economy’ has emerged as a broadly encompassing concept that integrates many prior ideas and addresses a more extensive set of environmental issues and sustainability solutions.

A circular economy is defined as “a system of production and consumption that minimizes waste, optimizes the resources used with minimal pollution, regenerates natural capital, creates opportunities for jobs and entrepreneurship, and reshapes production and consumption from a life cycle and recycling perspective” (Fernholz et al., 2020).

The concept of a circular economy has much in common with long-standing efforts to address waste and pollution and includes a strong focus on the recycling and reuse of materials. It also considers redesign and ‘de-coupling’ within linear production and use

systems. These system modifications lead to changes in multiple considerations and the associated impacts from the very beginning to the very end of production and use cycles (Fernholz et al., 2020).

The circular economy is also a concept that proposes to slow down the rate of EEE consumption by circulating such items within the system for the longest possible time and minimizing or eliminating e-waste generation through smarter product design and business models (Parajuly & Wenzel, 2017). Electrical and electronic equipment (EEE) are complex by the very nature of their design. They comprise of up to 69 elements as listed in the periodic table and may include precious metals such as gold, silver, copper, platinum, palladium, ruthenium, rhodium, iridium, and osmium. They also include critical raw materials such as cobalt, palladium and osmium and non-critical metals such as aluminium and iron (Forti et al., 2020).

The circular economy model promotes the mining of e-waste as an important source of secondary raw materials. Forti et al. (2020) state that it has become important to improve the mining of secondary resources and reduce the use of natural resources due to material scarcity, unavailability, price fluctuations, and limited access. Moreover, the recycling sector in both developed and developing countries is faced with challenges such as high costs, rapid technological advancements, a poor collection system, the involvement of the private sector versus the government, and the need for effective training in the informal waste recycling sector.

5.5 Summary

WEEE may contain more than 1 000 different components, many of which are harmful to human health and toxic to the environment. Due to this reality, there are not many e-waste recyclers in the eThekwini Municipality area or even in the country at large, even though the demand for recycled electronic equipment is very high. The lifespan of electrical equipment is also decreasing, and this results in the accumulation of such equipment which, when improperly discarded, pollutes the environment.

Although the respondents reported that there had been an increase in the number of customers that they had been servicing over the years, they still felt that more

organisations should be educated and informed about proper processes to be followed when disposing of WEEE. They argued that all stakeholders (the e-waste industry, manufactures, associations, all spheres of government, and recycling companies) should work together. They lamented the fact that support for e-waste collectors and recyclers was lacking and felt that better strategies should be developed and implemented to make e-waste recycling more viable and cost-effective.

The market for recovered valuable e-waste materials is very limited nationally, and thus many companies export the material they harvest. However, legislation is very strict regarding this practice, primarily to prevent theft and illegal operations. Many components that are not recyclable, such as cathode ray tube monitors, are regrettably discarded at landfill sites where they pose a danger to the environment.

Cost is another huge constraint in e-waste management as most recyclers are faced with the cost of setting up a recycling plant and its associated logistics. These are all issues that the industry could overcome if there is cohesion. Proper e-waste management presents opportunities for job creation and economic development through formal recycling. The methods of and the infrastructure for the collection, transportation, sorting, and recycling of e-waste need to be reviewed and formalised to ensure that this waste stream is managed effectively and in a responsible and sustainable manner. To do so, e-waste recycling companies need to function within the law, and the government needs to review those policies that incur heavy financial expenditure for developing e-waste recycling businesses.

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CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

Electronic waste is one of the most rapidly growing pollution problems globally. This study evaluated current e-waste management practices and issues associated with e-waste recycling in the eThekwini Metropolitan area. The findings of the study are summarised in this chapter. Conclusions are drawn and recommendations are offered for possible consideration by both private and public institutions.

6.2 Conclusions

6.2.1 The composition of e-waste

Waste from electrical and electronic equipment (WEEE) consists of various materials. Some of these materials contain a variety of toxic substances that can harm human health and contaminate the environment if not properly managed and discarded. Materials in the e-waste stream can be grouped into five categories: ferrous metals, non-ferrous metals, glass, plastics, and other materials. Some of these materials can be recycled, which will reduce the mining of virgin materials and result in the protection of the environment.

6.2.2 Predominantly used equipment and devices associated with e-waste

Equipment and devices mostly used by the organisations under study were IT devices such as desktop computers, laptops, printers, photocopying machines, and cellular phones. Televisions sets and air conditioners were also used quite extensively. This finding came as no surprise as all organisations and institutions nowadays require IT equipment to perform their functions. They thus acquire suitable and increasingly advanced devices to meet their personal and their organisations' respective needs. The downside is that such devices contribute to fast-growing e-waste volumes as they become obsolete at an increasingly fast rate.

6.2.3 Challenges experienced

6.2.3.1 Large volumes of e-waste

Most electrical and electronic products are designed to have a short lifespan as, this increases sales and boosts income. Cellular phones can be used optimally for two years while the average lifespan of computers/laptops is three to five years. The participants corroborated this and agreed that their respective companies/organisations generated or handled large volumes of e-waste.

The volume of e-waste is growing fast because of fast-paced technology and innovation that result in the rapid undesirability of old devices before they reach their end-of-life obsolescence. The annual production of EEE globally is thus increasing rapidly, but the recycling rate is only between 15-20% worldwide.

6.2.3.2 Fluorescent light fittings

South Africa has adopted the waste management hierarchy which is widely accepted by most countries including Europe (Ferrari et al., 2016) and therefore, when decisions regarding waste management are taken, they should be pivotal to the plan. The diversion of e-waste from landfill is of utmost importance as such waste, for instance fluorescent lighting, contains hazardous materials. As from August 2016, the disposal of fluorescent lighting tubes and globes is not allowed at landfill sites in South Africa, as stated in the National Norms and Standards for Disposal of Waste to Landfill (South Africa, 2008).

The study could trace only two companies in South Africa that are recycling lighting material, namely Reclite and E-waste Africa. Some participants admitted that their companies were disposing of fluorescent lighting material with their general waste, which was attributed to a lack of proper facilities.

6.2.3.3 Lack of awareness

Most of the respondents were not aware that e-waste is hazardous. Awareness programmes should thus be conducted over a wide front to educate the staff of all organisations/institutions/companies (large and small) to reduce the negative impact

on the environment caused by e-waste that is not properly managed. Although it is not the responsibility of the local municipality to collect hazardous waste, it can play a major role in making people aware of the proper management and disposal of such waste. Using flyers, notices at key points, advertisements in newspapers and on television, and various digital platforms can serve this purpose.

Many people buy devices and gadgets every year, but they do not know where they can dispose of their discarded devices safely. The Education and Waste Minimisation section of the Cleansing and Solid Waste Unit of the eThekwini Municipality can play a pivotal role if it forges a partnership with other organisations such eWASA and the Institute of Waste Management of South Africa (IWMSA), KZN branch. Together, these structures can provide important and easily accessible information about e-waste to the public.

6.2.3.4 Lack of procedures and guidelines

Some companies have not established a protocol on how to handle electrical and electronic devices and equipment that have reached their end of life. As a result, waste from electrical and electronic equipment is stored in company stock rooms for long periods of time without a proper disposal plan. Some companies have established e-waste disposal procedures, but these are not being followed because they are not properly communicated to all the employees in the organisation. In other instances, such procedures are not clear, or they are simply not enforced.

6.2.3.5 Lack of awareness of the services provided by e-waste companies

E-waste collection and recycling companies are not well known in the community. Some participants in the study mentioned that they do not have information about e-waste management companies even though they are willing to dispose e-waste correctly, they struggle to find the right service providers in their area of operation. There are approximately twenty-three e-waste recycling companies in South Africa, according to a survey that was conducted for the Waste Research Development and Innovation Roadmap (Lydall et al., 2017). Of the 23 identified companies, very few are

based in KZN, and this creates challenges for the collection and recycling of e-waste in this province.

There are parts of the eThekwini Metropolitan area where recycling in general is not viable. Companies are not willing to travel to these areas due to the distances they need to cover and the volumes of waste that need to be collected. Location and distance are therefore some of the barriers that impede the e-waste recycling process because the costs incurred must be recovered by the sale of the items and, in many instances, this is just not viable. The respondents representing their recycling companies mentioned the challenges they faced, namely logistics, high costs, poor infrastructure, and high volumes of waste. They argued that a lack of support and the community's unwillingness to participate exacerbated these challenges.

6.2.4 E-waste regulations

Most of the respondents stated that they were not aware of legislation on e-waste handling and disposal. The recyclers' main concern was that, although the country has a clear legislative framework for e-waste management, there is no enforcement; as a result, e-waste still ends up at general waste landfill sites.

In South Africa there are regulations and policies that provide guidelines on the management of hazardous waste, including e-waste. A significant improvement was seen in 2016 when the national government introduced the National Pricing Strategy for Waste Management, which is a policy that guides the implementation of extended producer responsibility (EPR) initiatives in two ways, namely the introduction of (i) industry waste management plans and (ii) government managed fees.

6.2.5 Recycling of e-waste

Most e-waste recycling companies in the study area have been in operation for more than 10 years. Most offer services to customers across KZN, but their customers are predominantly located in the eThekwini area. These companies collect e-waste, provide e-waste drop-off points, and recycle this waste. There is also an informal recycling sector, but its nature and activities were beyond the scope of the study. Suffice it to say that informal recyclers collect waste from various sites, sort and manually dismantle old electrical equipment, and sell these parts to first-level recyclers. This information is not documented and figures of their contribution to e-waste

collection and recycling patterns are unknown, but their contribution is estimated at approximately 20%.

6.2.6 Volumes of recycled e-waste

Most recycling companies process more than five tonnes of e-waste every month. The participants argued that they would be able to process more and expand their businesses if they could access more customers.

Although the South African market for recycled e-waste is relatively limited, different types of equipment and devices are collected for recycling and are also re-purposed. ICT equipment such as PCs, laptops, printers, and small appliances are the items that are predominantly recycled.

Developed countries such as the United States and United Kingdom employ various measures to effectively manage and recycle their e-waste. Examples of these efforts are included in the WEEE Directive in European Union countries, which is a mandate to all member states to facilitate collection, resource recovery of electrical and electronic waste (European Court of Auditors, 2021). However, it can be argued that these efforts have not been satisfactory because, despite a relatively well-established waste management infrastructure, European countries only collect about one third of their generated e-waste, with significant quantities going to non-compliant waste management channels (Forti et al., 2020)

Lack of awareness or knowledge on how to recycle electronics or why it is important contributes to low recycling rates. The perceptions and opinions of consumers who do not care for the environment also hinder growth in the collection and recycling of e-waste.

6.3 Recommendations

6.3.1 Education and awareness

Consumers of electronic and electrical equipment need to be made aware about the composition of electronic waste – and more particularly of the fact that it contains both precious resources and hazardous material. They must be educated to understand that, once these devices have reached the end of their lifespan, they should be handled and discarded in a responsible manner. Educating the citizenry and making clear

information available to them will enable institutions, organisations, and companies to make informed decisions and formulate strategies to manage e-waste appropriately. This information should focus on proper disposal methods and providing the names and whereabouts of companies that provide e-waste removal and recycling services.

Such education and awareness programmes should be conducted at national, regional, and local level. All stakeholders, including the manufacturing industry, recycling companies, various organisations, and all spheres of government, should create partnerships to develop strategies for the implementation of appropriate e-waste management and disposal strategies. The eThekwini Municipality has an Education and Waste Minimization branch that falls under the Cleansing and Solid Waste Department, and this unit should play a pivotal role in creating public awareness regarding the negative impact of e-waste that is improperly discarded.

6.3.2 Recycling e-waste

To increase the recycling rates of e-waste, collection systems need to be improved in the eThekwini region. A central control system is required that allocates responsibility to various stakeholders to ensure high recycling rates. Incentives to encourage consumers to recycle their e-waste should also be considered. It is common knowledge that people respond better to national calls for cooperation if there is ‘something in it’ for them.

6.3.3 Designing an extended producer responsibility scheme

An extensive producer responsibility (EPR) policy will place responsibility for a product’s end-of-life impact on the shoulders of the original producer and seller of that product. EPR schemes are intended to compel producers to take responsibility for the environmental costs of their product. They also provide incentives for these manufacturers to make design changes that will reduce waste management costs. Such changes could include product recyclability and reusability through green design initiatives.

The process to implement the concept of EPR in South Africa needs to be accelerated. Once EPR regulations have been implemented, specific targets will have to be met to reduce e-waste footprints.

6.3.4 Job creation

South Africa faces the dire challenge of unemployment, and there are large numbers of informal recyclers who already operate in eThekwini and its surrounding areas. There is an urgent need to identify these people and to train them. This will open opportunities for them to gain sustainable employment with a certain income. This can also be achieved if the formal and informal recycling sectors work together. Resource recovery and economic and environmental benefits are thus positive outcomes that could be achieved if informal and formal recycling systems collaborate.

6.3.5 Sustainable e-waste management

To mitigate problems caused by the incorrect disposal of end-of-life electrical and electronic equipment and devices, the manufacturing industry and government need to develop strategies to manage e-waste in an environmentally friendly way. Levels of hazardous and toxic substances used to make EEE need to be reduced. Moreover, EEE manufactures need to take responsibility for the footprint of their products from production to their end of life.

Eco-design principles must be considered by all manufactures with the aim of preventing and reversing obsolescence. They should thus design durable devices and equipment that can be upgraded and repaired. The effective management of WEEE will contribute towards achieving many of the United Nations Sustainable Development Goals which are: Goal 3 (good health and well-being), Goal 6 (clean water and sanitation), Goal 12 (responsible consumption and production), Goal 14 (life below water), and goal 8 (decent work and economic growth) (Forti et al., 2020).

6.3.6 Legislation

The South African government has put ample legislation and policies on the management of e-waste in place, but the study highlights the fact that enforcement is lacking. If this is so, these Acts and policies are hardly worth the paper they are printed on. Therefore, once intensive education and awareness programmes have been

conducted and established, a sound and sustainable strategy to ensure compliance must be executed. It is undeniable that an effective regulatory system is required to monitor e-waste recycling and encourage sustainable e-waste management.

6.4 Summary

The inappropriate handling of WEEE is unsafe for both human health and the environment. All stakeholders in the eThekwini Metropolitan Area including government and private organisation should work together to improve the current status. It is important to firstly raise the awareness and to ensure that facilities or services for safe disposal are provided. E-waste collection schemes such incentivised retail trade-in and deposit/refund system should be explored to increase collection of obsolete electrical and electronic waste. Once these approaches have been achieved, enforcement strategies need to be developed and implemented.

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APPENDICES

CENTRAL UNIVERSITY OF TECHNOLOGY, FREE STATE
FACULTY OF HEALTH AND ENVIRONMENTAL SCIENCES

QUESTIONNAIRE FOR COMPANIES GENERATING E-WASTE

AN EVALUATION OF E-WASTE MANAGEMENT IN ETHEKWINI REGION, KWAZULU-NATAL

The aim of this study is to assess the current handling and disposal practices of e-waste and also to evaluate the extent of recycling taking place in the eThekwini Metro, KZN.

The objectives of this questionnaire are to determine the potential quantity of e-waste generated and e-waste management practices in the eThekwini Municipal area, in Kwazulu-Natal.

I, Miss Z Dlamini, student number, 217012372 declare that I am student currently registered for a Master's degree in Environmental Health, at the above-mentioned institution and that the information received from the questionnaires will only be used for the purpose of the study and all names and contact details will be used only for verification purpose and will not be published.

Participation in this study is undertaken with an understanding that:

1. Your anonymity and confidentiality will be assured at all times.
2. The questionnaire to be completed is not a test but contains questions to determine the knowledge and current practices on the of e-waste management.
3. There are no rights and wrong answers.
4. To unsure the best value from the results, you should answer the questionnaire truthfully and as accurately as possible.
5. Participation is voluntary and you have a right to choose not to participate in this survey at any point.

PERMISSION:

I, ...in my capacity of ....., hereby give permission for information gained by the completion of the questionnaire to be used in the study.

....

Signature **Date**

QUESTIONNAIRE FOR E-WASTE GENERATORS

SECTION A: BIOGRAPHICAL INFORMATION

1. Name of Respondent: _____

2. Gender

Male		Female		

3. Age of respondents

18 to 25 years			
26 to 35 years			
36 to 45 years			
46 to 55 years			
Older than 55 years			

4. Indicate your educational level

No formal school education		
Primary school		
High school		
Tertiary education		

5. Have you got any waste management Training?

Yes		
No		

6. If yes, what was the duration of the course:

SECTION B: PLEASE INDICATE THE MOST APPROPRIATE ANSWER BY MAKING A CROSS (x) IN THE CORRESPONDING BLOCK.

ELECTRONIC WASTE INFORMATION

1. What do you understand by the term “electronic waste (e-waste)”?

_____

_____

_____

_

2. Which of the following items do you consider to be e-waste?

1.	Monitors		7.	Copiers	
2.	Phones		8.	Laptops	
3.	CPU		9.	Printers	
4.	Mobile phones		10.	Fax machine	
5.	Television		11.	Fluorescent light bulbs	
6.	Air conditioners		12.	DVD Player	

3. Indicate which of the items listed in Question 2, are currently used by your company?

1.		7.	
2.		8.	
3.		9.	
4.		10.	
5.		11.	
6.		12.	

4. Do you consider e-waste hazardous?

Yes			
No			

Not sure	

5. Do you agree or disagree with this statement: “our company generates large volumes of e-waste?

Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree

C. MANAGEMENT OF E-WASTE

6. Does your company have specific procedures and guidelines about e-waste handling?

Yes	
No	
Not sure	

If the answer to Q6 is yes, what is your company protocol/guideline regarding the handling of e-waste?

_____

_____

_____

7. If the equipment categorised as e-waste breaks down or becomes obsolete what does your organisation do?

Immediately replace with new equipment	
Repair	
Replace if cannot repair	

8. What does your company do with unusable electrical and electronic waste?

Store		
Discard		
Not sure		
Repair/ Refurbish		
Recycle		
Donate		

Other (please specify)		

9. Does e-waste from your company collected by an e-waste removal company?

Yes		
No		
Do not know		

10. If your e-waste is collected by an e-waste removal company, please indicate the name of the company?

_____

11. Are you aware of what happens to the equipment you have discarded?

Yes		
No		
Do not know		

12. Will your company be able to pay for collection and recycling of e-waste?

Yes		
No		
Do not know		

13. What do you do with unwanted/burnt out fluorescent light bulb?

Throw in the waste bin	
Cover with a plastic and throw in the bin	
Throw in a special bin	
Other (please specify)	

15. Which appliances do you discard of mostly?

Small appliances	
Large appliances	
ICT equipment	
Lighting equipment	
Batteries	
Other (please specify)	

16. Are you aware of any legislation regulating handling of e-waste?

_____

_____

_____

17. General comments or any other important information

_____

_____

_____

THANK YOU FOR YOUR PARTICIPATION

Central University of Technology, Free State

CENTRAL UNIVERSITY OF TECHNOLOGY, FREE STATE
FACULTY OF HEALTH AND ENVIRONMENTAL SCIENCES

QUESTIONNAIRE FOR E-WASTE MANAGEMENT COMPANIES AND E-WASTE RECYCLERS

AN EVALUATION OF E-WASTE MANAGEMENT IN ETHEKWINI MUNICIPALITY, KWAZULU-NATAL

The aim of this study is to assess the current status of handling and disposal of e-waste and also to evaluate the extent of recycling taking place in the eThekwini Metro, KZN.

The objectives of this questionnaire are to determine the potential for e-waste generated and e-waste management practices in the eThekwini Municipal area in Kwazulu-Natal.

I, Miss Z Dlamini, student number, 217012372, declare that I am student currently registered for a Master's degree in Environmental Health, at the above-mentioned institution and that the information received from the questionnaires will only be used for the purpose of the study and all names and contact details will be used only for verification purpose and will not be published.

Participation in this study is undertaken with an understanding that:

6. Your anonymity and confidentiality will be ensured at all times.
7. The questionnaire to be completed is not a test but contains questions to determine the knowledge and current practices on the of e-waste management.
8. There are no rights and wrong answers.
9. To unsure the best value from the results, you should answer the questionnaire truthfully and as accurately as possible.
10. Participation is voluntary and you have a right to choose not to participate in this survey at any point.

PERMISSION:

I, ...in my capacity of ....., hereby give permission for information gained by the completion of the questionnaire to be used in the study.

..... **.....**

Signature **Date**

Questionnaire for E-Waste Management Companies/E-Waste Recyclers

SECTION A: BIOGRAPHICAL INFORMATION

1. Name of respondent: _____

2. Gender

Male		Female		1 2

3. Indicate your age

18 to 25 years		
26 to 35 yrs		
36 to 45 yrs		
46 to 55 yrs		
Older than 55 years		

4. Indicate your educational level

No formal school education		
Primary school		
High school		
Tertiary education		

5. Have you received any waste management training?

Yes		
No		

6. If yes, what was the duration of the course? (*Please tick the one applicable to you)*:

0 – 6 months		
6 – 12 months		
1 – 2 yrs		
2 – 3 yrs		
3 yrs or more		

7. How long have you been working in the e-waste management industry?

_____

SECTION B. E-WASTE COLLECTION & RECYCLING

1. Name of company: _____
2. How long has the company been in operation? _____
3. Which areas are being serviced?

_____

_____

4. Do your customers

Bring material to your site	
Collection services are provided	
Bring material to your site and collection services are offered	

5. In your opinion, do you think that e-waste generators are aware of how e-waste should be properly disposed of?

Yes		
No		

Do not know	

6. Would you say that there has been an increase in your clientele?

Yes	
No	
Do not know	

7. If an increase in clientele has been noticed, indicate what you think is a contributing factor.

_____

_____

8. Please indicate when an increase was noticed:

< 2010	
2010 – 2012	
2012-2014	
2014 – 2016	
2016 – 2018	

9. Do you think the public is aware that e-waste is hazardous?

Yes	
No	
Do not know	

10. In your opinion, what can be done to create awareness among the public of e-waste recycling? *(Please tick. More than one option can be selected)*

Television Ads	
Newspapers	
Government roll-out programmes	
Industry awareness initiatives	

Other		

11. Indicate an average volume of electronic waste that you receive on a monthly basis.

Less than 500 kg	
Between 501 to 1000 kg (1 ton)	
More than 1000kg but less than 1500kg (1 ½ ton)	

12. Indicate which type of equipment your company recycles. *(Please tick. More than one option can be selected)*

Computer monitors	
Computer keyboards	
CPU	
Laptop computers	
Printers	
Mobile phones	
Televisions	
Air conditioners	
Fluorescent light bulbs	
CD & DVD players	
Household electrical equipment **e.g kettles, fridges, washing machines, microwaves, stoves**	
Other (please specify)	

13. Please list the type of commodities extracted or recovered and the estimated value of each.

COMMODITY	VALUE (estimate)

14. The valuable materials recovered are:

Sold		
Reused to produce other products		
Do not know		

15. If valuable materials from e-waste are sold, indicate the market:

Local		
National		
International		

16. If other products are manufactured from reused e-waste, indicate what products are being produced?

_____

17. Out of the total e-waste you receive per month, how much is not recyclable?

_____ kg (%)

18. In your opinion, what are the most important obstacles to proper recycling of electric and electronic equipment in the country? *(Please tick. More than one option can be selected.)*

Costs			
Company Policy			
Lack of knowledge			
Absence of recycling possibilities			
Lack of legislation			
Non-compliance with legislation			
Other: (Please specify)			

19. What training do you think will be beneficial to the personnel in the e-waste management and recycling industry?

_____
_____
_____

20. General comments or any other important information

_____
_____
_____

THANK YOU FOR YOUR CO-OPERATION

Information Brochure - Electronic and Electrical Waste

What is e-waste?

Electronic waste or e-waste describes discarded electrical or electronic devices. Used electronics which are destined for refurbishment, reuse, resale, salvage recycling through material recovery, or disposal are also considered e-waste.

Examples of electronic waste

Electronic **waste** includes computers, laptops, monitors, keyboards, copiers, VCRs, fax machines, cell phones, printers, scanners, hard drives, stereo equipment, cables and cords, shredders, microwaves, and more. Basically, anything that uses electricity or batteries and no longer works or has become obsolete is considered to be electronic **waste**.

Is e-waste dangerous (hazardous)?

Electric waste (E-waste) has been described as hazardous due to the presence of some toxic materials such as **mercury, lead and brominated flame retardants found in some electrical equipment.**

E-waste management and disposed

Some components in the electrical equipment contain materials that are considered hazardous waste, so it must be disposed of properly. Old equipment like computers can be given to **charity** or brought to an **e-waste facility**. To find a nearest e-waste facility please contact the following numbers:

- DSW Education and waste Minimization Section – 031 322 0780
- eWASA (e-Waste Association of South Africa – 031 535 7146

Environmental benefits of recycling e-waste

- It protects the environment
- Prevent usage of landfills
- E-waste recycling helps reduce air pollution
- Reduce health hazards
- Reduce mining of virgin resources
- Earn little cash